Creating an Engineering Learning Module for the Technology Learning Center

This *Interactive Qualifying Project* Proposal, submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements of the Degree of Bachelor of Science, was completed by the team members listed below:

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Abstract

The project team developed an engineering-based learning module for middle-school visitors to the Museum of Science. The module both helps teachers implement national and state standards for engineering education and improves the efficacy of the Museum of Science's Technology Learning Center as an outreach tool.

Executive Summary

This project team assisted the Museum of Science in creating learning modules that teach engineering to middle-school students. This endeavor involved interpreting the educational goals of Massachusetts middle schools and translating those goals into interactive learning modules, defined as educational activities that are supplemented by pre- and post-visit activities.

While the Massachusetts Science and Technology/Engineering Curriculum Framework adopted in May 2001 requires that middle-school students learn engineering, many teachers lack the formal training to implement the engineering aspect of the curriculum. At the same time, teachers also struggle with the constraints as they prepare students for the MCAS exam.

The Museum of Science readily volunteers itself as a resource for teachers as part of their initiative to become a leader in informal science and technology education. To this end, the non-profit organization strives to offer different resolutions to challenges teachers face in implementing the engineering components of the Massachusetts curriculum.

The newly constructed Technology Learning Center (TLC) is a byproduct of the Museum's latest initiative to become an informal education leader. The TLC houses courses and programs which cover a broad range of subject areas including adult technology education and family enrichment. The Museum of Science would like to use the TLC to teach fundamentals of engineering to middle-school students in an effort to lessen the burden on teachers and increase the Museum's appeal to school audiences.

The teams' interpretation of the goals of Massachusetts middle schools resulted in academic objectives for the learning module. After careful analysis, the project team decided that the engineering design process was the most fundamental engineering concept that students should understand. Technologies dominate the Massachusetts Science and Technology/Engineering Curriculum Framework while the engineering design process lays the foundation necessary to understand the concept of technology. Thus, the project team clearly saw the priority for the engineering design process as the learning objective for the learning module. Based on this underlying concept, the project team created a template which facilitated fast prototyping of learning modules. Feedback from Museum staff and careful analysis narrowed down the candidates to a single learning module: *Break Stuff*.

Break Stuff is complimented by classroom activities that take place before and after a the Museum visit itself. The pre-visit activity requires that students solve an Egyptian puzzle found on the Museum website. The puzzle will reveal a hieroglyphic mission for the students, familiarizing them with their upcoming Museum agenda while introducing them to hieroglyphics. The post-visit activity, also online-based, will allow students to provide feedback to the Museum about how they would redesign the activity.

The students will be motivated by a descriptive story which will set the tone for their Museum visit. To start, the student teams are given a mission to deliver a secret hieroglyphic message to the Pharaoh. To protect the message from bandits and other perils, the message is divided, engraved onto multiple Egyptian artifacts whose identities are kept undisclosed, and delivered separately. By accident, the mystery artifacts are broken into several pieces (with the artifact hidden from view inside a brown paper bag, the students are given the chance to break the artifacts themselves). To complete their objective, the student teams must first think as engineers and reassemble their artifacts. Each team is asked to search in

the Egyptian exhibit for an artifact that matches the actual artifact's design specifications and clues. The students will use a picture of the matching artifact as a guide in their rebuilding effort. Upon completion of the reconstruction, the students use educational software to translate their segments of the hieroglyphic message and then, by collaborating with each other, deliver the full message to the Pharaoh.

The students undergo the engineering design process in the reconstruction portion of the learning module. Students first *identify* the problem: reconstruct the artifact. Next, the students *research* the possible materials they could utilize to reassemble the pieces. The student teams then brainstorm and *develop solutions*: hypothesize the identity of the artifact given the design specifications and find attainable materials to rebuild the artifact. Then, the students *select the best solution*: use the most appropriate materials to reassemble the mystery artifact. Afterwards, the teams *construct a prototype*: reassemble the artifact, and then *test and evaluate* it using advanced computer tools and the Cubit ruler. The students then *communicate* their process of reconstruction, briefly discussing the failures and successes in their attempt.

The project team selected the Egypt as a theme because of its popularity as a Museum exhibit. From discussion with the Museum staff, the project team learned that in the past, the Egyptian exhibit attracted large crowds of which school groups were a part. The project team so inferred that a link to this exhibit would theoretically draw large school groups to the corresponding TLC program. The Egypt connection would particularly interest middle schools because of the requirement for Ancient Egypt according to the Massachusetts History and Social Science Curriculum Framework.

Due to time limitations, actual implementation of the learning module was not possible, and thus, evaluative measures were also not feasible. For the future, the project team suggests that the learning module be executed with a middle-school-level audience. Development of the candidate learning modules is also suggested in order for the Museum to broaden its upcoming engineering programs. Any forthcoming projects should take advantage of the Museum's evaluation team in the development of a successful learning module.

1 Introduction

The recent addition of engineering into the Massachusetts Curriculum Frameworks has presented a challenge to middle-school educators. As a result of the recent adoption of engineering into the Massachusetts curriculum, teachers may not know of ways to implement the newly developed framework. The Technology Learning Center at the Museum of Science offers teachers an option to implement this standard curriculum and students the ability to understand engineering in a fun interactive environment.

While the Technology Learning Center at the Museum of Science in Boston, Massachusetts is in its early developmental stages, the learning center is seeking to standardize their own educational programs for school groups to comply with the Massachusetts Science and Technology/Engineering Curriculum Framework. The objective of this project was to assist the members of the Student and Teacher Programs Department at the Museum of Science in interpreting the educational goals of Massachusetts public schools in the field of engineering and to create learning modules.

The following chapters include the background information necessary in understanding the scope of this project, the methodology used to assist the Museum in integrating the Massachusetts curriculum frameworks into the Technology Learning Center, the results and analysis, and finally the conclusions and recommendations the team arrived at.

- **Chapter 2** includes information on the Museum of Science, Massachusetts education system, and interactive technology learning centers.
- **Chapter 3** outlines the methodology employed to assist the Museum of Science.
- **Chapter 4** is the results.
- **Chapter 5** presents the analysis.
- **Chapter 6** displays the conclusions.
- **Chapter 7** lists the recommendations.
- **Chapter 8** is comprised of bibliographical references.
- **Appendix A** contains project sponsor information.
- **Appendix B** extracts the technology/engineering focus from the Massachusetts Science and Technology/Engineering Curriculum Framework.
- **Appendix C** includes teacher emails.
- **Appendix D** information obtained from the brainstorming session.
- **Appendix E** reveals the notes taken from shadowing.
- **Appendix F** displays the nine candidate learning modules.
- **Appendix G** is a floor map of the Museum of Science.
- **Appendix H** shows the final presentation slides.
- **Appendix I** displays a link to our project web page.

2 Background

This chapter includes the background information the project team considered necessary to understand the scope of the project. The team divided this chapter into the following sections:

- The Museum of Science
- The TLC
- Massachusetts Public Education System
- "Technology" and "Engineering"
- Interactive Science and Technology Learning Centers

The first section describes the historical background of the Museum of Science from its founding in 1864 to present time. This section highlights some of the important shifts during the Museum's history, including the new technology focus which resulted from the merger with the Computer Museum.

The second section discusses the organization of the TLC. This section describes in detail the classrooms located in the TLC as well as the various courses that are offered there.

The third section discusses the public education system in Massachusetts. This section also describes the correlation between the middle-school technology education standards from the *Standards for Technological Literacy* and those from the *Massachusetts Science and Technology/Engineering Curriculum Framework*. In addition, this section briefly touches upon the challenges that teachers face with the newly adopted framework.

The fourth section makes a distinction between the terms "technology" and "engineering, so often conflated by educators. This section briefly describes the commonly misconceived definitions of the two words.

The fifth section defines a "technology learning center." It gives concrete examples of programs offered in interactive science and technology learning centers around the world in order to give a sense to the reader of what a technology learning center is.

2.1 The Museum of Science

Figure 1: The Museum of Science

The Museum of Science, as shown in Figure 1, is one of the largest museums in the world whose undertaking is devoted to science and technology. The Museum of Science is a non-profit organization with a staff consisting of three hundred people, who work in the following nine divisions: Development, Exhibits, Finance, Human Resources, Information Technology, Marketing, Programs, Technologies and Visitor Services/Community Relations. The Museum is the home to over 400 interactive exhibits and hosts over 1.6 million visitors each year. "The mission of the Museum of Science is to stimulate interest in and further understanding of science and technology and their importance for individuals and society."[1] The Museum of Science's mission is strongly dedicated to the idea that learning is fun and exciting, and this spirit is reflected in all of their undertakings.

2.1.1 A Look Back in Time

Figure 2: New England Museum of Natural History

The Boston Society of Natural History founded the Museum of Science in 1864 as the *New England Museum of Natural History*, a single building located at the corner of Berkeley and Boylston Streets in Boston's Back Bay. Figure 2 displays a photograph of the Museum's first building. At the conclusion of World War II, under the direction of Bradford Washburn, the Museum's name was changed to the *Boston Museum of Science*. In hopes of expanding the Museum, Washburn bought a 99-year lease for the land around the Charles River Basin area, currently known as Science Park. With plenty of land, the leaders of the Museum embarked upon programs to promote and fund the construction of a new museum.

[1] Museum of Science, "Our Mission," <http://www.mos.org/info/mission.html> (2001).

Figure 3: Temporary Building

In 1948, the Museum designed and created the first-ever traveling planetarium, which led to the construction of the new Museum in Science Park. This building, shown in Figure 3, temporarily housed the Museum's collections and staff while the Museum gained the momentum and resources to expand. In 1951, the first wing of the Museum opened encompassing 14,000 square feet of exhibit space.

Figure 4: Science Park Subway Stop

Over the next two decades, both building and exhibit expansion were in effect. To attract more people to the Museum, in 1956, the Museum campaigned and successfully obtained a stop on the MBTA green line at Science Park. Figure 4 is a map of the MBTA, which shows the location of the Science Museum subway stop. In 1958, the Charles Hayden Planetarium opened as a result of funding from the Charles Hayden Foundation. In the early 1970's, the Museum's west wing was constructed, and in the early 1980's, the Elihu Thomson Theater of Electricity opened as well. Another addition came later that decade, the Hall Wing, which houses the Roger L. Nichols Gallery and the Mugar Omni Theater. And most recently in August of 1999, the Museum's newest addition, the TLC, was constructed. A floor map of the Museum of Science is displayed in Appendix G.

2.1.2 A New Initiative

After merging with the Computer Museum in Boston in August 1999, the Museum of Science set out on an initiative to become a leader in informal technology education. Prior to the merger of these two museums, the primary focus of the Museum of Science was science rather than technology. With the joining of the two museums, the Museum's strong focal point on science shared the spotlight with technology. This new focus on technology led to the birth of the TLC in May 2001.

2.2 The Technology Learning Center

The TLC is a high-technology learning suite at the Museum of Science. The learning center consists of a $1.1-million suite of the *Computer Clubhouse* along with three computer-based classrooms: a Mac-based *Multi-Media Laboratory*, a PC-based *Science Simulator*, and a PC-based *Inventor's Workshop*. The goal of these classrooms is to support a multiplicity of paths to learning with fun and engaging programs. The TLC provides the latest high-technology creativity tools, educators, and programs that enable visitors to increase their knowledge about technology as well as their ability to use technology to enhance their own creativity.

The TLC is comprised of a recreational computer room-the Computer Clubhouse-and three classrooms equipped with personal computers and multimedia equipment-the Inventor's Workshop, the Multi-Media Laboratory, and the Science Simulator. Each classroom is distinguished by factors including room structure (layout), cosmetics (color), and program usage. In addition to these distinguishing factors, two rooms promote group work while the third classroom is more oriented towards individual work.

The Computer Clubhouse

The Computer Clubhouse, recently incorporated into the TLC, was co-founded in 1993 by the MIT Media Lab and the Computer Museum "to bridge the 'digital divide'-the ever-widening gap between those who have access to computers and those who do not."[2] The Computer Clubhouse targets visitors ages ten to eighteen. The mission of the Computer Clubhouse is in developing technological confidence, gaining job and life skills, and building self-assurance, all in a fun interactive environment. Although it is considered part of the TLC, the Computer Clubhouse operates as a separate entity. Therefore, the project team will only consider the Inventor's Workshop, the Multi-Media Laboratory, and the Science Simulator for the purposes of this project.

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[2] Museum of Science, "Educator Resources Learn More," The Computer Clubhouse, <http://www.mos.org/learn_more/ed_res/clubhouse.html> (2001).

The Inventor's Workshop

Figure 5: The Inventor's Workshop

The *Inventor's Workshop* is a classroom where visitors are able to use their creativity to design and invent. The classroom, as pictured in Figure 5, includes workbenches with tools, computers, and boxes of toys that encourage creativity, such as "LEGO®/Logo", "Mindstorm Intelligent Bricks", "Crickets", and an assortment of robot-building kits. The classroom desks are arranged in clusters to promote group hands-on activities.

The Multi-Media Laboratory

Figure 6: The Multi-Media Laboratory

The *Multi-Media Laboratory* was designed to emulate a computer artist's studio. The workspaces are set up in groups to encourage collaboration. Along with the cutting-edge Macintosh computer displayed in Figure 6, the classroom's collection also includes color laser printers, scanners, and cameras.

The Science Simulator

Figure 7: The Science Simulator

The *Science Simulator* classroom was designed to allow visitors to become immersed in a simulated experience and control what is happening. This classroom has a high-definition video projector. Computers in this classroom, as shown in Figure 7, are arranged in rows and set side-by-side.

2.2.1 Current Programs at the Technology Learning Center

As of yet, the TLC has not been used by school groups for curriculum-based activities. That is, the learning center has not hosted interactive educational sessions in support of the Massachusetts Curriculum Frameworks. However, the Inventor's Workshop, the Multi-Media Laboratory, and the Science Simulator are currently being used for other purposes, including adult technology courses, children and family courses, computer courses for teachers, and technology education or training for Museum staff.

Inventor's Workshop Programs

A variety of courses are offered in the Inventor's Workshop, including "LEGO® Bugs." "LEGO® Bugs" is made possible with LEGO®/Logo, which is an inventive combination of LEGO® building blocks and Logo, the children's computer programming language. In this creative course, students use LEGO®/Logo to invent and build their own bug with LEGO® components and instruct their bugs to move, turn, and react to the environment with Logo programming.

Multi-Media Laboratory Programs

The Multi-Media Laboratory offers courses such as "Digital Video and Sound Production," and "Web Design." "Digital Video and Sound Production" show visitors how to produce their own videos using computers, home video cameras, and sound gear. Students in this course learn and practice the fundamentals of sound recording, visual storytelling, camerawork, and lighting. At the end of the course, students can bring home their creations on a CD or tape. On the other hand, in "Web Design," course participants create their own web page with graphics, text, animation, and sound. Visitors in this course can scan photos of themselves or friends and insert them into their personal pages.

Science Simulator Programs

The Science Simulator also hosts different courses, including internal training courses for the Museum staff. A course on "CyberTracker" trains staff on the use of PalmPilots coupled with global positioning system (GPS) devices. Other courses show staff how to navigate the computer systems as well as walk through tutorials of standard programs used at the Museum (i.e. MeetingMaker, Microsoft Office).

2.3 Massachusetts Public Education System

In 1993, Massachusetts passed some of the most radical and ambitious legislation regarding public education. With the passing of The Education Reform Act of 1993 Massachusetts saw changes in all aspects of public education. Two of the most visible areas that were affected by this legislation were school standards and evaluations.

2.3.1 The Learning Standards

The 1993 laws called for the development of a set of standards that would describe in detail the topics each student in Massachusetts public schools should be taught at each grade level. These standards are called the Massachusetts Curriculum Frameworks. Currently there are seven frameworks: Arts, English Language Arts, Foreign Languages, Comprehensive Health, Mathematics, History and Social Science, Science and Technology Education.

The frameworks, in general, are devised by the Massachusetts Department of Education in collaboration with a board of experts and teacher consultants. In the creation of these standards, the curriculum developers researched the benchmarks for technology and engineering education set forth at the national level. Two of the main sources that the developers used, as listed in the introduction of the Science and Technology/Engineering Framework, are *Benchmarks for Science Literacy-Project 2061* and the *National Research Council's National Science Education Standards.*

The *Standards for Technological Literacy*, published by a grant from the National Science Foundation in 2000, is the name for the most recent *National Research Council's National Science Education Standards* that relate to technology and engineering. At the national level, there are twenty benchmarks for technology literacy. Of the seven standards that Massachusetts has for middle schools, four correspond with national benchmarks as shown in Table 1 below.

National Benchmark (2000) →	Massachusetts Standard
9. Engineering Design	2. Engineering Design
11. Apply the Design Process	
17. Information and Communication Technologies	3. Communication Technologies
18. Transportation Technologies	6. Transportation Technologies
19. Manufacturing Technologies	4. Manufacturing Technologies
20. Construction Technologies	5. Construction Technologies

Table 1: Correlation between National and State Learning Standards

The current structure of the Massachusetts Science and Technology/Engineering Curriculum Framework consists of four strands of material for different grade levels: Earth and Space Science, Life Science, Physical Sciences, and Technology/Engineering. Each strand of learning is organized by grade and grouped by grade spans from pre-kindergarten to the high-school level (i.e. Pre K-2, 3-5, 6-8, 9, 10). Subject area topics are listed under each grade span and are followed by broad concepts along with the learning standards which outline the knowledge and skills that the students should acquire at the end of each grade span.

The Massachusetts Department of Education has spent the last nine years making the MCAS a realization. Starting in 2003, passing the MCAS exam will be a statewide requirement for high school graduation. With such a short time remaining for the full implementation of the MCAS exam, the majority of educators in Massachusetts have been struggling to adapt their lesson plans to cover all material that will be presented on the MCAS exam. Currently only three of the frameworks are being tested by the MCAS exam. However, the adoption of these standards has placed new focus on all of the subject areas covered by the frameworks, in particular the Science and Technology/Engineering Curriculum Framework.

2.3.2 The Challenge for Teachers

In addition to the tight time schedule for the MCAS, teachers are faced with a daunting challenge of teaching concepts in engineering, an unfamiliar subject area for most teachers. Before the integration of technology and engineering with the curriculum frameworks in 2001, a majority of teachers did not study topics in engineering or technology in their formal education. Oftentimes as a result of teachers' lack of training and time, they overlook the technology/engineering strand of the curriculum framework for these reasons. Faced with this challenge, teachers are calling for alternative methods to fulfill the engineering education requirements set by the state.

2.4 "Technology" and "Engineering"

Many people misconstrue "technology" and "engineering" as synonymous terms. These terms are so interconnected that the line between them is often incorrectly blurred. Others think that technology is strictly desktop computers or electronic devices. Some people interpret engineering as "building something" while others perceive it as "making things better."

The project team interpreted engineering as the design process and technology as its result. Technology is not necessarily electronic; however, it can range from the common ballpoint pen to the most advanced automobile in the world. Each of those technologies resulted from an iterative process of designing, constructing, testing, evaluating, and redesigning. Therefore, the team utilized the definition of *engineering* in the Massachusetts Science and Technology/Engineering Curriculum Framework as the design process used to "manufacture useful devices or materials, defined as *technologies*, whose purpose is to increase our efficacy in the world and/or our enjoyment of it."[3] The team believed this definition accurately and appropriately correlated with their conceptions about the relationship between technology and engineering, and therefore, this is the definition they utilized throughout the project.

2.5 Interactive Science and Technology Learning Centers

Improving the Student and Teacher Programs at the TLC at the Museum of Science necessitates a definition of a *technology learning center* or, in a broader sense, an *interactive science and technology center*. Because the Museum currently does not have programs in the TLC in place for visiting school groups, researching different learning centers revealed examples of such programs.

Interactive science and technology centers (ISTCs), on the one hand, are different from more traditional museums in that they present a hands-on learning environment intended to convey scientific and technological ideas and concepts. On the other hand, science and technology centers are like other museums in that they attract a wide variety of visitors, such as school groups, teachers, and families.

Interactive science and technology centers are often categorized as informal environments in which visitors learn science and technology. Lack of structure and open-endedness are key characteristics of the informal learning environment in ISTCs. However, that is not to say that the learning which occurs in technology and science centers is different from that which occurs in other museums. It is not the learning that is different, but rather the methods in which the learning is achieved. The following are situations for learning which are found in technology and science centers:

- the learner sets explicit personal goals for learning
- the learner decides what he or she would like to visit and investigate
- the learner participates strongly in the learning process
- the learning usually takes place as a result of the visitor making a direct physical interaction with the exhibit, and unintended outcomes may result
- the learning may provoke surprise or may be unexpected from the learner's point of view

Interactive science and technology centers allow the learner to have a hands-on experience that promotes a feeling of individual discovery. The visitor's interaction with the science and technology center is intended to spark curiosity as well as answer questions he or she arrived at during the hands-on experience.

The "Children's Technology Workshop" in Ontario, Canada runs programs for school

[3] Massachusetts Department of Education. Massachusetts Science and Technology/Engineering Curriculum Framework. 2001: 4.

groups similar to the programs which the Student and Teacher Programs Department at the Museum of Science is working to initiate. An example of an activity which this center offers to seventh graders concerns the topic of structural strength and stability. This activity is an hour long and enables the students to apply their knowledge of tension, compression, and failure while constructing structures and testing them. In this activity, the students use computers to model and test the failures in their structures using a structural analysis computer program. The Workshop also offers an eighth-grade activity: teaching robotics and pneumatics. In the robotics module, students learn how to construct simple robotic devices and how to program mechanical devices using software. In the pneumatics module, students construct pump, valve, and piston systems, and then construct pneumatic presses or lifting devices.

The Technology Museum of Innovation in San Jose, California offers science and technology labs designed for academic groups in grades K-12. All of their field-trip workshops are aligned with the California State Framework for science, technology, and society. Some examples of these programs include "Animation Sensation," "Lights! Camera! Action!," "Robo Challenge Workshop," and "Robot Explorers on the Go." In "Animation Sensation," students use computers to create animated clips while gaining a better understanding of the design process and the skills animators use in their work. "Lights! Camera! Action!" empowers students to direct, edit, and star in their own productions. Using digital cameras, students record and reflect upon their museum experience, then bring that footage to life using video editing software. In the "Robo Challenge Workshop," students work collaboratively to develop creative solutions to a real-world problem. The design process comes alive with their use of LEGOs®, sensors, motors and computer control. "Robot Explorers on the Go" is a lab that allows students to learn about the use of mobile robots to explore hostile environments, such as the ocean or outer space. As they build and test their own LEGO® robots, students explore the differences between remotely operated and autonomous vehicles.

Concisely stated, a technology learning center is a multimedia interactive environment, which stimulates learning in science, technology, and engineering amongst its users through active involvement.

A clear understanding of the meaning of a *technology learning center* provides the essential starting point from which to propose improvements for the TLC at the Museum of Science. The next section will outline specific components of the team's approach in implementing their project.

3 Methodology

The objective of this project was to create a learning module that teaches the fundamentals of engineering to middle-school students from Massachusetts public schools. To this end, the project team interpreted the educational goals of Massachusetts public schools and translated those goals into a learning module to take place in the TLC.

The accomplishment of this mission relied on two critical objectives:

1. Interpret the educational goals of Massachusetts public schools in implementing the Massachusetts Science and Technology/Engineering Curriculum Framework
2. Translate those goals into an interactive learning module utilizing the TLC

The domain of this project was restricted to middle-school level engineering education and specifically to the development of interactive experiences for school groups on field trips to the Museum accompanied by their teachers from local schools. Although school groups from other states often visit the Museum, the study was further limited to Massachusetts public schools due to the fact that curricula differ from state to state.

In general, a *school group* must be academic in nature and include students in grades pre-kindergarten through twelve. A *field-trip program* is a class taught by a Museum educator that takes place in parts of the Museum such as the TLC or an exhibit hall. A *learning module* is a threefold educational activity composed of pre- and post-visit activities to take place in the classroom and an activity to take place in the TLC that teaches important concepts of engineering to middle-school students. A *learning module template* is a document having a preset format, which is used as a starting point to create a learning module so that the format does not have to be recreated each time it is used.

The time frame over which this project was conducted was from March 12 through April 30, 2002. School groups on field trips to the Museum of Science are generally limited to three hours per visit to the Museum. Two hours of this time include tours of the Museum's theaters, labs, and exhibits. The remaining time will be spent in the TLC, which is comprised of the Multi-Media Lab, the Science Simulator, the Inventor's Lab, and the Computer Clubhouse. In general, the learning modules in the TLC will be limited to fifty minutes.

The following sections document the methods needed to fulfill the project's objectives:

Section 3.1 details the process involved in interpreting the educational goals of Massachusetts public schools that enabled the team to identify a range of topics to be translated into an interactive learning module.

Section 3.2 documents the process of creating a learning module to teach key concepts in engineering to middle-school students on field trips.

3.1 Interpretation of the Educational Goals of Massachusetts Public Schools

The educational goals of Massachusetts public schools enabled the project team to determine the objective(s) of the learning module. To this end, the team analyzed the Massachusetts Science and Technology/Engineering Curriculum Framework and researched how middle-school students interacted with the Museum on a field trip, how Museum educators perceived the resources of the TLC to convey fundamentals of engineering, and how middle-school teachers are implementing the newly adopted curriculum framework. It is important to emphasize that the result of the team interpreting the educational goals not only provided teachers with an alternative to teach engineering in a stimulating and interactive environment, but also aided the Museum in both achieving its mission to be a resource to educators and in expanding its list of programs devoted to technology.

3.1.1 Analysis of MA Science and Technology/Engineering Curriculum Framework

Analysis of the Massachusetts Science and Technology/Engineering Curriculum Framework, in particular the technology/engineering strand for students in grades six through eight, required thorough examination. Through examination of the framework and discussions with each other and Museum educators, the team created and tabulated a concise description for each learning standard displayed in the curriculum framework that is displayed below.

7th and 8th Grade Standard Topic	Short Description
Materials, Tools, Machines	Given a design task, identify appropriate materials based on specific properties and select tools needed to construct a prototype.
Engineering Design	Execute the engineering design process, which includes identification and research of the problem, creation and selection of possible solutions, construction of a prototype, evaluation and communication of solutions, and redesign.
Communication Technologies	Technologies that communicate ideas through engineering drawings, written reports, pictures and presentations; explain the components of a communication system, and compare communication technologies and systems.
Manufacturing Technologies	Mechanisms that convert raw materials into physical goods along with systems that design, develop, make, and service products and systems.
Construction Technologies	Involves building structures in order to contain, shelter, manufacture, transport, communicate, and provide recreation.
Transportation Technologies	Systems and devices that move goods and people from one place to another across or through land, air, water, or space.
Bioengineering Technologies	Mechanical devices, products, biological substances, and organisms to improve health and/or contribute improvement to our daily lives.

It is important to emphasize that the development of the learning module, intended to teach fundamentals of engineering, revolved around a solid understanding of the material contained in the curriculum framework for middle-school students.

3.1.2 Research

In addition to applying the analysis of the curriculum framework to guide the project team in creating learning modules to teach engineering, the team also used middle-school students and teachers along with Museum educators and programs as resources. A better understanding of the audience and their educators were obtained via email as well as through informal interviews and interaction with middle-school field trip groups attending educational programs in the Museum. The email sent to the teachers enabled the team to assess the current implementation of the Massachusetts Science and Technology/Engineering Curriculum Framework in the classroom. Additionally, the email gave the team information on the background of the students and teachers in terms of engineering. To obtain information on whether or not the teachers were teaching engineering to their students the team offered a list of suggested learning activities from the curriculum framework and asked whether they currently carried out activities in the classroom that were comparable. The project team obtained similar information through informal interviews with teachers, as they did from emails sent to teachers.

Interacting with middle-school field trip groups enabled the team to gain insight into what exhibits/experiences held students' attention. This required "shadowing" the students during their visits to the exhibit halls and classrooms of the Museum. "Shadowing" included observing the students in an unobtrusive manner. The objective of this was to determine their thoughts about what they were engaged in, their extracurricular and curricular interests, their behavior, and the factors that motivated them to learn.

In shadowing middle-school students on field trips the team familiarized themselves with the various resources the Museum has available for them. In addition, the team researched the various programs the Museum offers outside of field trips in order to develop ideas for their learning module.

Prior to creating a learning module, the project team brainstormed with Museum educators in order to determine how the resources of the TLC could help to convey the engineering design process to middle-school students on a field trip. The project team conducted a formal brainstorming session which entailed four stages: brainstorm, clarify, advocate, and canvas. During the brainstorming process a facilitator and a recorder are necessary. To start the process, the brainstorming question is written in large letters and displayed on the board the entire time. The facilitator is in charge of all aspects of the brainstorming session such as keeping track of time, maintaining the participants' attention to the question at hand, and translating the participants' comments into a concise sentence for the recorder.

The facilitator begins by reading the question to the audience and informing them that they have two to three minutes to process it. At the end of the three minutes, the audience forms small groups of two to three people, and they share their ideas. Next, the facilitator calls on people to share their ideas and the recorder writes them down in bright colors for the audience to see. This concludes the brainstorming portion. The next step is for the participants to clarify their ideas for each other. This step is followed by the participants advocating the ideas, which they consider important. It is important to emphasize that during a brainstorming session ideas are never criticized, only advocated. And finally during the canvas step, the participants of the brainstorming session vote on the top five to seven ideas depending on the number of people who participated.

The team used the information they obtained from emailing and interviewing teachers, observing students on field trips, and brainstorming with Museum educators to reach the ultimate goals of defining the objective(s) of the learning modules and, subsequently, creating the learning module.

3.1.3 Objective(s) of Learning Module

Utilizing the table of learning standards created in analyzing the curriculum framework as well as the information obtained through emailing and interviewing teachers, observing middle-school students on field trips at the Museum, and brainstorming with Museum educators, the team defined and clearly stated the objective of the learning module.

The project team determined that the objective of the learning module was to utilize the TLC to teach the engineering design process to middle-school students on a field trip. The team based their learning module on the engineering design process displayed in the curriculum framework. The engineering design process is comprised of the following eight steps:

Step 1: Identify the Need or Problem
Step 2: Research the Need or Problem
Step 3: Develop Possible Solution(s)
Step 4: Select the Best Possible Solution(s)
Step 5: Construct a Prototype
Step 6: Test and Evaluate the Solution(s)
Step 7: Communicate the Solution(s)
Step 8: Redesign

The rationale for choosing the engineering design process as the objective of the learning module will be further discussed in the analysis sections that follows.

3.2 Process of Creating a Learning Module

Creating a learning module was a challenging and creative task, which occupied the majority of the team's time. In developing a learning module the project team first created a template and defined parameters and restrictions. Next the team developed possible topics and applied them to the template which were in turn presented as proposals to the Museum educators for feedback. Finally, the team evaluated the proposals and created a learning module that reflected characteristics of two of the proposals.

3.2.1 Development of Learning Module Template

The first step taken in translating the educational goals of Massachusetts public schools into a learning module was to create a learning module template. The format of the learning module template was based on the objective of the learning module, the engineering design process. The learning module template used in creating the learning module is displayed in Figure 8.

Learning Module Title

Synopsis:

Pre-Visit Activity:

Story/Setting:

Design Process Step 1 – Identify the Problem:

Design Process Step 2 – Research:

Design Process Step 3 - Develop Solutions and Selection:

Design Process Step 4 - Develop a Prototype:

Design Process Step 5 - Test and Evaluate:

Design Process Step 6 - Communicate:

Lecture on the Design Process

Post-Visit Activity:

Figure 8: Learning Module Template

In addition to developing the learning module template, the team also determined preset parameters and restrictions, which were obtained through discussions with Museum educators, informal interviews with middle-school teachers, and observation of middle-school students. Examples of parameters the team considered were that the learning module must be group oriented because the team's research proved that middle-school students work best in a group environment. Another example of a parameter the team regarded was that the pre- and post-visit activities to take place in the classroom should be optional. Teachers might lack resources and/or time to complete these activities, however, they may still want to participate in the TLC activity. On the other hand, examples of restrictions the team considered were that the component of the learning module to take place in the TLC must be 50 minutes and the students must utilize the technology available in the TLC.

3.2.2 Application of Learning Module Template

The team determined potential topics for the learning module based on the interests of both the Museum and its visitors. The team concluded that the most important topic to the Museum was Egypt as a result of its upcoming exhibition *The Quest for Immortality* scheduled to arrive in fall 2002. Topics other than Egypt were not excluded, but an emphasis was made on translating topics related to Egypt into learning module templates.

The learning module template was used to translate the potential topics into proposals. In other words, once the team decided on several possible topics for the learning module, the learning module template was used to evaluate whether or not they topics fit into the engineering design process.

The project team produced nine proposals based on the learning module template, which they presented to Museum educators for feedback. These candidate learning modules ranged from designing and testing a rocket in a vacuum, building and manipulating a lunar rover in the Museum, and constructing and evaluating the design of a cable-stayed bridge using Bridge Software®. The remaining of the nine candidate learning modules were related to content theme Egypt. Although the team created a wide range of candidate learning modules, all candidates had the same learning objective: the engineering design process. Using the standardized organization of the learning module template increased readability and facilitated valuable feedback. Feedback was essential in the process of creating the module, and the team used the expertise of the Museum educators to assess them.

3.2.3 Translation of Learning Module Template into Learning Module

Transitioning from nine learning module proposals to one learning module was a complicated task. To this end, the team took into consideration their own expectations for the learning module and the feedback obtained from Museum educators. In evaluating the team's expectations for the learning module, the team reinforced the fact that the team was looking to develop a learning module, which would be a success to the Museum, have a connection to the Museum, and exemplify universal design. Any learning module which teaches the engineering design process was considered a success to the team; however, not all of the learning module proposals created would be considered a success in the Museum's environment. In determining that the team sought to develop a learning module, which would be a success to the Museum, they determined that the learning module must have a direct connection to something in the Museum, for example, an exhibit. In addition, the team decided that universal design was a very important aspect of the learning module so that the Museum could use their learning module repeatedly by altering it with different exhibits in the Museum.

Evaluating the feedback obtained from the Museum educators was very important in the development of the learning module. The feedback the team obtained for each proposal was in the form of questions, concerns, and comments. The Museum educators are familiar with what kinds of activities work best in the Museum, and the team valued their feedback very highly. Before the Museum educators let the project team know what learning module they believed work best in the Museum, they let the team interpret their feedback and come to their own conclusions. Consequently, the team's conclusions and the Museum's did indeed mesh.

In coming to a conclusion, the team also took into consideration the parameters and restrictions they had developed for the learning module. Because the project team found that one learning module template did not address every parameter, restriction, expectation, and feedback from the Museum, they decided to not develop a learning module from one of the existing learning module proposals, but rather to incorporate different ideas to create a new proposal.

From this point, the team worked toward creating various types of documentation that would appropriately describe the module. This took the form of text documentation, which described step by step what an instructor would need to know in order to execute the learning module not only at the Museum but in the form of pre- and post-visit activities. The information needed for the teacher to execute both the pre-visit activity and the post-visit activity will be available on the Museum's web page. All of these materials should create a comprehensive resource for the Museum to use to run a program in the TLC.

4 Results

This section displays text documentation of the learning module *Break Stuff*. The text documentation serves as a manual for teachers and Museum educators to execute the learning module in a successful manner. Each component of the learning module, pre-visit activity, TLC activity, and post-visit activity, are further organized by the following sections: overview, background, materials, team dynamics, set up, expectations, engineering design process, and procedure. The chapter to follow analyzes the various parts of the learning module.

The *overview* provides a brief synopsis of the activity in which the students will participate. The *background* states the pertinent knowledge that the participating students should understand beforehand. The *materials* section list every item needed for the activity. *Team dynamics* describes the manner in which the students should be divided. Brief preparation of the room before the activity begins is explained in *set up*. In the *expectations* section, students should accomplish each of the listed points. An elaboration of each step in the design process is clarified in the section *engineering design process*. Finally, the *procedure* explains each stage of the activity with an expected time frame for each step.

Break Stuff
Pre-Visit Activity

Overview
Students are given a mission to construct an online puzzle. When completed the puzzle reveals a hieroglyphic message. The challenge is to translate the hieroglyphic message displayed in the puzzle using the border of the puzzle, the hieroglyphic alphabet. Utilizing computers and Internet access at school, students work in small groups to uncover the problem they will be faced with at the Museum.

The hieroglyphic message on the puzzle is:

Background
Knowledge of Ancient Egypt is assumed.

Materials
Computer with Internet access

Team dynamics
Two-member teams

Set up
Computer lab

Expectations
Students will
…be introduced to hieroglyphics.
…work collaboratively.

Engineering Design Process
Identify the problem. *The Egyptian puzzle will deliver the students' mission when they come to the Museum through a hieroglyphic story which the students will translate using a hieroglyphic alphabet included in the puzzle.*

Procedure

Step	Description	Time needed
1	Give student teams the web address for the Egyptian puzzle.	2 mins
2	Let each team assemble the online puzzle.	15 mins
3	Have students translate the hieroglyphic message.	20 mins

Break Stuff

Overview

Students are given a mission to deliver a secret hieroglyphic message to the Pharaoh. The challenge is to convey the mystery message within certain design specifications. Working collaboratively, student teams will each reconstruct an Egyptian artifact provided by the Museum of Science that together conveys a single hieroglyphic message.

Each artifact will be broken into medium-sized pieces and reconstructed by a different team who must unveil the identity of the mystery artifact before rebuilding it. Design specifications and other clues will help students identify the unknown artifact. In addition, students must do supplementary research in *Egypt: the Quest for Immortality* to find clues on the identity of the artifact.

Before reconstruction begins, teams venture into the Egypt exhibit to make sketches and take notes on the artifacts that resemble the design specifications given at the beginning of the field trip. The students then regroup at the TLC to begin the rebuilding process. The sketches and notes taken in the exhibit will help serve as a guide for students during their reconstruction. Students can use the sketches and notes to identify their artifact and thereby assessing their progress as they rebuild. Located in the TLC will be a bulletin board displaying pictures of the artifacts found in the Museum. The students will determine which artifact most closely resembles their drawings and will begin reconstructing based on this picture.

After teams successfully reassemble their given artifact, they must compare the artifact's measurements to the design specifications. Students will also interpret the etched message segment from their reconstruction. At the end, students will come together to translate the full message for the Pharaoh.

While teams are reconstructing their artifact, other teams will be in the Mugar Omni Theater watching *Mysteries of Egypt* or at a Plantarium show on Egypt.

Background
Knowledge of Ancient Egypt is assumed.

Room Capacity
80 students, 20 per TLC classroom

Materials
a) 10 models/pictures of Egyptian artifacts
b) Egyptian artifacts
c) washable paint and paint brush
d) large zip-loc bags
e) brown paper bags
f) Cubit ruler
g) design specifications for Egyptian artifacts
h) story script
i) PhotoModeler® (photogrammetry software – www.photomodeler.com)
j) digital camera (with uplink to PC and necessary camera software)
k) Unidentified modeling adhesives, labeled ONLY with properties
l) Unidentified non-adhesive cement-like materials
m) Breaking tools
n) hieroglyphic educational software

Team dynamics
Four-member teams, each with assigned roles based on ability

Set up
At each workstation, there should be two computers with PhotoModeler® and camera software installed and an uplink cable for the digital cameras that the students will use. Place each zip-locked artifact in a brown paper bag with its design specifications and put them at each workstation. Equip each station with breaking tools, Cubit ruler, and adhesives.

Expectations
Students will
…be introduced to a new measurement tool and unit of measure.
…work collaboratively.
…learn basic hieroglyphics.
…be taught the engineering design process.
…use effective communication skills.
…develop problem-solving skills.
…use their creativity.

Engineering Design Process
Identify. *Determine the identity of the Egyptian artifact; Reconstruct Egyptian artifact*

Research. *Students go to the Egypt exhibit, make sketches and take notes on artifacts that match their given specifications and clues.*

Develop and Select Solutions. *Choose the Egyptian artifact from the sketches and notes taken in the Egypt exhibit that best matches the given design specs and clues. Compare sketches and notes to bulletin board displaying pictures of Egyptian artifacts.*

Construct Prototype. *Students will reconstruct their model.*

Test and Evaluate. *Students determine if they were correct in their choice; take measurements with PhotoModeler and Cubit ruler and compare to design specifications.*

Communicate. *Students will quickly present to the rest of the class how their reconstruction went using the information obtained from the Test and Evaluate step.*

Procedure

Museum floor

Step	Description	Time needed
1	Instruct students to search through the *Quest for Immortality* for an artifact that matches the given design specifications and clues. Recommend notes and sketches on any possible matches. Also, inform the students that they must meet back in the Technology Learning Center at a specific time.	10 mins
2	Distribute design specifications and clues (one set per team).	5 mins

TLC

Step	Description	Time needed
1	Allow students to examine the available tools and unidentified adhesives set in front of them. Let them infer which materials are the most appropriate for their purposes based on the specific properties of each material.	5 mins
2	Give the students a chance to break the mystery artifact that they will be rebuilding. Advise them not to pulverize the model artifacts because they will be responsible for reconstructing the models.	5 mins
3	Let students carefully remove the pieces from the bag. Tell them that their job now is to rebuild the broken artifact using the given materials.	20 mins
4	After reconstruction is complete, have students use Cubit ruler and PhotoModeler® on their computer to check for specifications. While two members are measuring, have the other two use their computer to study and translate the hieroglyphics on the artifact. As students translate their segment of the full message, their translations will be displayed onto a projector.	10 mins
5	When every team's message is finally displayed, have the different student teams work together to organize the message segments so that it will make sense for the Pharaoh.	10 mins

Break Stuff
Post-visit activity

Overview
Students are given the mission to reflect on their Museum visit through an online activity in order to present the Museum with feedback.

Background
Successful completion of Museum learning module

Materials
Computer with Internet access

Team dynamics
Work done individually

Set up
This is a classroom activity done by writing, no setup needed

Expectations
Students will
…evaluate their performance in reconstructing the Museum artifacts.
…complete the engineering design process.

Engineering Design Process
Redesign. *Based on the results the students obtained from reconstructing, they will determine what materials and adhesives were most effective in delivering the hieroglyphic message to the Pharaoh.*

Procedure

Step	Description	Time needed
1	Have students prepare a paper on their Museum reconstruction experience that addresses what problems they encountered and how they would correct them if they were to repeat the exercise. In particular, students assess the different materials they would use if they were given the chance to reconstruct the artifact again.	10 mins
2	Have students submit their papers to a link on the Museum's web page.	5 mins

5 Analysis

In this project, the team created an original approach and an original learning module *Break Stuff*. The sections below contain an analysis of the team's learning module *Break Stuff*. If the Museum decides to further develop any of the nine candidate learning modules they could utilize the team's approach and justifications for including various components as displayed below.

5.1 Museum and TLC Activity

The TLC activity presented in the learning module *Break Stuff* is the result of several weeks of research at the Museum combined with an in-depth analysis of the Massachusetts Science and Technology/Engineering Curriculum Framework. The follow sections give more detail as to the origins of and reasons for the different aspects of the learning module *Break Stuff*.

5.1.1 Learning Module Theme

In the creation of a successful learning module, the project team wanted to stress that an activity must have a connection to the Museum. From informal talks with the Museum educators and Massachusetts teachers, the team determined that the TLC would be most useful to teachers if they could easily justify coming to the TLC to their supervisors. The project group learned that teachers in Massachusetts have to obtain the approval from several sources before being allowed to go on a field trip. The teacher must receive permission from the school principal, the superintendent of the school system, the parents of the students, and sometimes the parent-teacher association before being allowed to go on a field trip. The field trip must be academic in nature and must relate to current course material.

By establishing a connection with the Museum, such as the Egypt exhibit, in the learning module, teachers can use the Egypt theme as justification for coming to the Museum. Another justification for teachers is that Egypt is included in the History and Social Science Curriculum Framework. In addition, as a result of the success and popularity of past Egypt exhibits at the Museum of Science, teachers are likely able to justify bringing their students to the Museum.

Although the main focus of the learning module is teaching the engineering design process, the content theme of the activity is Egypt. The project group originally had nine candidate learning modules that covered a range of themes. Lunar exploration, home entertainment, designing a rocket, and Boston's Leonard P. Zakim Bunker Hill Bridge were themes that were proposed along with Egypt. Each of these proposed learning modules are located in Appendix F.

5.1.2 Engineering design process

Foremost in discussion of the learning module *Break Stuff* was the decision structured around the engineering design process. The decision to use this process as the focus of *Break Stuff* was derived from the project team's analysis of the Massachusetts Science and Technology/Engineering Curriculum Framework. Of the seven subject area topics in this framework, six of them are results of the engineering design process, and the seventh topic is the engineering design process. The first subject area topic—Materials, Tools, and Machines—is directly related to the research and prototyping stages of the design process. The five other topics—Communication Technologies, Manufacturing Technologies, Transportation Technologies, Bioengineering Technologies, and Construction Technologies—are all products of the engineering design process. As a result, the project team determined in order for students to obtain a comprehensive understanding of these technologies, they first need a solid understand of the engineering design process. Therefore, the project team agreed that the engineering design process would be the logical choice for the basis of a learning module to teach engineering.

The team determined that it is extremely powerful for an activity, whether it be in the classroom at school or in the TLC, to encompass several topics listed in the curriculum framework. Choosing the engineering design process as the objective of the learning module and Egypt as the content theme enabled the team to incorporate the following subject area topics: Materials, Tools, and Machines, Communication Technologies, and Construction Technologies. When the students select the appropriate tools to break their artifact and the best material to reconstruct with, they are fulfilling several of the learning standards associated with Materials, Tools, and Machines. Similarly, having the students decipher and deliver a hieroglyphic message introduces them to Communication Technology. Finally, students touch upon Construction Technologies in reconstructing their artifact.

It is important for students to understand that although technologies have significantly evolved from ancient times, the engineering process has remained the same. Using the content theme, Egypt, and the objective, the engineering design process, within the learning module relays this point to the students.

5.1.3 Team dynamics

The project group wanted to incorporate teamwork into the learning module because their research showed that middle-school students work best in groups and working in groups is essential in engineering. The decision for the learning module to be group-oriented arose during an informal interview with a middle-school teacher from Newburyport, Angela Bik. The teacher explained that fairness, responsibility, and accountability are very important issues for middle-school students. Students want everyone to be given the same opportunity in a project, which is why the project group determined that students would be assigned rotating roles in the learning module. Also, a trial of the reconstruction component of the learning module with middle-school students demonstrated that teamwork is critical. The trial run did not assign roles to team members. As a result, one team member acted as an observer and was not productive to achieving the team's objective. Rotating roles will enable all team members to be involved and contribute equally.

In considering fairness, responsibility, and accountability as parts of group dynamics, the project team also decided that the students should be grouped into teams ahead of time. The project group observed from shadowing middle-school fieldtrip groups at the Museum (Appendix E) that the students naturally formed into their own groups, typically their friends, and in several cases became counterproductive to the goals of the teacher. To address this issue the learning module suggests that teachers pre-select the groups based on ability and personality.

5.1.4 The "Wow Effect"

In addition to the team dynamics established from the team's shadowing (Appendix E) of school groups, the project group observed that middle-school students have a short attention span. While observing school groups, the project team saw that students would stay at an exhibit for a few minutes, focusing mainly on exhibits that they could interact with. These exhibits allowed them to push buttons, assemble objects, and in general, gain control of the situation. The exhibits that caught the attention of the field trip groups were usually a flashy visual or interactive display. It was seen that students were drawn into a spectacle, a "wow effect," which attains and maintains their attention. This "wow effect" is seen in the learning module, *Break Stuff*, when students are given the chance to break their mystery artifacts. In the traditional classroom setting for example, students are given the task to build a napkin holder. They are given the tools and materials to do so and the outcome is twenty five of the same objects. Allowing the students to break and reconstruct their artifacts however they believe will be most effective draws the students' attention and enthusiasm.

5.1.5 Classroom Setup

Students need computers and sufficient workspace to reconstruct their artifacts and be engaged in the activity. Based on the current set up of the TLC classrooms, the most effective classrooms for this mission are the Inventor's Workshop and the Multi-Media Laboratory. Both rooms are set up so that students are able to work in groups in a comfortable setting, with plenty of space to reconstruct their artifact and use computers to research and evaluate it.

5.1.6 Materials and Technology

During the research stage and development of possible solutions in *Break Stuff*, the activity calls for various materials to be presented to the students to reconstruct their artifacts. All of the materials have similar properties, some being beneficial for their reconstruction purposes and some not beneficial. The intent of this is to force students to make educated choices about which materials are appropriate to use. This also allows each group the opportunity to succeed even though there might be variation from group to group. One must keep in mind that the materials are not labeled; only information about their characteristics is presented to remove the possibility of students using products because they are familiar with them.

Break Stuff also offers more advanced types of technology such as computers, photogrammetry software, and digital cameras to complete the research and test and evaluate stages of the design process. Along with these high technologies, the Museum has various types of engineering software and various electronic tools at its disposal. Examples of potential use for these other technologies are included in the nine candidate learning modules in Appendix F. Incorporation of these technologies was done to comply with one of the objectives of the TLC to use advanced technology in the engineering learning module.

In creating the learning module, the team did not want to promote the misconception that all technology is strictly computers or other electronic equipment. Technology, being the product of engineering, can range from a simple hammer to the international space station. Providing the students with a range of technologies will help to correct this misconception. Common misconceptions such as this will be included in the lecture on the design process following the activity.

5.2 Classroom Activities Prior to and After Museum Visit

Email from teachers helped the project team decide to include pre- and post-visit activities as part of the learning module (See Appendix C). One of the emails revealed that teachers often prepare take-home assignments for students to complete prior to the actual design-oriented classroom activity. In addition, an idea from the brainstorming session with Museum staff suggested that certain steps of the design process occur outside of the TLC.

The project team chose to bring two steps of the design process into activities outside the walls of the Museum. The project team designed a pre-visit activity that initiates the design process with identifying the problem. The post-visit activity brings the redesign step in the engineering design process into the classroom where students will break from the group dynamic and work individually.

5.2.1 Pre-visit Activity

The project team introduced the students to the first step in the engineering design process—*identify the problem*—to set the students in the right frame of mind for their Museum visit, thereby saving valuable time. The story script delivered in the hieroglyphic puzzle will give the students their mission for the day at the Museum—to deliver a secret message to the Pharaoh. With this mission in their minds, the students will understand the purpose of their day and establish motivation for their project at the Museum.

Computers with Internet access are necessary for the pre-visit activity because it is online-based. The Internet allows easy access for teachers and also allows for immediate feedback for the Museum. In addition, the project team wants all materials readily available to the teachers. Most schools have computers with Internet access in their library or computer labs so teachers will not be faced with the difficulties of searching for appropriate supplies.

5.2.2 Post-visit Activity

The post-visit activity will assess the students' learning experience at the Museum. The activity asks students to address any challenges they faced during the reconstruction and how they would fix the problem if they were given a chance to repeat the learning activity. The students work individually here because the project team does not want individual ideas to be overwhelmed by a different idea of another dominating team member. The form that the students complete online will allow them to complete the last step of the engineering design process: redesign. The responses will be indirect feedback to the Museum and will strengthen the learning module.

5.2.3 Variations

In the event that the students do not complete the pre-visit activity, the project team plans for a backup procedure that will cover the goal of the pre-visit activity in the Museum. That is, instead of the students discovering their mission from assembling the puzzle, the mission will be dictated to the students when they arrive at the Museum. The backup plan ensures that the learning module will run smoothly even if the students did not do the pre-visit activity.

The team developed a couple of versions of the pre-visit activity. In one version, students were given a mission to build a model of an Egyptian artifact and then to stamp a secret hieroglyphic message onto the model. The model artifact would then be broken and reconstructed at the Technology Learning Center. The major problem was finding a material that would break in such a way that the model could be rebuilt without enormous effort, could be obtained by the teachers, and would not require kiln firing or great amounts of time to set.

The project team experimented with different self-hardening clays with unsuccessful results. The clays were difficult to work with or broke into too many pieces, and more importantly, the actual work with the clay consumed a lot of time. In addition, finding materials for the pre-visit activity may be a difficult task for teachers. Besides the difficulty of finding a suitable material for building the model artifacts in minimal time, the hieroglyphic stamps and the Cubit ruler are not common items found in an arts and crafts store.

The current version of the pre-visit activity uses technology to eliminate the burden of finding materials. The only required material for the new pre-visit activity is a working computer with access to the Internet. The students would be asked to visit a Museum of Science webpage where they construct a puzzle to discover their mystery mission. When they arrive at the Museum, pre-built artifacts would be waiting for them in the Technology Learning Center.

The Museum's production of model Egyptian artifacts reduces inconsistencies that may occur between the models that the students would build. The thickness of the molding material can affect the time required to dry and the manner in which it breaks. Students can build their model in a way that, when broken, would shatter into pieces that cannot be reconstructed, or they could build one that is very difficult to break. Also, some students may require more time than others to build their project. With a limited amount of time per class, students would be rushed to complete their models and therefore may not be able to pay much attention.

Having students build their own artifacts brought up the important point of fairness, whose topic arose in an informal interview with a middle-school teacher. Some students, who may be more artistic than others, may build incredibly elaborate models while others may not be able to build something as complicated. Having the Museum manufacture the artifacts for the students rids of the chance of inequality or superiority of one student's work over another.

6 Conclusions

A learning module is comprised of many complex components. In developing an effective learning module, an assessment of students, teachers, and the Museum of Science, is essential. The diverse and competing needs of all interests must be evaluated and considered throughout the stages of creating a learning module. Assessing the needs of teachers through analyzing the curriculum framework and informal interviews and emails, students through observation, and the Museum through brainstorming sessions and frequent discussions, enabled the project team to determine the criterion needed to create an effective learning module. The conclusions the project team arrived at are reflective of the needs of students, teachers, and the Museum with regards to what would work as an effective learning module.

6.1 Components of an Effective Learning Module

6.1.1 Assessment of Students' Needs

The project team assessed the needs of middle-school students by shadowing them on a field trip to the Museum of Science and introducing a small group to a component of the learning module. The project team concluded that the following are the most important needs of students to be addressed in the learning module:

- "Wow effect"
- Group orientation
- Pre-grouping
- Role rotation
- Fairness, responsibility, and accountability
- Freedom
- Real world problem
- Interactive
- Reflection

The team concluded that incorporating a "wow effect" into the learning module was extremely effective in attaining and maintaining students' attention and enthusiasm. The team observed that students are pulled in by a spectacle such as an explosion. In the traditional classroom setting, students are not exposed to such a thrilling experience, and thus the team concluded that incorporating a "wow effect" was important in creating an effective learning module. Also, making the Museum experience different from that of the regular classroom is important. Creating a learning module which is group-oriented was another factor which the team deduced from assessing the needs of students. The team concluded that middle-school students enjoy being in control, and by creating a highly structured learning module with rotating roles, the students have a sense of responsibility and accountability. Enabling students to "test their limits" gives them a sense of freedom, which the team concluded was a very important element to include in the learning module. Also, the team determined that the groups should be pre-selected ahead of time by the teacher in order to ensure heterogeneous groups. Middle-school students need to be ensured that what they are doing is fair, and by creating groups with rotating roles, fairness is achieved.

In addition, the team concluded that it is imperative for the learning module to be based on a "real-life" experience. The team's research showed that middle-school students are most motivated when they can relate to the subject at hand. Thus creating a learning module which students can associate with is essential for an effective learning experience. In speaking with teachers about their students, the team was informed that teachers are most successful in conveying important points to their students when they address the emotional needs of their students. The team concluded that students learn most efficiently when they can connect or relate to the topic at hand. Thus the team determined that in creating an effective learning module, it should be based on a real-life theme.

Another critical conclusion the team arrived at in assessing the needs of middle-school students was that students learn more in an informal environment when they are allowed to interact with a hands-on activity. For example, allowing a student to actually apply different forces in determining how much force it will take to break something is more effective than simply telling them how much. Showing verse telling is an essential element for an effectual learning module. An important restriction of the learning module was its technology component, and the team concluded that it was key for the students to interact with the technology.

The final realization the team reached in assessing the needs of middle-school students was that the learning module must include a component devoted to reflection. The team concluded that it was essential for students to reflect on what they learned in order for reinforcement. The component of reflection the team included in the learning module was both a post-visit activity as well as a showcase of their work completed in the TLC in the Museum. The post-visit activity is an effective component of the learning module because oftentimes after a field trip students are not given a chance to revisit and assess what they learned. The post-visit activity not only measures what the students actually attained, but it also reinforces the aspects of the learning module they did not. Providing students with the opportunity to showcase their work in the Museum encourages them and further sparks their interest.

6.1.2 Assessment of Teachers' Needs

The project team evaluated the needs of middle-school teachers through informal interviews at the Museum as well as in the classroom and through emails. However, the project team was aware that the most important need of middle-school teachers was to implement the goals outlined by the state in the curriculum framework. The team concluded that the following elements are the most important to teachers to be included in the learning module:

- Massachusetts Science and Technology/Engineering Curriculum Framework
- Learning module options
- Pre- and post-visit activities

As mentioned above, teachers are preoccupied with preparing lessons that address the components of the MCAS. When teachers take their students on field trips they need to be assured that the learning module will indeed aid them in implementing the technology/engineering strand of the curriculum framework. Thus the most important component of an effective learning module is that it is aligned with the Massachusetts Science and Technology/Engineering Curriculum Framework.

In creating the learning module, the team determined many different options as discussed in the analysis. These options are very important for teachers because resources and time are not consistent in Massachusetts schools. The pre-visit activity the team proposed requires the students to complete an activity using a computer and the internet. However, not all schools have efficient access to the internet or sufficient number of computers for the students. The team was aware of these limitations, and created a pre-visit activity, which was not critical or necessary in completing the activity in the TLC. The team concluded that if teachers are given options they are more likely to sign up for a field trip and the learning module in the TLC.

Although teachers are given the option whether or not to implement the pre- and post-visit activities, the team concluded that these activities serve as an alternative for teachers to implement the curriculum framework. The pre-visit activity prepares the students and teachers for the learning module. The team concluded that many teachers are unfamiliar and intimidated by the new curriculum framework. The pre-visit activity can give teachers confidence and familiarity with the learning module before they take their students to the Museum. The post-visit activity allows teachers, if they desire, to take the learning module one step further, and fulfill their goal to implement the curriculum framework.

6.1.3 Assessment of Museum of Science's Needs

As the Museum of Science strives to achieve their initiative to be an outreach tool for teachers in implementing the new curriculum framework, they had specific needs to be addressed in the learning module. In addition to these fundamental needs, the project team also assessed the needs of the Museum obtained through brainstorming sessions and evaluating feedback obtained throughout the various stages of creating the learning module. The following are the conclusions the project team arrived at as to what the Museum envisions the most important components of the learning module.

- Alignment with mission statement
- Active particpation in Egypt program
- Original learning module approach

"Learning is exciting and fun" at the Museum of Science.[4] As stated in its mission, the Museum strives to encourage curiosity, questioning and exploration, inform and educate, enhance a sense of personal achievement in learning, respect individual interests, backgrounds and abilities, and promote life-long learning and informed and

[4] Museum of Science, "Our Mission," <http://www.mos.org/info/mission.html> (2001).

active citizenship.[5] An extremely important component of an effective learning module to the Museum is one that adheres to the actual mission statement of the Museum.

In evaluating the needs of the Museum, the team determined that a learning module connected to the Museum would be an effective component. Relating the content theme of the learning module to either a Museum exhibit and/or an Omni or planetarium show will aid the Museum in promoting the learning module and attracting a wide-range of visitors. For example, a sixth grade teacher studying Egypt is likely to take a field trip to the Museum to see the Egypt exhibition as well as sign up for the learning module. Although the learning module is designed to teach the engineering design process, aligning it with a current theme at the Museum will increase the likelihood of teachers unfamiliar with the engineering design process to sign up for the module. The upcoming Egypt program at the Museum will enable students to passively participate in watching Omni and planetarium shows and exploring the exhibition. However, a learning module connected to the Museum enables students to actively participate in the Egypt program.

The team created an original approach to create a learning module. The Museum will be able to emulate this approach in creating additional learning modules in the future. A universal learning module is extremely important in meeting the needs of the Museum.

[5] *Idem.*

7 Recommendations

In the process of creating a learning module, the project team also determined specific recommendations which will further aid the Museum of Science in fulfilling its initiative to be an outreach tool for teachers in implementing the new Massachusetts Science and Technology/Engineering Curriculum Framework. The Museum's new Technology Learning Center has great potential to provide teachers with an alternative to teaching engineering in the classroom. The TLC also has the potential to be as engaging to students as the Museum's flagship Computer Clubhouse. The learning module developed by the project team, in addition to the various activities currently being created by other Museum educators, are the initial steps in transforming a suite of three computer-based classrooms into an actual "Technology Learning Center" for students. The following sections display the suggestions the project team has to offer with regards to the learning module they developed as well as the TLC in general.

7.1 Evaluation of Learning Module

The project team has two very important recommendations with regards to the success of their learning module. The first recommendation is for the Museum to employ an evaluation system. The Museum currently has an evaluation committee run by Lynn Baum, the Museum Program Manager of Student and Youth Programs. The team recommends that this evaluation system be used to appropriately measure the effectiveness of the learning module. The information obtained as a result of the evaluation system will enable the Museum to make revisions, which will strengthen the likelihood of students achieving the goal of the learning module. Activities in the TLC for students on field tips are new to the Museum, and the team recommends that an evaluation system would enhance the chance of success.

The second recommendation is for the Museum to test the learning module on several groups of middle-school students and teachers from different school districts in Massachusetts as well as on Museum educators. In order to obtain accurate information about the learning module, it is critical to deliver it to students and teachers in different school districts because the level of implementation of the curriculum framework varies throughout Massachusetts public schools. Similarly, students' and teachers' interaction with the learning module will also vary. Although the learning module is intended for middle-school students, testing the learning module on Museum educators will provide useful feedback because Museum educators have a wide range of experience with working with all age levels.

As previously described in the analysis chapter, the learning module developed by the team has several different variations. In order to assess which version of the learning module will be most successful, it is very important to employ each version. If it is concluded that every version of the learning module is successful, teachers should be given the opportunity to choose which version meets their needs.

As reflected throughout the team's process in creating a learning module, feedback was the most essential factor in the development of a module to teach the engineering design process to middle-school students on a field trip. Thus, the project team highly recommends that the Museum of Science acquires and evaluates feedback both prior to and throughout the execution of the learning module.

7.2 Development of Learning Module

In developing the learning module, the project team created nine candidate learning modules. The team filtered the nine candidate learning modules to one candidate: *Break Stuff*. As a result of the time constraint of seven weeks, the project team was unable to develop the remaining seven learning module proposals. However, the team recommends that the Museum further explore the possibility of translating the remaining seven proposals into learning modules to teach the engineering design process.

Although team chose the engineering design process as the focus for their learning module, the team recommends that the Museum create a set of programs based on other main topics covered in the technology/engineering strand of the Massachusetts Science and Technology/Engineering Curriculum Framework, displayed in the Appendix B, such as *Materials-Tools-Machines*, *Construction Technologies*, *Transportation Technologies*, *Communication Technologies*, *Manufacturing technologies*, and *Bioengineering technologies*. To this end, the project team believes the Museum will truly serve as an outreach tools for teachers in implementing the newly adopted curriculum framework.

In addition to developing a set of learning modules based on the other topics in the curriculum framework for middle-school students, the team also recommends that the Museum adjust the learning module that the team created with different exhibits and/or Omni and Planetarium shows. As previously discussed, one of the criteria for choosing a learning module was its universal design. Currently the theme of the learning module is Egypt as a result of the upcoming exhibit *The Quest for Immortality*. However, when this exhibit closes next spring, it could still be modified to incorporate another theme. The Museum can adapt the learning module to any theme they see as an interest amongst visitors.

7.3 Learning Module

The project team has recommendations with regard to each of the components of the learning module: the pre-visit activity, TLC activity, and post-visit activity. The team suggests that all resources needed for teachers to execute the pre-visit and post-visit activities be available via a link on the Museum's web page. Although our learning module states this information will be available as an internet resource, this resource does not currently exist. This internet resource would enable teachers not to only implement the pre- and post-visit activities, but will also include general information to allow teachers to better prepare their students and themselves to participate in a learning module in the TLC. Teachers and students will arrive at the TLC better prepared and confident, and Museum educators will in turn be able to use the time in the TLC to execute the learning module.

As a result of the limited access many Massachusetts public schools visiting the TLC have to technology in the classroom, the team suggests the learning module be a multiple visit. Completing the learning module in fifty minutes is quite a challenge, especially for students who are not familiar at all with the engineering design process. Although the team anticipates that teachers will expand on what they learned in the TLC in their own classrooms, they understand that preparation for the MCAS might limit the amount of time spent in this project. Thus, rather than students coming to the Museum once a year for fifty minutes in the TLC to learn the engineering design process, the team proposes that the Museum creates a multiple-visit program. The Museum would have to work out the problems associated with a multiple visit such as fees for the bus ride and field trip, insufficient chaperones, and justification of time spent out of the classroom.

7.4 Technology Learning Center

In the process of creating a learning module to take place in the TLC, the project team arrived at a few recommendations for the Museum with regards to its TLC. Because students on field trips are not currently using the TLC, the team believes this information will be useful in implementing all future activities to take place in the TLC.

As the Museum educators are well aware, there is a common misconception that "technology" is equivalent to "computers." This misconception, which we determined in analyzing the curriculum framework and interacting with middle-school students and teachers, is highly conceived by students and teachers alike. Schools frequently interchange "technology" with "computers," and although a computer is indeed a type of technology, technology is not defined solely as a computer. This point is not emphasized enough in school. For example our research revealed that schools often refer to a computer class as "Technology Education."

The Museum is working to illuminate distinctions between the two terms yet in calling the three classrooms with computers the "Technology Learning Center," the Museum seems to be suggesting that "technology" is analogous to "computers." Visitors to the Museum see the sign "Technology Learning Center" and when they enter, they see only three classrooms filled with computers. Because the project team is aware this is not the Museum's intention, they suggest that the Museum equip the TLC with technologies other than computers. The emphasis on the computers in the TLC needs to be either removed or minimized and an emphasis on other types of technology needs to be established.

8 Bibliography

American Association for the Advancement of Science. Benchmarks for Science Literacy Project 2061. New York, NY: Oxford University Press, 1993.

International Technology Education Association. Standards for Technological Literacy Content for the Study of Technology. Reston, VI: International Technology Education Association, 2000.

Department of Education. Massachusetts Science and Technology Engineering Curriculum Framework. Malden, MA: Massachusetts Department of Education, 2001.

Museum of Science http://www.mos.org.html (2001).

Appendix

A. Sponsor Information

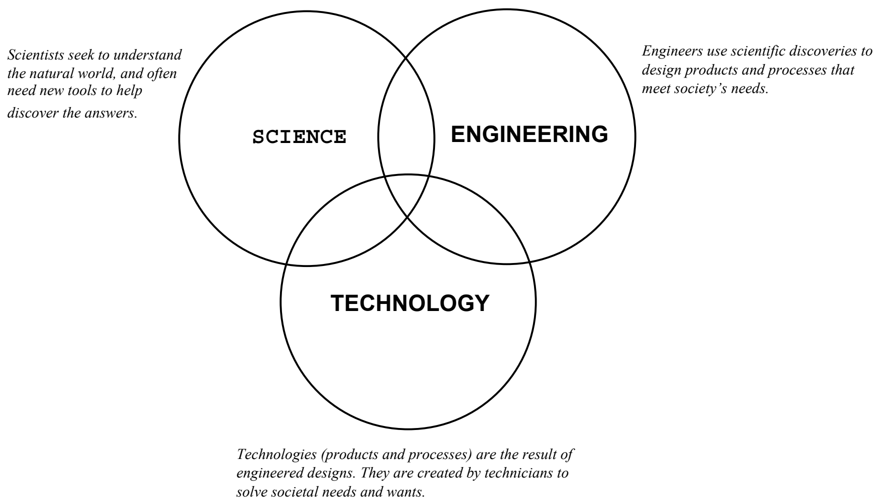
Reflections, the Museum's annual report for 2001 is enclosed.

B. Strand 4: Technology/Engineering

Science tries to understand the natural world. Based on the knowledge that scientists develop, the goal of engineering is to solve practical problems through the development or use of technologies. For example, the planning, designing, and construction of the Central Artery Tunnel project in Boston (commonly referred to as the "Big Dig") is a complex and technologically challenging project that draws on knowledge of earth science, physics, and construction and transportation technologies.

Technology/engineering works in conjunction with science to expand our capacity to understand the world. For example, scientists and engineers apply scientific knowledge of light to develop lasers and fiber optic technologies and other technologies in medical imaging. They also apply this scientific knowledge to develop such modern communications technologies as telephones, fax machines, and electronic mail.

The Relationship Among Science, Engineering, and Technology



Although the term *technology* is often used by itself to describe the educational application of computers in a classroom, instructional technology is a subset of the much broader field of technology. While important, computers and instructional tools that use computers are only a few of the many technological innovations in use today.

Technologies developed through engineering include the systems that provide our houses with water and heat; roads, bridges, tunnels, and the cars that we drive; airplanes and spacecraft; cellular phones, televisions, and computers; many of today's children's toys; and systems that create special effects in movies. Each of these came about as the result of recognizing a need or problem and creating a technological solution. Figure 1 on page 53 shows the steps of the engineering design process. Beginning in the early grades and continuing through high school, students carry out this design process in ever more sophisticated ways. As they gain more experience and knowledge, they are able to draw on other disciplines, especially mathematics and science, to understand and solve problems.

Students are experienced technology users before they enter school. Their natural curiosity about how things work is clear to any adult who has ever watched a child doggedly work to improve the design of a paper airplane, or to take apart a toy to explore its insides. They are also natural engineers and inventors, builders of sandcastles at the beach and forts under furniture. Most students in grades PreK-2 are fascinated with technology. While learning the safe use of tools and materials that underlie engineering solutions, they are encouraged to manipulate materials that enhance their three-dimensional visualization skills–an essential component of the ability to design. They identify and describe characteristics of natural and manmade materials and their possible uses and identify the use of basic tools and materials, e.g., glue, scissors, tape, ruler, paper, toothpicks, straws, and spools. In addition, students at this level learn to identify tools and simple machines used for a specific purpose (e.g., ramp, wheel, pulley, lever) and describe how human beings use parts of the body as tools.

Students in grades 3-5 learn how appropriate materials, tools, and machines extend our ability to solve problems and invent. They identify materials used to accomplish a design task based on a specific property and explain which materials and tools are appropriate to construct a given prototype. They achieve a higher level of engineering design skill by recognizing a need or problem, learn different ways that the problem can be represented, and work with a variety of materials and tools to create a product or system to address it.

In grades 6-8, students pursue engineering questions and technological solutions that emphasize research and problem solving. They identify and understand the five elements of a technology system (goal, inputs, processes, outputs, and feedback). They acquire basic skills in the safe use of hand tools, power tools, and machines. They explore engineering design; materials, tools, and machines; and communication, manufacturing, construction, transportation, and bioengineering technologies. Starting in these grades and extending through grade 10, the topics of power and energy are incorporated into the study of most areas of technology. Students integrate knowledge they acquired in their mathematics and science curricula to understand the links to engineering. They achieve a more advanced level of skill in engineering design by learning to conceptualize a problem, design prototypes in three dimensions, and use hand and power tools to construct their prototypes, test their prototypes, and make modifications as necessary. The culmination of the engineering design experience is the development and delivery of an engineering presentation.

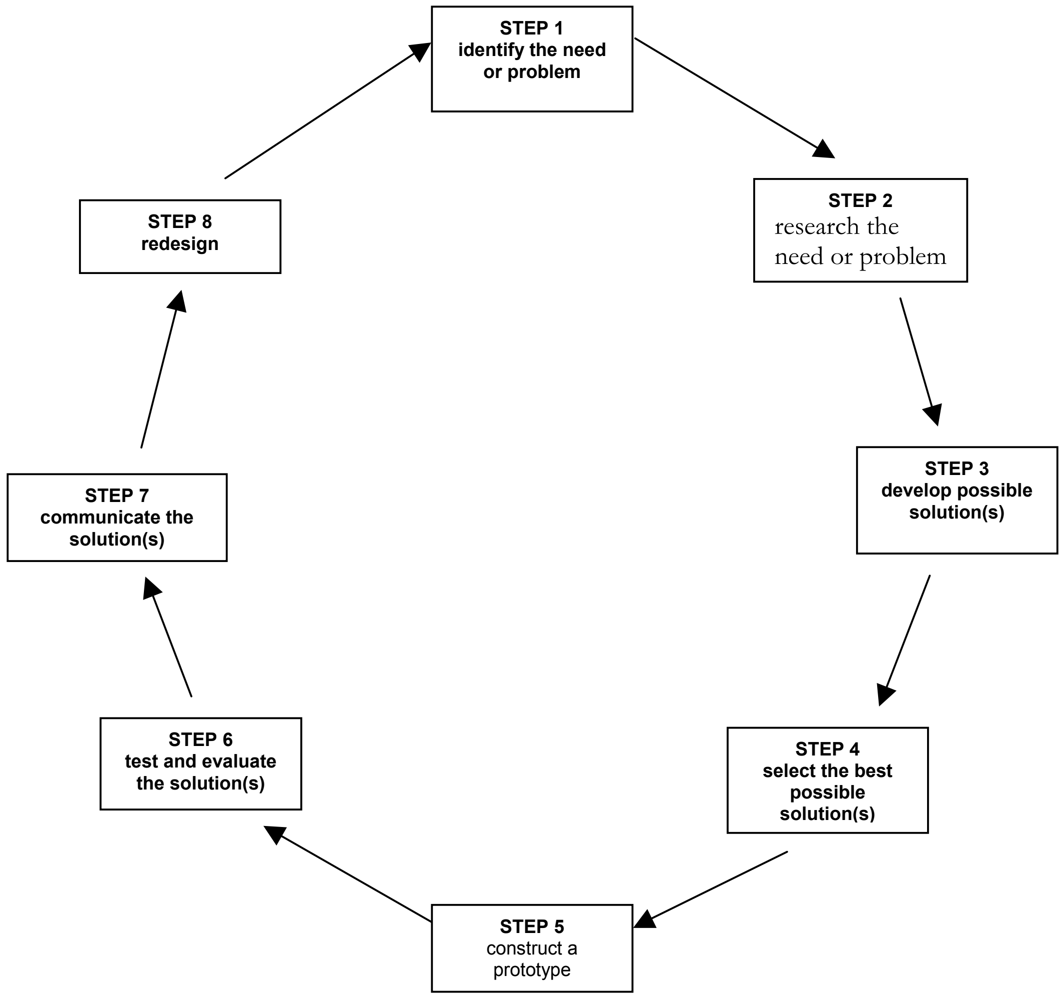
Students in grades 9 and 10 learn to apply scientific and mathematical knowledge in a full-year, comprehensive technology/engineering course. The topics addressed include engineering design; construction technologies; power and energy technologies in fluid, thermal, and electrical systems; communication technologies; and manufacturing technologies. Students engage in experiences that enhance their skills in designing, building, and testing prototypes. The culmination of this level of design experience is also the development and delivery of an engineering presentation.

Technology/engineering curricula in grades 11 and 12 follow the approaches used for the previous two grades but expand in a variety of areas based on available school expertise and student interest. Students may explore advanced technology/engineering curricula such as automation and robotics, multimedia, architecture and planning, biotechnology, and computer information systems. They may continue building on their background in engineering design by working on inventions. Course offerings in the high school grades should engage students who are interested in:

- expanding their studies in the area of engineering and technology because they are interested in a college-level engineering program,
- pursuing career pathways in relevant technology fields, or
- learning about certain areas of technology/engineering to expand their general educational background, but who will not necessarily follow a technical career.

All areas of study should be taught by teachers who are certified in that discipline. Because of the hands-on, active nature of the technology/engineering environment, it is strongly recommended that it be taught in the middle and high school by teachers who are certified in technology education, and who are very familiar with the safe use of tools and machines.

Figure 1
Steps of the Engineering Design Process



1. Identify the need or problem
2. Research the need or problem
   - Examine current state of the issue and current solutions
   - Explore other options via the internet, library, interviews, etc.
3. Develop possible solution(s)
   - Brainstorm possible solutions
   - Draw on mathematics and science
   - Articulate the possible solutions in two and three dimensions
   - Refine the possible solutions
4. Select the best possible solution(s)
   - Determine which solution(s) best meet(s) the original requirements
5. Construct a prototype
   - Model the selected solution(s) in two and three dimensions
6. Test and evaluate the solution(s)
   - Does it work?

- Does it meet the original design constraints?

7. Communicate the solution(s)
   - Make an engineering presentation that includes a discussion of how the solution(s) best meet(s) the needs of the initial problem, opportunity, or need
   - Discuss societal impact and tradeoffs of the solution(s)
8. Redesign
   - Overhaul the solution(s) based on information gathered during the tests and presentation

Technology/Engineering Learning Standards

Please note: Suggested extensions to learning in technology/engineering for grades PreK-5 are listed with the science learning standards. See pages 12-21 (earth and space science), 31-38 (life science), and 46-51 (physical sciences).

Grades PreK-2

1. Materials and Tools

Broad Concept: Materials both natural and human-made have specific characteristics that determine how they will be used.

1.1 Identify and describe characteristics of natural materials (e.g., wood, cotton, fur, wool) and human-made materials (e.g., plastic, Styrofoam).

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

1.3 Identify and describe the safe and proper use of tools and materials (e.g., glue, scissors, tape, ruler, paper, toothpicks, straws, spools) to construct simple structures.

2. Engineering Design

Broad Concept: Engineering design requires creative thinking and consideration of a variety of ideas to solve practical problems.

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

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

Grades 3-5

1. Materials and Tools

Broad Concept: Appropriate materials, tools, and machines extend our ability to solve problems and invent.

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

1.2 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.

1.3 Identify and explain the difference between simple and complex machines, e.g., hand can opener that includes multiple gears, wheel, wedge gear, and lever.

2. Engineering Design

Broad Concept: Engineering design requires creative thinking and strategies to solve practical problems generated by needs and wants.

2.1 Identify a problem that reflects the need for shelter, storage, or convenience.

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

2.3 Identify relevant design features (e.g., size, shape, weight) for building a prototype of a solution to a given problem.

2.4 Compare natural systems with mechanical systems that are designed to serve similar purposes, e.g., a bird's wings as compared to an airplane's wings.

Grades 6-8

Please note: For grades 6-high school, there are suggested learning activities after each set of learning standards. The number(s) in parentheses after each activity refer to the related technology/engineering learning standard(s).

1. Materials, Tools, and Machines

Broad Concept: Appropriate materials, tools, and machines enable us to solve problems, invent, and construct.

1.1 Given a design task, identify appropriate materials (e.g., wood, paper, plastic, aggregates, ceramics, metals, solvents, adhesives) based on specific properties and characteristics (e.g., weight, strength, hardness, and flexibility).

1.2 Identify and explain appropriate measuring tools, hand tools, and power tools used to hold, lift, carry, fasten, and separate, and explain their safe and proper use.

1.3 Identify and explain the safe and proper use of measuring tools, hand tools, and machines (e.g., band saw, drill press, sanders, hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) needed to construct a prototype of an engineering design.

Suggested Learning Activities

- Conduct tests for weight, strength, hardness, and flexibility of various materials, e.g., wood, paper, plastic, ceramics, metals. (1.1)
- Design and build a catapult that will toss a marshmallow the farthest. (1.1, 1.2, 1.3)
- Use a variety of hand tools and machines to change materials into new forms through forming, separating, and combining processes, and processes that cause internal change to occur. (1.2)

2. Engineering Design

Broad Concept: Engineering design is an iterative process involving modeling and optimizing for developing technological solutions to problems within given constraints.

2.1 Identify and explain the steps of the engineering design process, i.e., identify the need or problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.

2.2 Demonstrate methods of representing solutions to a design problem, e.g., sketches, orthographic projections, multiview drawings.

2.3 Describe and explain the purpose of a given prototype.

2.4 Identify appropriate materials, tools, and machines needed to construct a prototype of a given engineering design.

2.5 Explain how such design features as size, shape, weight, function, and cost limitations would affect the construction of a given prototype.

2.6 Identify the five elements of a universal systems model: goal, inputs, processes, outputs, and feedback.

Suggested Learning Activities

- Given a prototype, design a test to evaluate whether it meets the design specifications. (2.1)
- Using test results, modify the prototype to optimize the solution, i.e., bring the design closer to meeting the design constraints. (2.1)
- Communicate the results of an engineering design through a coherent written, oral, or visual presentation. (2.1)
- Develop plans, including drawings with measurements and details of construction, and construct a model of the solution, exhibiting a degree of craftsmanship. (2.2)

3. Communication Technologies

Broad Concept: Ideas can be communicated though engineering drawings, written reports, and pictures.

3.1 Identify and explain the components of a communication system, i.e., source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination.

3.2 Identify and explain the appropriate tools, machines, and electronic devices (e.g., drawing tools, computer-aided design, and cameras) used to produce and/or reproduce design solutions (e.g., engineering drawings, prototypes, and reports).

3.3 Identify and compare communication technologies and systems, i.e., audio, visual, printed, and mass communication.

3.4 Identify and explain how symbols and icons (e.g., international symbols and graphics) are used to communicate a message.

4. Manufacturing Technologies

Broad Concept: Manufacturing is the process of converting raw materials (primary process) into physical goods (secondary process), involving multiple industrial processes, e.g., assembly, multiple stages of production, quality control.

4.1 Describe and explain the manufacturing systems of custom and mass production.

4.2 Explain and give examples of the impacts of interchangeable parts, components of mass-produced products, and the use of automation, e.g., robotics.

4.3 Describe a manufacturing organization, e.g., corporate structure, research and development, production, marketing, quality control, distribution.

4.4 Explain basic processes in manufacturing systems, e.g., cutting, shaping, assembling, joining, finishing, quality control, and safety.

5. Construction Technologies

Broad Concept: Construction technology involves building structures in order to contain, shelter, manufacture, transport, communicate, and provide recreation.

5.1 Describe and explain parts of a structure, e.g., foundation, flooring, decking, wall, roofing systems.

5.2 Identify and describe three major types of bridges (e.g., arch, beam, and suspension) and their appropriate uses (e.g., site, span, resources, and load).

5.3 Explain how the forces of tension, compression, torsion, bending, and shear affect the performance of bridges.

5.4 Describe and explain the effects of loads and structural shapes on bridges.

Suggested Learning Activities

- Design and construct a bridge following specified design criteria, e.g., size, materials used. Test the design for durability and structural stability. (5.3)

6. Transportation Technologies

Broad Concept: Transportation technologies are systems and devices that move goods and people from one place to another across or through land, air, water, or space.

6.1 Identify and compare examples of transportation systems and devices that operate on each of the following: land, air, water, and space.

6.2 Given a transportation problem, explain a possible solution using the universal systems model.

6.3 Identify and describe three subsystems of a transportation vehicle or device, i.e., structural, propulsion, guidance, suspension, control, and support.

6.4 Identify and explain lift, drag, friction, thrust, and gravity in a vehicle or device, e.g., cars, boats, airplanes, rockets.

Suggested Learning Activities

- Design a model vehicle (with a safety belt restraint system and crush zones to absorb impact) to carry a raw egg as a passenger. (6.1)
- Design and construct a magnetic levitation vehicle as used in the monorail system. Discuss the vehicle's benefits and trade-offs. (6.2)
- Conduct a group discussion of the major technologies in transportation. Divide the class into small groups and discuss how the major technologies might affect future design of a transportation mode. After the group discussions, the students draw a design of a future transportation mode (car, bus, train, plane, etc.). The students present their vehicle design to the class, including a discussion of the subsystems used. (6.1, 6.3)

7. Bioengineering Technologies

Broad Concept: Bioengineering technologies explore the production of mechanical devices, products, biological substances, and organisms to improve health and/or contribute improvement to our daily lives.

7.1 Explain examples of adaptive or assistive devices, e.g., prosthetic devices, wheelchairs, eyeglasses, grab bars, hearing aids, lifts, braces.

7.2 Describe and explain adaptive and assistive bioengineered products, e.g., food, bio-fuels, irradiation, integrated pest management.

Suggested Learning Activities

- Brainstorm and evaluate alternative ideas for an adaptive device that will make life easier for a person with a disability, such as a device to pick up objects from the floor. (7.1)

Local Wonders

Adapted from the Building Big Activity Guide, pp. 36-37

Technology/Engineering Grades 6-8

Your community may not have an Eiffel Tower or a Hoover Dam, but you can choose any structure in your community that is significant because of its appearance, uniqueness, or historical or social impact. Consider local bridges, tunnels, skyscrapers or other buildings, domes, dams, and other constructions. You can e-mail the American Society of Civil Engineers at buildingbig@asce.org to connect with a volunteer civil engineer for this activity. To help select your local wonder, have the class brainstorm a list, take a bus tour around town for ideas, or collect some photographs for discussion.

After building newspaper towers and talking about structures and foundations, fifth and sixth graders at the Watertown, Massachusetts Boys and Girls Club brainstormed a list of interesting structures in their town. They selected St. Patrick's, an elaborate church across the street from the clubhouse. The children brainstormed questions about their local wonder. Those with an engineering focus included: When was it built? How long did the construction take? Who built it? What is it made of? Why did the builders choose that material? What is underneath the building? What holds it up? What keeps it from falling down? How was it built? Were there any problems during construction and how were they solved? Questions with a social/environmental focus included: Why was it built? What did the area look like before it was built?

Next, the students investigated their local wonder with some hands-on activities that explore basic engineering principles such as forces, compression, tension, shape, and torsion. They toured the structure, took photographs, researched the structure, interviewed long-time community members about their memories about the structure, and interviewed engineers, architects, and contractors who worked on the project. They conducted research at the library, the Historical Society, and the Watertown Building Inspector's office, where they acquired the building's plans and copies of various permits. They used this information to develop a timeline of the building's history.

Students can use the following method to estimate the size of a large structure. First, measure a friend's height. Have your friend stand next to the structure, while you stand a distance away (across the street, for instance). Close one eye and use your fingers to "stack" your friend's height until you reach the top of the structure. Multiply the number of times you stacked your friend by his/her height to find the total estimated height of the structure.

The outline of the final report may look like this:

I. Name of group submitting report
II. Name and description of structure (identify the type of structure, e.g., bridge, skyscraper, and decribe and explain its parts)

III. Location
IV. Approximate date structure was completed
V. Approximate size
VI. Why we chose this particular local wonder
VII. What's important about our local wonder
VIII. Things we learned about our local wonder (include information such as type of construction, engineering design concepts, and forces acting on the structure)
IX. Interesting facts about our local wonder

Any group that completes this project can submit its investigation to pbs.org/buildingbig. Send them your complete report, including photographs or original drawings of your local wonder. Students should be encouraged to draw the structure from a variety of different perspectives. Students can also share their reports with other classes in their school or at a local town meeting.

Assessment Strategies

- Share examples of other groups' completed investigations with the students at the beginning of the project. Discuss and develop criteria for effective write-ups, and identify what constitutes quality work.
- Students can record their learning in an engineering journal. Students can write down each day what they have learned, questions that they may have, resources they found helpful, and resources they need to find. The teacher should read the journals to monitor students' progress and level of participation, and to identify what topics the students have mastered and which areas of learning need to be reinforced by additional instruction.
- Post your local wonder report on your school district website, on the town website, or on a town agency's website, e.g., the Chamber of Commerce. Include an e-mail address and encourage feedback.
- At the end of the unit, provide the students with a photograph of a similar structure from another town or area. Ask them to write a final paper that compares this structure to the local wonder they just studied. How are they alike? Different? Compare the materials, design, and purpose of these structures.

Note: The applicable standards may vary depending upon the type of structure selected.

Engineering Design Learning Standards

2.2 Demonstrate methods of representing solutions to a design problem, e.g., sketches, orthographic projections, multi-view drawings.
2.5 Explain how such design features as size, shape, weight, function, and cost limitations would affect the construction of a given prototype.

Construction Technologies Learning Standards

5.1 Describe and explain parts of a structure, e.g., foundation, flooring, decking, wall, roofing systems.
5.2 Identify and describe three major types of bridges (e.g., arch, beam, and suspension) and their appropriate uses (e.g., site, span, resources, and load).
5.3 Explain how the forces of tension, compression, torsion, bending, and shear affect the performance of bridges.
5.4 Describe and explain the effects of loads and structural shapes on bridges.

Technology/Engineering Learning Standards for a Full First-Year Course in Grades 9 or 10

1. Engineering Design

Broad Concept: Engineering design involves practical problem solving, research, development, and invention and requires designing, drawing, building, testing, and redesigning.

1.1 Identify and explain the steps of the engineering design process, i.e., identify the problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.

1.2 Demonstrate knowledge of pictorial and multi-view drawings (e.g., orthographic projection, isometric, oblique, perspective) using proper techniques.

1.3 Demonstrate the use of drafting techniques with paper and pencil or computer-aided design (CAD) systems when available.

1.4 Apply scale and proportion to drawings, e.g., ¼" = 1'0".

1.5 Interpret plans, diagrams, and working drawings in the construction of a prototype.

Suggested Learning Activities

- Create an engineering design presentation using multimedia, oral, and written communication. (1.1)
- Choose the optimal solution to a problem, clearly documenting ideas against design criteria and constraints, and explain how human values, economics, ergonomics, and environmental considerations have influenced the solution. (1.1)
- Visit a local industry in any area of technology and describe the research and development processes of the company. (1.1, 1.5)
- Have students utilize library resources/internet to research the patent process (1.1, 1.2, 1.5)
- Create pictorial and multi-view drawings that include scaling and dimensioning. (1.2, 1.3, 1.4, 1.5)
- Create plans, diagrams, and working drawings in the construction of a prototype. (1.2, 1.3, 1.4, 1.5)
- Create drawings that include scale and dimension. (1.2, 1.3)

2. Construction Technologies

Broad Concept: Various materials, processes, and systems are used to build structures.

2.1 Distinguish among tension, compression, shear, and torsion, and explain how they relate to the selection of materials in structures.

2.2 Identify and explain the purposes of common tools and measurement devices used in construction, e.g., spirit level, transit, framing square, plumb bob, spring scale, tape measure, strain gauge, venturi meter, pitot tube.

2.3 Describe how structures are constructed using a variety of processes and procedures, e.g., welds, bolts, and rivets are used to assemble metal framing materials.

2.4 Identify and explain the engineering properties of materials used in structures, e.g., elasticity, plasticity, thermal conductivity, density.

2.5 Differentiate the factors that affect the design and building of structures, such as zoning laws, building codes, and professional standards.

2.6 Calculate quantitatively the resultant forces for live loads and dead loads.

Suggested Learning Activities

- Demonstrate the transmission of loads for buildings and other structures. (2.1, 2.2, 2.6)

- Construct a truss and analyze to determine whether the members are in tension, compression, shear, and/or torsion. (2.1, 2.3, 2.4, 2.5)
- Given several types of measuring tools and testing tools, give students a challenge and have them evaluate the effectiveness of a tool for the given challenge. (2.2)
- Construct and test geometric shapes to determine their structural advantages depending on how they are loaded. (2.3, 2.5, 2.6, 2.6)
- Using a chart from the state building code, students should be able to correctly use the stress strain relationship to calculate the floor joist size needed. (2.4, 2.6)

Boldface type indicates core standards for full-year courses.

- Design and conduct a test for building materials such as density, strength, thermal conductivity, specific heat, and moisture resistance. (2.4, 2.5)
- Calculate the live load for the second floor of a building and show how that load is distributed to the floor below. (2.5, 2.6, 2.6)
- Identify ways to protect a watershed, e.g., silt barriers, hay bales, maintenance of watershed areas. (2.5)

3. Energy and Power Technologies–Fluid Systems

Broad Concept: Fluid systems are made up of liquids or gases and allow force to be transferred from one location to another. They also provide water, gas, and oil, and remove waste. They can be moving or stationary and have associated pressures and velocities.

3.1 Differentiate between open (e.g., irrigation, forced hot air system) and closed (e.g., forced hot water system, hydroponics) fluid systems and their components such as valves, controlling devices, and metering devices.

3.2 Identify and explain sources of resistance (e.g., 45º elbow, 90º elbow, type of pipes, changes in diameter) for water moving through a pipe.

3.3 Explain Bernoulli's Principle and its effect on practical applications, i.e., airfoil design, spoiler design, carburetor.

3.4 Differentiate between hydraulic and pneumatic systems and provide examples of appropriate applications of each as they relate to manufacturing and transportation systems.

3.5 Explain the relationship between velocity and cross-sectional areas in the movement of a fluid.

3.6 Solve problems related to hydrostatic pressure and depth in fluid systems.

Suggested Learning Activities

- Demonstrate how the selection of piping materials, pumps and other materials is based on hydrostatic effects. (3.1, 3.5, 3.6)
- Demonstrate how a hydraulic brake system operates in an automobile. (3.1, 3.5, 3.6)
- Design a private septic system with consideration to the type of soil in the leach field. (3.1, 3.4)
- Identify the elements of a public sewer system and a private septic system. (3.1, 3.4)
- Explain engineering control volume concepts as applied to a domestic water system. Does the amount of water entering a residence equal the amount of water leaving the residence? (3.5)
- Design an airfoil or spoiler to examine Bernoulli's Principle. (3.3)
    - Create a hydraulic arm powered by pistons that is capable of moving in three dimensions. (3.4, 3.6)

- Have students do a simple calculation with velocity and cross-sectional pipe size. Velocity times cross sectional area is a constant. As the pipe size changes the velocity will have to change as well. For example, if the pipe changes from a 2-inch diameter to a 1-inch diameter, the velocity will have to quadruple. (3.5, 3.6)

4. Energy and Power Technologies–Thermal Systems
Broad Concept: Thermal systems involve transfer of energy through conduction, convection, and radiation, and are used to control the environment.

4.1 Differentiate among conduction, convection, and radiation in a thermal system, e.g., heating and cooling a house, cooking.

4.2 Give examples of how conduction, convection, and radiation are used in the selection of materials, e.g., home and vehicle thermostat designs, circuit breakers.

4.3 Identify the differences between open and closed thermal systems, e.g., humidity control systems, heating systems, cooling systems.

4.4 Explain how environmental conditions influence heating and cooling of buildings and automobiles.

4.5 Identify and explain the tools, controls, and properties of materials used in a thermal system, e.g., thermostats, R Values, thermal conductivity, temperature sensors.

Boldface type indicates core standards for full-year courses.

Suggested Learning Activities

- **Create a model to test the concept of conduction and compute heat losses, e.g., through the multi-layer wall of a building. (4.1, 4.2, 4.4)**
- Design and build a hot water solar energy system consisting of a collector, hoses, pump (optional), and storage tank. After it has been heated, calculate the heat gains achieved through solar heating. (4.1, 4.5)
- Design and build a model to test heat losses through various materials and plot the results. (4.2, 4.5)
- Design and build a solar cooker for various food substances. Each student should design their solar cooker for her or his specific food. (4.1, 4.2)
- Design an awning for a business based upon the seasonal changes in the angle of the sun. (4.2)

5. Energy and Power Technologies–Electrical Systems
Broad Concept: Electrical systems generate, transfer, and distribute electricity.

5.1 Describe the different instruments that can be used to measure voltage, e.g., voltmeter, multimeter.

5.2 Identify and explain the components of a circuit including a source, conductor, load, and controllers (controllers are switches, relays, diodes, transistors, integrated circuits).

5.3 Explain the relationship between resistance, voltage, and current (Ohm's Law).

5.4 Determine the voltages and currents in a series circuit and a parallel circuit.

5.5 Explain how to measure voltage, resistance, and current in electrical systems.

5.6 Describe the differences between Alternating Current (AC) and Direct Current (DC).

Suggested Learning Activities

- Design and create an electrical system containing a source, a switch, and multiple loads. Be able to measure the voltage and current at each load. (5.2)

- Design and create an electrical system with either motors or lights. All of the motors in the system will operate at different speeds, or the lamps will operate at different intensities. (5.2, 5.3)
- Create schematics for series, parallel, and combination (series-parallel) circuits, and construct them from the schematics. (5.4)

6. Communication Technologies

Broad Concept: The application of technical processes to exchange information includes symbols, measurements, icons, and graphic images.

6.1 Identify and explain the applications of light in communications, e.g., reflection, refraction, additive, and subtractive color theory.

6.2 Explain how information travels through different media, e.g., electrical wire, optical fiber, air, space.

6.3 Compare the difference between digital and analog communication devices.

6.4 Explain the components of a communication system, i.e., source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination.

6.5 Identify and explain the applications of laser and fiber optic technologies, e.g., telephone systems, cable television, medical technology, and photography.

Suggested Learning Activities

- Give an example of the following types of communication: human to human (talking), human to machine (telephone), machine to human (facsimile machine), and machine to machine (computer network). (6.4)
- Create specific types of communication: human to human (e.g., talking, telephone), human to machine (e.g., keyboard, cameras), machine to human (e.g., CRT screen, television, printed material), machine to machine (e.g., CNC, internetworking). (6.2, 6.3, 6.4)
- Explain what is meant by the size and focal length of a lens and its application for light theory. (6.5)
- Research a communication technology and the impact lasers or fiber optics have had on that technology. (6.4, 6.5)

Boldface type indicates core standards for full-year courses.

7. Manufacturing Technologies

Broad Concept: Manufacturing processes can be classified into six groups: casting and molding, forming, separating, conditioning, assembling, and finishing.

7.1 Explain the manufacturing processes of casting and molding, forming, separating, conditioning, assembling, and finishing.

7.2 Differentiate the selection of tools and procedures used in the safe production of products in the manufacturing process, e.g., hand tools, power tools, computer-aided manufacturing, three-dimensional modeling.

7.3 Explain the process and the programming of robotic action utilizing three axes. (7.3)

Suggested Learning Activities

- Design a system for mass producing a product. (7.1, 7.2)
- Design, build, and program a robotic device capable of moving through three axes. (7.3)

Boldface type indicates core standards for full-year courses.

A Look at Energy Efficient Homes

Adapted from *Standards for Technological Literacy,* p. 197

Technology/Engineering Grades 9-10

The city of Westlake and the surrounding areas experienced an accelerated growth in the construction industry, especially in new home construction. The local high school technology teacher, Mr. Morales, thought it would be helpful for his students, as future consumers, to have an in-depth understanding of the housing industry and to know about the latest developments in home construction techniques, materials, and practices.

Mr. Morales decided to organize a lesson where students were invited to participate in designing an energy-efficient home for a family of four. He guided the students to consider all forms of energy and not to limit their imaginations. Students were instructed to consider costs of using energy-efficient designs and how those costs might affect the resale value of a home.

The students in the technology classes were challenged to design, draw, and build a scale model of a residential home using heating and cooling systems that were energy-efficient, aesthetically pleasing, functional, marketable, and innovative. The house also had to accommodate a family of four with a maximum size of 2100 square feet. The students had to work within a budget of $150,000, and they had nine weeks to complete the project.

The students began by researching homes in their area that already incorporated features that were required in their home. They conducted library and internet searches to learn about the latest materials and techniques available in the housing industry. Students also interviewed local architects and building contractors to learn about various practices and how they were integrating innovative features. For example, they learned about incorporating increased day lighting, which takes into account the home's orientation, into the design of the home. They also learned about designing and installing environmentally sound and energy-efficient systems and incorporating whole-home systems that are designed to provide maintenance, security, and indoor air-quality management.

The students then began the process of sketching their homes. Many students had to gather additional research as they realized they needed more information to complete their sketches. Using their sketches, the students built scale models of their homes out of mat board.

A group of building industry professionals from across the area was invited to evaluate students' work and provide feedback on their ideas in several categories, including design, planning and innovations, energy conservation features, drawing presentation, model presentation, and exterior design.

As a result of this experience, the students learned firsthand what it takes to design a home for the 21st century. Students also learned how to successfully plan and select the best possible solution from a variety of design ideas in order to meet criteria and constraints, as well as how to communicate their results using graphic means and three-dimensional models.

Assessment Strategies

- Students can research building codes and zoning laws in the community. Write a detailed report on the building codes and zoning laws.
- Students can compare construction efficiency of various house designs and evaluate the advantages and disadvantages of each design (e.g., ranch vs. colonial, lumber vs. steel framework). Create a chart illustrating the differences.
- Students can create an engineering presentation of the design, efficiency, and prototype using appropriate visual aids, e.g., charts, graphs, presentation software. Presentation may include any other factors that might impact the design of the house, e.g., the site, soil conditions, climate.
- Students will use a rubric to assess design specification, heat efficiency, and final prototype of the design challenge.

Engineering Design Learning Standards

1.6 Identify and explain the steps of the engineering design process, i.e., identify the problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.
1.7 Demonstrate knowledge of pictorial and multi-view drawings (e.g. orthographic projection, isometric, oblique, perspective) using proper techniques.
1.8 Demonstrate the use of drafting techniques with paper and pencil or computer-aided design (CAD) systems when available.
1.9 Apply scale and proportion to drawings, e.g., ¼" = 1'0".
1.10 Interpret plans, diagrams, and working drawings in the construction of a prototype.

Construction Technologies Learning Standards

2.7 Identify and explain the engineering properties of materials used in structures, e.g., elasticity, plasticity, thermal conductivity, density.
2.8 Differentiate the factors that affect the design and building of structures, such as zoning laws, building codes, and professional standards.
2.9 Calculate quantitatively the resultant forces for live loads and dead loads.

Energy and Power Technologies–Thermal Systems Learning Standards

4.6 Identify the differences between open and closed thermal systems, e.g., humidity control systems, heating systems, cooling systems.
4.4 Explain how environmental conditions influence heating and cooling of buildings and automobiles.

C. Teacher emails

Mary Beth Clark:

I do several design/build/revise activities in my classroom. Some of them actually originated in the Museum, I think... I took 'em from a guy who took 'em from Bernie Zabriski (sp?). Anyway, I'd be glad to give you input:

1. Do you do anything in your classroom that is similar to these activities? Please specify.

I do a tops activity at the start of the year, in which I give the kids simple materials (cardboard, old AOL CDs, shish kebab skewers, etc.) and have them design a top that will spin the longest time. After watching the in-class building process and results (and discussing mass and inertia), I assign homework where the kids must build their own top from whatever they have around the house. The hours they put into this are impressive, and the work is amazing. Some of the tops have spun for more than 10 minutes; if I let them launch with a drill, the times go up over 20 minutes, believe it or not!

I do a windmill activity (I know this idea came from Bernie's book originally!) in which I give them shish kebab skewers, cardboard, pasta wheels, and string, and have them build a windmill that will lift the maximum weight (hung from the string via an S-hook on a bucket that holds pennies or washers).

I have them build hot-air balloons with tissue and glue; mini-scale models first out of graph paper, then the "real thing." We heat them with a blow dryer and heat gun (littel danger of fire that way) and launch them outside on a cool, windless day. A great crowd-pleaser!

Throughout the year I'll give kids "mini-challenges" and have them work on those for a day or two. "Build a paper tower that will hold the most books on its top" (I give them limited paper)... "Build a balloon-launched car out of pasta and glue..." etc.

3. Are there any discussions at your school regarding the MA Science and Technology/Engineering Curriculum Framework (May 2001)?

Mostly a sort of "Ugh! We're supposed to teach this WHERE?" We dont' have a tech class at my school; I love the design/build process things in science, but some of the specific vocabulary and business-oriented language is not something I care to add to the science curriculum.

<< Any information you have available would be helpful to us. >>

Here's my KEY piece of advice about doing these things with middle-school students: Buy some low-temp glue guns, and keep them well-stocked with glue sticks. Building anything with Elmer's glue is hopeless... it takes forever to dry and allows structures to collapse in the meantime. I used to do toothpick bridges with Elmer's and watched kids pour hours into them, only to have them stick together or collapse overnight as the glue dried. Replace the Elmer's with a low-temp glue gun and you've got INSTANT gratification. Plus, if a design doesn't work, the kid hasn't invested 3 weeks in it. I've found parents (and students) pretty generous about donations, but even without them, a glue gun is only $1.97 at Wal-Mart, and a bag of 100 glue sticks about $3.00. You can outfit a class for a project with less than $25, if kids pair up.

If you have any other questions, let me know. I'm fairly well-versed at conducting these things with middle-schooll kids so that the management piece (keeping track of supplies, storing things, setting up grading and guidelines) doesn't take away the thrill of the experience for the kids OR the teacher.

Lorraine Theroux:

I teach K-5; made some minor responses below.

t0ny wrote:

> March 22, 2002
>
> Dear Seventh and Eighth-Grade Teachers,
>
> The Museum of Science is interested in creating learning modules
> that teach engineering to seventh and eighth graders. We believe that
> obtaining input from seventh and eighth-grade teachers will give us
> insight which will facilitate our progress in implementing this project.
>
> The following section displays examples of learning activities
> that teach important concepts in technology/engineering.
>
> -Design and build a catapult that will toss a marshmallow the
> farthest.
>
> -Given a working model, devise a test to evaluate whether it meets
> the design specifications. Using the test results, modify the model to
> optimize the solution, i.e., bring the design closer to meeting
> the design constraints.
>

> -Design and construct a bridge following specified design
> criteria, e.g., size, materials used. Test the design for
> durability and structural stability.
>
> -Design a model vehicle (with a safety belt restraint system and
> crush zones to absorb impact) to carry a raw egg as a passenger.
>
> 1. Do you do anything in your classroom that is similar to these
> activities? Please specify.
>

No - I've done some bridge building in the past and am thinking about more design projects, especially for my 4th and 5th graders.

>
> 2. If not, is there any course offered in your school that is similar
> to these activities? Please specify.

No

>
>
> 3. Are there any discussions at your school regarding the MA Science
> and Technology/Engineering Curriculum Framework (May 2001)?

Only by me (I do sometimes talk to myself :) but I do raise the issue but it falls flat - I'm the only teacher of science in my building.

>
>
> Even if the answer is no to all of the above, we would appreciate your
> response.
>
> Any information you have available would be helpful to us. Please feel
> free to contact us via email (mos@wpi.edu) with any questions or comments.
> We hope to hear from you soon.
>
> Sincerely,
>
> Tony Trinh (Intern)

Rosemary Smith:

At Pine Hill School in Sherborn Mass. the fourth graders are part of the NSTA/Craftsman tool project where the students design a muscle powered tool that solves a problem. It is a home-school project that ends in an afternoon of the fourth graders viewing the projects that others have made. Children may go on to the national level if they wish. It fits the Mass. Framework for Science/Technology.

David Bouvier:

Answers:

-Design and build a catapult that will toss a marshmallow the farthest.

Framingham students, especially at Walsh, use the design process to create catapults. We're investigating the possibility of Paint Balls rather then marshmallows for a greater effect.

-Given a working model, devise a test to evaluate whether it meets the design specifications. Using the test results, modify the model to optimize the solution, i.e., bring the design closer to meeting the design constraints.

All three middle schools are into prototype development. We've concentrated on the Rube Goldberg device at the seventh grade but the design process permeates every investigation that we consider including Transportation devices at the 6th grade and Manufactured items at the 8th grade.

-Design and construct a bridge following specified design criteria, e.g., size, materials used. Test the design for durability and structural stability.

This is part of our 7th grade program. Bridges are popular, but we've also looked at towers. Included in bridges for advanced problem-solving is a problem to including gears and a DC motor to create a drawbridge. With towers, we include earthquake resistant problem solving with attachments to a vibrating sander.

-Design a model vehicle (with a safety belt restraint system and crush zones to absorb impact) to carry a raw egg as a passenger.

Everyone does this. We ask students to devise a guidance system to be included to hit a specific target.

1. Do you do anything in your classroom that is similar to these

activities? Please specify.

See above. Also, in the framework, we need to be able to visually represent our solutions through a drawing and talk about the 5 elements of the univeral systems model.

2. If not, is there any course offered in your school that is similar to these activities? Please specify.

Framingham offers technology/engineering to every middle-schooll student. 6th and 7th graders have 30 sessions and 8th graders have 60 sessions. The design process includes the usage of tools and machines. This is best accomplished in a tech ed lab.

3. Are there any discussions at your school regarding the MA Science and Technology/Engineering Curriculum Framework (May 2001)?

Absolutely. We use it as a guide. We understand the tech ed/engineering component of MCAS at this level.

D. Brainstorming Session

March 27, 2002 1:00 PM (brainstorming-clarify-advocate-canvas)

Approximately 1 hour.
Distributed project brief and design process taken from MA Science and Technology/Engineering Curriculum Framework.

Facilitator: Sharon
Recorder: Lesley
Observers: Heather, Tony, and Bryan
Audience: Emily, Ellen, Lorin, Sue, Susan, and Mike

How do we use the resources of the Technology Learning Center to convey the engineering design process to seventh and eighth graders on a field trip?

1. Play out design challenge through entire visit
   - No worksheets during visit

2. Hands-on for some of the steps at MOS

3. Pre-trip info online to support MOS work; research ahead, come in and do

4. Solving real world problem as they relate to community

5. Multiple-visit program
   - Multiple-visit program needed for a "real" reflection of design process

6. Museum connection can't be done at school
7. Museum connection may include staff and exhibit resources
8. Use computers to model in order to inform construction
9. "Add an exhibit", steps 2, 3, 4 of engineering design process, use Museum w/TLC
10. Use the Museum for research
11. Connect "design process" and inquiry process or other pre-experience
12. During visit product, perhaps not start -> finish
13. Invite teacher to select from menu of steps
14. Professional presentation of design ideas
15. Exhibit products
16. Concentrate on steps 6 and 7 at MOS
17. Post-visit product showcased at MOS

E. Observations from shadowing

Heather's notes:

Behavioral:
Had food on their minds.
Walking by the food-court totally distracted them.
Love anything they can physically do.
Like to see themselves-camera, mirrors, Liberty Bell exhibit.
Girls are constantly looking in the mirror or in the windows fixing their hair.
Boys were pushing the girls.
Short attention span.
Flirting.
So excited for the Planetarium.
Love anything they can physically do.

Related to Worksheet:
What do we write?
What's the answer?
Once they were done filling out worksheet, they were done and were only focused on getting to the Planetarium on time.
Finished worksheet extremely quickly.

Bryan's Notes:

-Local connection
-Natural groups exist; form into pairs (2 girls, 2 guys)
-Use friends, 2 girls
-They will make it as simple as possible; copying, running
-Small groups will be more focused
-Smell interesting
-Attention span about 3 minutes
-Wanted to go into the hunting room, 4 guys
-Groups of 3 guys liked physical bird walker
-Lack of money, books not aligned because frameworks get revised
-Push buttons just to push, walked away right after
-Tried to aggravate others, 1 guy
-One person can attract the group, 4 guys
-4 girls, liked simulating schoolhouse
-Recounted memories in schoolhouse
-Fighting with guys
-They will ask questions
-Very literate
-"Hey a computer, electronics" 1 girl
-Feel, unique texture one-way to catch attention

-In the "palm tree thing" they were all interested but focused on different things, 4 guys, 3 girls
-4 girls liked feedback with video microscope
-3 girls (isolated from group) read and tried Mystery Shell game
-5 guys enjoyed being grossed out by viewing hand under microscope, a wart
-Dinosaurs exhibit microscope and earth crust
-Guy flirting with girl
-Food
-Let them walk around
-Some kids will move to the back or corner to avoid "school"
-Again interested microscopes "growing crystals"
-One girl controlled 8 people, 2guys, and 6 girls
-There is a very informal attitude with chaperones
- Touch screens, 2 girls

Tony's notes:

KIDS

1. like moving things
2. don't like filling out long answers
3. they like going inside things, pushing buttons
4. more concerned with playing than completing worksheets
5. pay attention more when teachers say that "this might be on the next test"
6. like playing with computers
7. copy each other's worksheets
8. girls doing more work than boys
9. like to put things together
10. like to test their limits
11. after passing through Mathematica and completing that section of the worksheet, some kids still do not understand how math is related to weather
12. like playing with camera, like seeing themselves on TV, like controlling the camera
13. like the Liberty Bell ride
14. some don't like to wait, others don't mind the wait
15. like interactive things that look like video games
16. peer pressure is overwhelming
17. lots of cliques

TEACHERS

1. have to push kids to do worksheets; one teacher threatened to cancel the Canobie Lake Park field trip
2. "Volcanoes have to do with weather."
3. "Go write something intelligent!"
4. "They like to play, to touch things. I think hands-on activities are the best to teach. They learn by playing."
5. "Whirling watcher has to do with weather."
6. "They love the cryogenics program. They love fun."
7. lets one kid cheat (favoring)

F. Learning Module Proposals

Engineering Learning Module
Break Stuff

Synopsis:

Students take pictures in Egypt exhibit with digital camera. Then, they choose an artifact from one of the pictures and build a clay replica, paying close attention to hieroglyphic detail. While they are waiting for the replica to harden, they can use the computer to study hieroglyphics and translate the writings on their model. After the clay hardens, students put the replica in the bag and gently break it up (not pulverize). The students then trade bags and reconstruct each other's replicas with the tweezers and glue. They will translate the hieroglyphics on their new model and then will compare translations with the owner's.

Pre-Visit Activity:

Students build a replica of the artifact using clay, stressing detail on the hieroglyphics The artifacts are put in clear zip-lock bags and broken up into pieces. They break up the replica into several pieces inside a plastic bag and then trade bags with each other. Each team reconstructs each other's models and translates the hieroglyphic writings.

Story/Setting:

Archaeologists spend a great deal of time recovering artifacts from Egyptian civilizations. These artifacts help us understand the early cultures of the Egyptian world. Many times, artifacts are not salvaged in mint condition. In fact, reconstructing the damaged artifact to its original state is a very delicate process.

Pretend you are a National Geographic archaeologist on a mission to study Thutmosis' tomb. During your mission, you fall upon a beautiful Egyptian artifact and break it. In order to keep your job, you must put the pieces back together again.

Design Process Step 1 – Identify the Problem:

Reconstruct it.

Design Process Step 2 – Research:

Students take pictures in Egypt exhibit. Students learn hieroglyphics from the computer. Students tour the Egypt exhibit and take pictures with a digital camera.

Design Process Step 3 - Develop Solutions and Selection:

Design Process Step 4 - Develop a Prototype:

Design Process Step 5 - Test and Evaluate:

Students compare their translations with the owner's.

Design Process Step 6 - Communicate:

They study hieroglyphics and translate the writings on their artifact. Then each group will present on how their translation compared to the original.

Lecture on the Design Process

Engineering Learning Module
Design a Burial Room for A Pharaoh

Synopsis:

None

Pre-Visit Activity:

None

Story/Setting:

You are an engineer for a pharaoh (the teacher or chaperone of the class). You have been asked to create a burial chamber out of your school classroom. Lucky you have modern technology to help you on your journey. Good Luck

Design Process Step 1 - Problem:

Students must identify the objective of this activity, which is to turn your classroom into a burial chamber for the pharaoh.

Design Process Step 2 – Research:

Students will pair up in pre-selected groups of four to complete the rest of the project. The computer can be used to reference any of the information that is out in the exhibits. A small group of selected students could be allowed to walk out to the exhibit and take digital pictures of any of the models. Second option: this can be done before hand, with the TLC setting already been given to the students prior to a visit to the museum.

Students will need to have seen the exhibit on burial chambers that the museum has displayed.

Design Process Step 3 - Develop Solutions and Selection:

This section might require the use of basic CAD architecture software that does simple 3D modeling. Preset rendering options, such as texture and lighting, will make all of the different designs have an ancient Egyptian look to them.

Design Process Step 4 - Develop a Prototype:

Design Process Step 5 - Test and Evaluate:

A brief summary should be given to the visiting chaperone or teacher. Based on this summary and hopefully only a little on their personal preferences the visiting adult should select the top two designs.

Design Process Step 6 - Communicate:

Using software similar to Timbucktoo the instructor in the TLC can display all of the models that the groups of students have created.

Lecture on the Design Process

Engineering Learning Module
Design a Futuristic Entertainment System

Synopsis:

Students, in project teams, are to design an entertainment system of the future. Each group designs and builds a part of the entertainment system (e.g., TV, VCR, etc.) within a given amount of time. Design blueprints and specifications from each group are displayed on the computer screen at the end of the design process. Each group will then be able to see what is lacking in their design, how their device needs to change in order for a bigger part of the system to work properly. After a redesigning process, each part in the entertainment system should work together. Students will model their design using the given material.

Pre-Visit Activity:

None

Story/Setting:

Somehow you've traveled into the future 100 years ahead. A huge company hires you to design a new entertainment system for them.

Design Process Step 1 – Identify the Problem:

Students must recognize the problem within the story. That is, the students must design an entertainment system of the future

Design Process Step 2 – Research:

Design Process Step 3 - Develop Solutions and Selection:

Students each design a separate part of the entertainment system. For example, one group works on a design for a television while another models a VCR.

Design Process Step 4 - Develop a Prototype:

The prototype would be the first design before the refining process. Students must redesign the prototype in order for the system to work.

Design Process Step 5 - Test and Evaluate:

The redesign is based on testing the interconnection of the system components. Through a trial-and-error process, students will develop their component to work successfully in the entertainment system.

Design Process Step 6 - Communicate:

Students model and display their design.

Lecture on the Design Process

Engineering Learning Module
Design an Egyptian Playground

Synopsis:

Students are broken up into four groups. Each group will use their knowledge about Egypt to originate a playground for Egyptian children. This will involve brainstorming ideas on paper or using a CAD tool, building a prototype with Legos, and explaining their ideas to the class (why they built the playground in that way) in a five-minute presentation.

Pre-Visit Activity:

None

Story/Setting:

Egypt's children are in dire need of a playground. The Pharaoh has just appointed you the new royal architect. Come up with a model playground and present it to the Pharaoh.

Design Process Step 1 – Identify the Problem:

Students must correctly identify the objective to design and model an Egyptian playground.

Design Process Step 2 – Research:

Computers will be used as a research/reference tool (i.e. instructions, background on Egypt, CAD tool for designing playgrounds, etc.) Students tour the Egypt exhibit and study the behavior of the Egyptian children to establish a sense of their unique culture. They should also see Egypt exhibit.

Design Process Step 3 - Develop Solutions and Selection:

Students design layouts of a playground and choose the best one to build.

Design Process Step 4 - Develop a Prototype:

Using the available resources, students construct a model of their playground based on their Egypt experience.

Design Process Step 5 - Test and Evaluate:

Each group will compare each other's playgrounds and discuss differences.

Design Process Step 6 - Communicate:

In a short presentation, students justify their playground architecture and layout. Students should explain the architecture of the model playground in a 5-minute presentation.

Lecture on the Design Process

Engineering Learning Module
Design a Rocket

Synopsis:

None

Pre-Visit Activity:

None

Story/Setting:

You are a NASA rocket scientist trying to develop a device to reach an altitude of 3000 feet.

Design Process Step 1 - Problem:

Given commercially available modeling products, design a rocket that will reach at least 3000 feet.

Design Process Step 2 – Research:

Knowledge needed beforehand: Any introduction to rocketry is good, the current Liberty 7 exhibit is good, as well as watching movies like October Sky

Activity:

- Have students record information about materials presented to them from the museum.
- Use the computer to research different designs of rockets and the benefits and drawbacks of certain designs and materials.

Design Process Step 3 - Develop Solutions and Selection:

Based on their research the groups should choose what materials they feel will design the best rocket.

Design Process Step 4 - Develop a Prototype:

This will occupy the majority of the time for this module. Given household materials the students will then be able to

Design Process Step 5 - Test and Evaluate:

This stage can be done outside the TLC classroom. It is impractical because of time constraints to allow students to test their rockets. This is will be added in as a post visit activity. Second option: students can test their rockets in a wind tunnel in which they can fire their rocket inside. This option will need an extended period of time in order to work.

Design Process Step 6 - Communicate:

This is also a post visit activity that the teachers have to add in to classroom time in a way that it satisfies their curriculum.

Lecture on the Design Process

Engineering Learning Module
Construct a Lunar Rover

Synopsis:

None

Pre-Visit Activity: None

Story/Setting:

NASA needs you to construct a lunar rover to explore the inside of the museum and gather various objects.

Design Process Step 1 - Problem:

Each group of students will need to focus their efforts on a different aspect of the lunar rover to develop.

Design Process Step 2 – Research:

The students will be setup in pre-selected groups of four. Each group should research different aspects of the lunar rover. How can it move around? How to will be able to see? How to gather objects? How to power it? Students will be able to use the computers as research tools to gather information about space exploration and remote presence. Student will need to catalog the available resources of the museum.

Design Process Step 3 - Develop Solutions and Selection:

In this stage, each group will now list different methods that each of their individual goals can be accomplished based on the information they researched. This stage will also involve a synthesis of each group's ideas into complete lunar rover.

Potential equipment could include. A video camera with wireless feed, and robot arm or shovel, and some type of RC car that is rather large.

Design Process Step 4 - Develop a Prototype:

This will mainly be selection of various parts. The classroom instructor will need to complete the assembly. This is still the prototyping stage, therefore the rover does not have to look good and all of the bugs do not have to be worked out.

Design Process Step 5 - Test and Evaluate:

This will be the fun part of the activity. Students will be able to take their creation out on the museum floor and move it around and see if they are successful. This should not be part of TLC time. This step should be delayed until the after the class has ended.

Design Process Step 6 - Communicate:

Hopefully having floor space in the museum will attract the attention of other museum visitors. The students will then have to justify to any museum visitors why they built the robot the way they did. As well as explain how the design process led them to their creation. This step should be delayed until the after the class has ended.

Lecture on the Design Process

Engineering Learning Module
Reconstruct a Monument for a Deity

Synopsis:

None

Pre-Visit Activity:

None

Story/Setting:

You are a present day archeologist who wishes to restore a "damaged statue" of an Egyptian god. Using present day technology and clues presented from a story (ex: where in the archeological site the statue was, any objects or pictures around it) along with information gathered from visits from the various exhibits.

Design Process Step 1 - Problem:

The student needs identify the task to know which god the damaged statue is of and how to reconstruct it once it has been identified.

Design Process Step 2 – Research:

Students will pair up in pre-selected groups of four to complete the rest of the project. The computer will be to research an archive of Egyptian gods with descriptions and a picture of statues from various angles. Showing only a 2D representation of the different gods will allow for flexibility in what the final statues will look like. Each student will have a unique model to take with them. Students will be able to take measurements from the remains of the statue using various high-end consumer instruments that the TLC offers. Students will need to gather information about the building materials available to them. In order to draw the attention of the students the materials that they select from should not be too familiar to them.

The students will need to have seen an exhibit on Egyptian deities.

Design Process Step 3 - Develop Solutions and Selection:

In this stage the students will use the knowledge they have just gathered to come up with rough designs for their group's statue. The use of simple CAD software could come into play or traditional paper and pencil sketches should work fine. Each group of students will be constructing similar statues however the material that they use should differ as well as the joining material (epoxy, tape, weld).

Design Process Step 4 - Develop a Prototype:

At this stage the students should build their statues.

Design Process Step 5 - Test and Evaluate:

The actual statue is then compared to the monuments the students constructed. This exploration is done with the use of various measuring devices. High technology could be the use of digital cameras and 3D photo analysis software to compare the final model with a digital copy of the original statue.

Design Process Step 6 - Communicate:

Students will then compare and present to the rest of the class why they felt their design was successful. This will be a very brief informal presentation.

Lecture on the Design Process

Engineering Learning Module
Leonard P. Zakim Bunker Hill Bridge

Synopsis:

A virtual visit to the construction site of the Leonard P. Zakim Bunker Hill Bridge will be created and shown in the Science Simulator. Large images of the stages of building this bridge will be accompanied with an engineer discussing the various phases of the bridge, the mishaps encountered, and a discussion on forces. This will be similar to an Omni show, but on a much smaller scale.

Throughout the virtual visit to the construction site of the bridge, the narrator will be describing the engineering design process. Although he/she will not come and say "for step one of the engineering design process…" it will be inherent.

Pre-Visit Activity:

Students will research different bridges in the world and will identify what kind of a bridge they are such as arch bridges, beam bridges, cable-stayed bridges, cantilever bridges, covered bridges, double-leaf bascules, drawbridges, hanging bridges, shallow arches, suspension bridges, swing bridge, transporter bridge, trestle bridge, truss-beam bridge, and vertical-lift bridge.

Story/Setting:

The Leonard P. Zakim Bunker Hill Bridge is the world's widest (10 lane) cable-stayed bridge in the world- and the shortest. Part of the Big Dig, it joins the new underground Central Artery with I-93 North out of Boston. It was named after Boston's former regional director of the Anti-Defamation League, Leonard P. Zakim.

Design Process Step 1 - Problem:

Design Process Step 2 – Research:

Knowledge needed beforehand:

Virtual visit to the construction site of the Leonard P. Zakim Bunker Hill Bridge.

What is a cable-stayed bridge: In a cable-stayed bridge, sections of the deck hang by cables attached to towers-pylons. The weight of the deck and its traffic pulls on the cables, which then pull on the pylons, which pass the force down to the foundations. Cable-stayed bridges are not very long, but they are cheaper to build.

Knowledge needed for activity:

Using the computers in the Technology Learning Center the students will research the different aspects of cable-stayed bridges, in particular research the design characteristics of the Leonard P. Zakim Bunker Hill Bridge.

Design Process Step 3 - Develop Solutions and Selection:

Create drawings/sketches of several possible designs of a cable-stayed bridge using the Leonard P. Zakim Bunker Hill Bridge as the model.

Design Process Step 4 - Develop a Prototype:

In groups of two to four, students will build a cable-stayed bridge. Many different materials will be at the students' disposal, and they will be able to choose which materials they believe are the best candidates for their bridges.

The students will be asked to determine how much of a load they believe can be applied to their bridges before it will collapse. Because the bridges are most likely going to break at the end of the activity, the students will take digital pictures of all angles of their bridges to be used in communicating their results to their classmates.

Design Process Step 5 - Test and Evaluate:
Use Bridge Simulation software to understand what happens when forces are applied to a bridge. This software enables the user to apply compression and tension forces in any direction individually or in combination. The bridge simulation begins with a basic bridge model; however, the users are able to create new bridge designs.

The students will create a bridge similar to the cable-stayed bridge they constructed and they will apply different forces and see how their bridge will hold up under different theoretical conditions.

In addition, the students will actually apply forces to the bridges they constructed. They will apply forces up to the point that their bridges will break.

Also, the computers will be used to see how weather, in particular storms and earthquakes would affect the students' bridges. The students' bridges would be put on the computer screen and winds and shaking forces would be applied enabling the students to see if their bridges would survive.

Design Process Step 6 - Communicate:
The students will project the digital images of the bridges they constructed on the computer and by hand. They will discuss why the believed their bridges withstood some forces and succumbed to others. They will discuss why they chose the location they did for their bridges and how it will make their lives and others easier.

In communicating, they will basically be presenting a smaller scale presentation of the virtual visit to the Leonard P. Zakim Bunker Hill Bridge, and even if they do not realize they are doing so, they will be describing the engineering design process.

Lecture on the Design Process
A standard lecture on the engineering design process will conclude the learning module. The students will realize that they underwent the same engineering design process as the engineers of the Leonard P. Zakim Bunker Hill Bridge did.

Post-Visit Activity:

When the students get back to the class they will analyze the results obtained from applying gale-force winds and violent shaking forces. They will then redesign their bridges will these newfound considerations, and once again perform the engineering design process.

Engineering Learning Module
Journey to the Afterlife

Synopsis:

In groups of four, have students **design an Egyptian funerary barge to transport the mummy through the underworld to the afterlife**. The design of the boat is extremely critical in order for the mummy to have a chance to reach and enter the afterlife. In planning the design of the boats, students should beware of the perils of the underworld. The student will be given the materials and tools the ancient Egyptians had at their disposal in constructing the boats. Once the students have determined the design of the boat, create it using the materials the ancient Egyptians used. The students will then be given the opportunity to use new materials and techniques, which are in fact based on the Egyptians construction technologies. Students must keep in mind throughout this design task the similarity and differences of the design of the boats with ancient Egyptian materials and tools (technologies) and with today's technologies.

Pre-Visit Activity:

Students should create a list of several construction technologies in their towns, both new and old.

Story/Setting:

Ancient Egyptians believed in an underworld known as the Duat. They believed the underworld to be filled with perils such as executioners, poisonous snakes, and lakes of fires. In the underworld, the deceased had to use the Book of the Dead, which contained spells to counteract the dangers and a map to navigate their way. Both the Book of the Dead and the map of the underworld were placed either in the coffin or transcribed on the coffin itself in hieroglyphics. The mummy was placed on a funerary barge while it traversed through the underworld. The ultimate danger in the underworld was the weighing of the heart-the dead man's heart was weighed against his past deeds. The goddesses interrogated the dead man, accusing him of crimes, and if he told the truth he would survive in the afterlife; however, if he lied, the goddesses would call upon the Devourer of the Dead to eat up his heart.

Design Process Step 1 – Identify the Problem:

Students must recognize the problem within the story. That is namely, students must design an Egyptian funerary barge to transport the mummy through the underworld to the afterlife

Design Process Step 2 – Research:

At the Museum of Science the students must visit *Egypt: Quest for Immortality* and pay close attention to the different materials, which the ancient Egyptians used in designing their construction technologies. While at this exhibition, record a few examples of construction technologies with a digital camera and/or a notebook and pencil.

In the Technology Learning Center the students will use the computers as a research tool to explore the different designs of Egyptian funerary barges, and the materials and techniques used by the Egyptian engineers in designing the boats. In addition, the students will research the different modern technologies that would enhance a successful voyage through the underworld to the afterlife.

Design Process Step 3 - Develop Solutions and Selection:

Create several sketches/drawings by hand or using a simple CAD program of the design ideas for both a boat that would have been created in ancient Egypt using the materials and techniques the Egyptians used as well as a boat with modifications as a result of today's technologies. Once finished creating multiple design possibilities, select the best possible design for both the ancient boat and the modern boat. This will require some discussion amongst the team as to which boat they perceive will be most successful in reaching the underworld.

Design Process Step 4 - Develop a Prototype:

Divide and conquer: Within the group of four students, half of the students will construct ancient Egyptian boats and the other half with construct a modern boat. It should be noted that both boats will go on the same journey through the underworld, with an ultimate destination to the afterlife. Materials for both the ancient Egyptian boat and the modern boat will be at your disposal. Make a list of the materials used for each boat.

Design Process Step 5 - Test and Evaluate:

This step contains two possibilities.

1. A water table will be located outside the Technology Learning Center to actually test the boats and determine which boats would indeed be successful in traveling through the underworld. Simulated conditions of the underworld and its dangers will be recreated in the water table such as applying pressure, wind currents, and rough seas. In addition electronic animals will be traversing through the water table and attacking the boats.

2. A computer program will be created which will enable the students to enter the materials they used in designing their boats and will ask them to select a design that most resembles their designs. The boats will actually go on a voyage through the underworld, which the students will control. Along the way they will indeed be encountered with dangers and be required to choose the appropriate spells to counteract the dangers. Thus the students will have to do a little research on reading simple hieroglyphics, which could be done in the exhibition prior to this learning module.

Design Process Step 6 - Communicate:

Once they have completed the activity it is very important the students are given the chance to present their designs to the other teams. This will be done through 3-D photo analysis and the images will be projected on a screen for the entire group to see.

Once the presentations are over the students will use PRS-Personal Response System to determine which boats were the strongest, the weakest, etc. PRS allows the students to each enter in a choice and it displays bar graphs of their decisions.

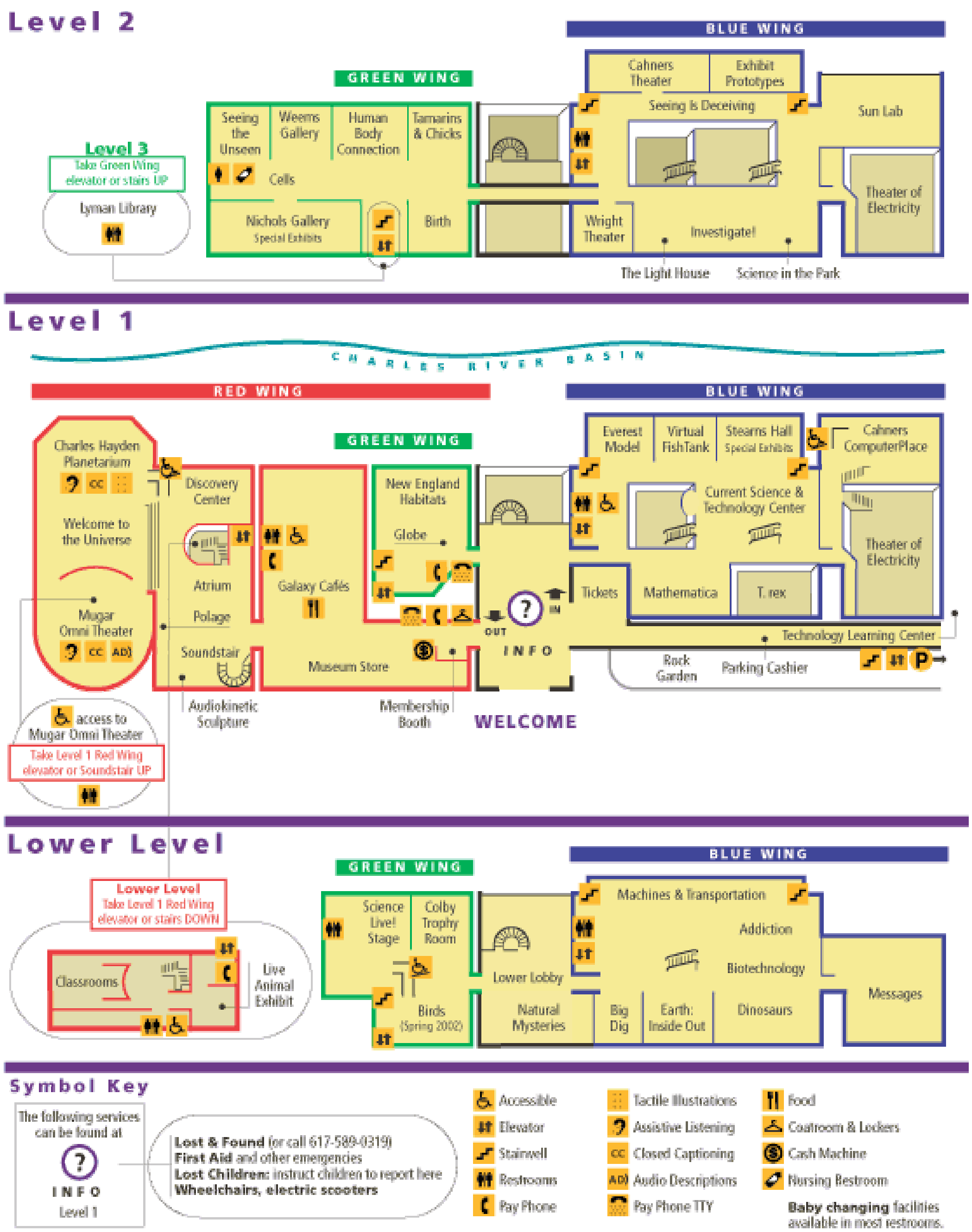
Lecture on the Design Process

A standard lecture on the engineering design process will conclude the learning module. The students will come to the realization that in creating both the ancient Egyptian boats and the modern boats the same engineering design process was used. And although technology has evolved significantly since ancient Egypt, the engineering design process is the same.

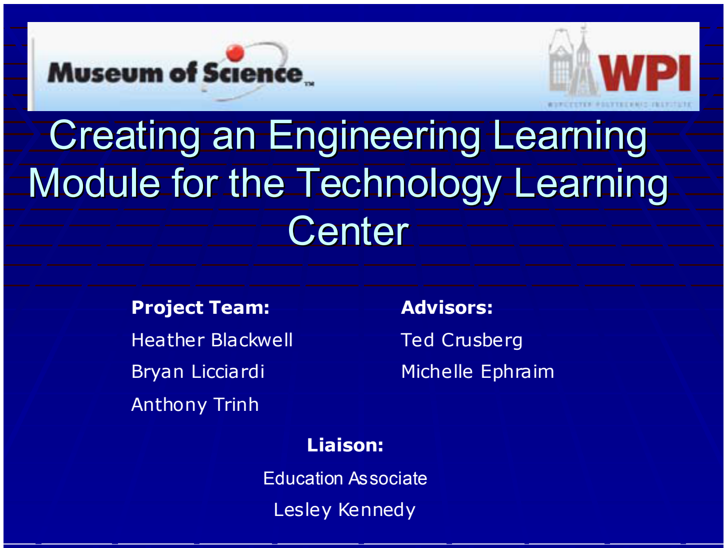
Post-Visit Activity:

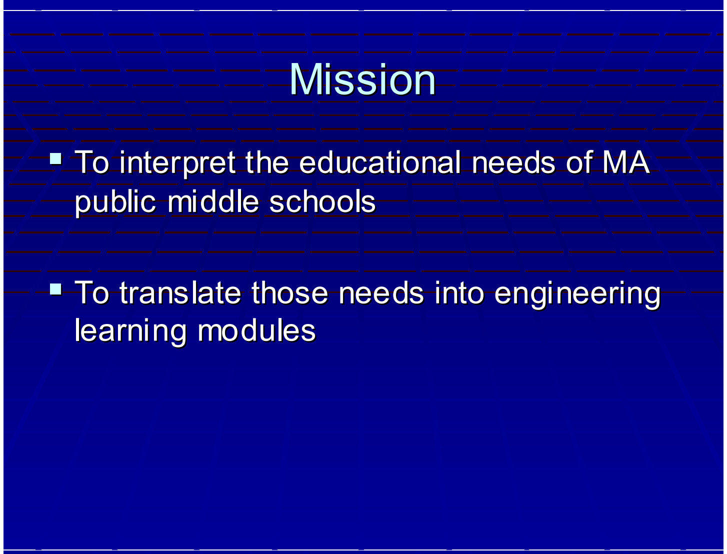
An activity, which the students could do in the classroom after their visit to the Museum, is to put hieroglyphics on their boats. Also to emphasize the point that the engineering design process has remained the same since ancient times and that it is the technology that has evolved, the students will compare and contrast the technology used in constructing their boats. They will come to the conclusion that technology is not only something totally new, but that technology is as old as human civilization. By comparing the different materials and techniques used by ancient Egyptians with modern materials and techniques, the students will see how modern builders copied and improved on the techniques developed by the ancient world.

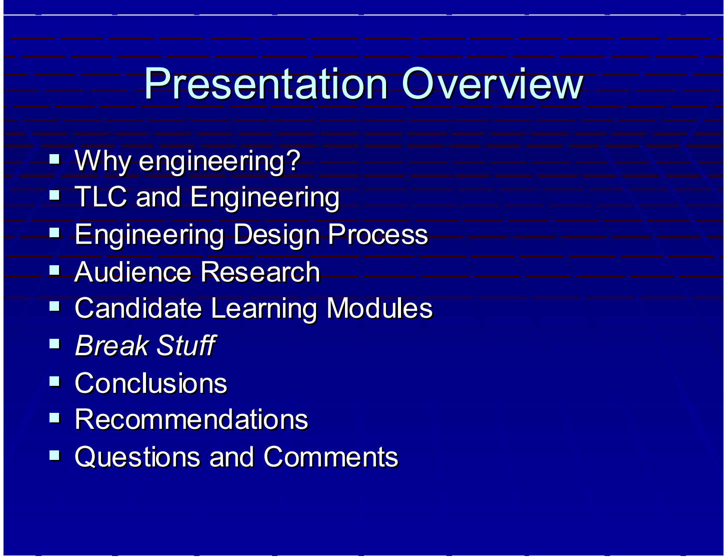
G. Floor Map of Museum of Science



H. Presentation Slides







Why engineering?

- MA Science and Technology/Engineering Curriculum Framework
- Misconception between “technology” and “engineering”
- Teachers are interested in teaching technology/engineering
- Teachers are struggling to prepare students
- Museum’s new initiative

TLC and Engineering

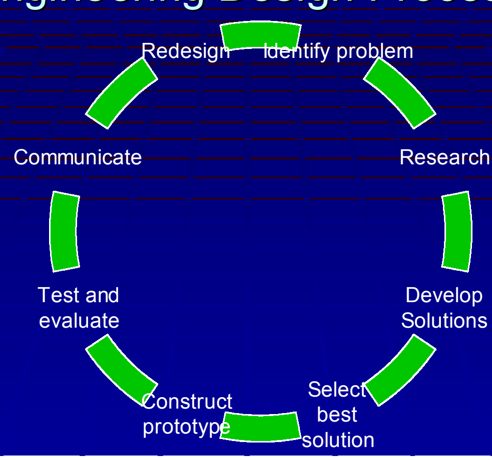
- Natural association

▪**Inventor’s Workshop**

▪**Multimedia Laboratory**

▪**Science Simulator**

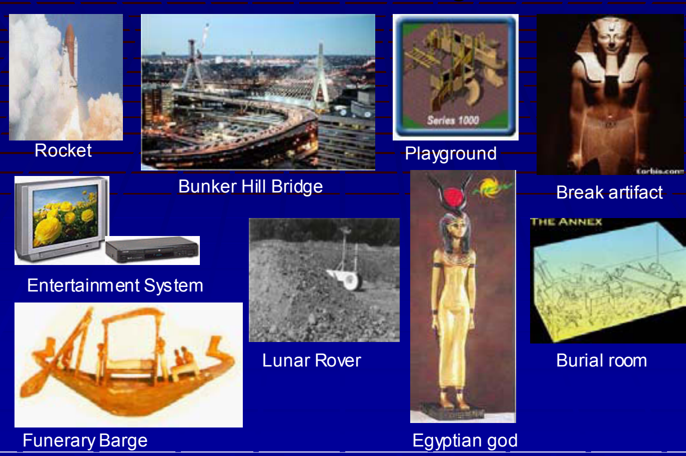
Engineering Design Process



Audience Research

- Students…
  - dislike worksheets
  - react to spectacles
  - like to be treated like adults
- Teachers…
  - partially implement technology curriculum

Nine Candidate Learning Modules

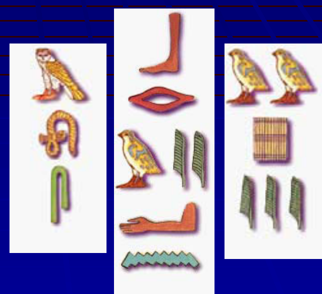


Break Stuff

- Three stage activity
  - TLC and Museum Activity
  - Pre-Visit
  - Post-Visit
- Learning module objective
  Engineering design process
- Content theme
  Egypt

Break Stuff Cont'd

- Deliver the message to the Pharaoh
  - Learn about hieroglyphs
  - Learn about artifacts
  - Entertaining Story



Break Stuff Cont'd

- Reconstruct a broken artifact
  - Research Materials and visit exhibit
  - Choose a Course of Action
  - Reconstruct
  - Use computers and measurement tools to evaluate
    - -Photogrammetry
    - -the Cubit Rule
  - Communicate Results

- Design Lecture

Break Stuff Cont'd

- Pre-Visit
  - Online-Based hieroglyphic puzzle

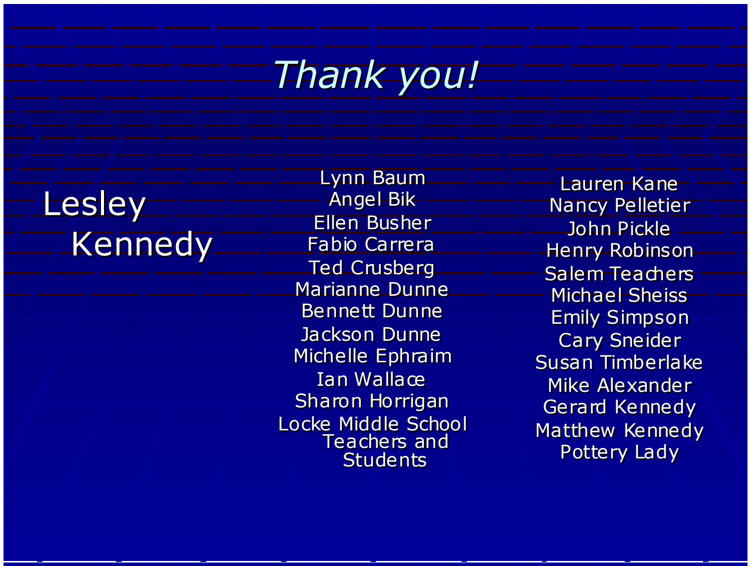
- Post-Visit
  - Online-Based
  - Reflection
  - Last step of engineering design process: *Redesign*.

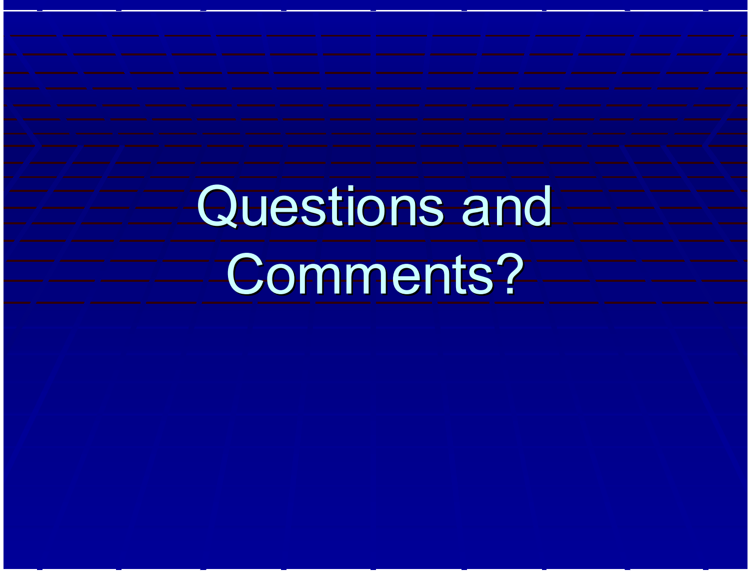
Conclusions

- Break stuff is effective in that it addresses the competing needs of…
    - Middle-school students
        - Group-oriented
    - Teachers
        - Aligned with curriculum framework
        - Optional pre- and post-visit activity
    - The Museum of Science
        - "Learning is exciting and fun"
        - Active participation in Egypt program
        - Original learning module and approach

Recommendations

- Explore other learning module proposals
- Employ evaluation system
- Equip TLC with different technologies


Thank you!
Lesley Kennedy
Lynn Baum
Angel Bik
Ellen Busher
Fabio Carrera
Ted Crusberg
Marianne Dunne
Bennett Dunne
Jackson Dunne
Michelle Ephraim
Ian Wallace
Sharon Horrigan
Locke Middle School Teachers and Students
Lauren Kane
Nancy Pelletier
John Pickle
Henry Robinson
Salem Teachers
Michael Sheiss
Emily Simpson
Cary Sneider
Susan Timberlake
Mike Alexander
Gerard Kennedy
Matthew Kennedy
Pottery Lady


Questions and Comments?

I. Web Page

A link to our final project web page:

www.wpi.edu/~hblackwe/mos