Project Number BZS-AAFE-13002

ELM PARK SCHOOL

SPACE ENRICHED SCIENCE EDUCATION – 5th GRADE CURRICULUM PROJECT

An Interactive Qualifying Project Report

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

Anibal Ramirez

Tashi Sonam

Tenzin Kalden

Seiichiro Ueda

Date: June 3, 2004

Professor Brigitte Servatius, Major Advisor

Professor John M. Wilkes, Co-Advisor

Worcester Polytechnic Institute

100 Institute Road, Worcester, Ma 01609-2280

Abstract

The Lunar Enhanced Science curriculum is designed to improve the current science curriculum for fifth grade students attending Elm Park School in order to better prepare them for the Massachusetts Comprehensive Assessment System (MCAS). The MCAS is the statewide assessment given to students from the third to tenth grades to measure their academic progress. Elm Park has struggled in recent years to improve its below average MCAS scores. The Enhanced Science curriculum leads the students through a lunar base design to reinforce the concepts that the students will be tested on during the MCAS. Students were given the opportunity to visit Worcester Polytechnic Institute and participate in hands-on lunar themed demonstrations in order to provide a capstone experience for the curriculum. The New England chapter of the American Institute of Aeronautics and Astronautics provided funding.

Acknowledgement

Prof. Brigitte Servatius

Prof. John McCamy Wilkes

Mr. Mahoney

Elm Park Community

America Institute of Aeronautics and Astronautics (AIAA)

Elm Park School Principle Joany Santa

Worcester Polytechnic Institute

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1. Introduction:

The Lunar Enhanced Science curriculum has been designed by previous IQP teams over the last two years (**last year's IQP**) to improve the current science curriculum for Elm Park's fifth grade students and better prepare them for the Massachusetts Comprehensive Assessment System (MCAS). The MCAS is the statewide assessment given to students from the third to tenth grades in order to gauge their progress for that academic year. It has three main subjects which are English Language Arts (ELA), Mathematics, and Science and Technology/Engineering. The team has focused on the Science and Technology/Engineering section of MCAS.

Elm Park is a diverse inner city school built in 1971 with open classroom designed for the teaching practices of that era. The school has struggled in recent years to improve its Science and Technology/Engineering MCAS scores and avoid slipping into level four status, the point at which the state becomes involved in the management of the school. Elm Park's MCAS data was obtained from the principal and the official website of the Massachusetts Department of Elementary and Secondary Education (ESE) in order to identify areas where the students were testing poorly in order to guide where the Enhanced Science curriculum should be focused.

The Lunar Enhanced Science curriculum team's goal was to design lessons on topics covered by the Science and Technology/Engineering section of MCAS, such as the phases of the moon, electrical circuits, the difference between insulators and conductors, and forces, with a focus on Elm Park's improvement targets. Another goal of our project was to field test our activities in Mr. Mahoney's fifth grade class to examine the effects the activities would have on the students' comprehension of the material.

The team researched about the school and its MCAS performance in section 2. It then analyzed the fifth grade textbook in section 4. After a thorough analysis of the school, textbook, MCAS and the framework the team prepared four activities for the fifth grade classroom. The activities are presented within the context of designing a lunar base. They are directly linked to chapter 13, "Earth, Moon and Beyond," chapter 15, "Electricity" and Chapter 18, "Forces," of the current fifth grade textbook. Each activity contains pre and post-tests with emphasis on questions that more frequently appeared on the MCAS over the past ten years. The detailed analysis of MCAS and the graphs of past 10 years MCAS questions will be found in Section 5.3.

The first activity, “Phases of the Moon”, takes approximately 50 minutes including set-up and handing out pre-test. Materials needed are polystyrene spheres, pencils and papers. It can be done with two groups with at most ten students each. There should be at least two persons to organize the activity. This activity is related to chapter 13, “Earth, Moon and Beyond. The lunar themes are to study differences and similarities between the Earth and the Moon and to discuss phases of the Moon.

The second activity,   “Electrify the Base” takes approximately 50 minutes. It can done with two groups (at most 10 students each) and one organizer for each group. It is related to chapter 15, “Electricity”. The activity extends the concepts in the Electricity chapter to lunar theme by discussing the problem of powering a lunar base and utilization of different sources of power such as solar energy to generate electricity on the Moon.

The third activity, “Shackleton crater” takes approximately 45 minutes including set-up and handing out pre-tests. Materials needed are 15, 30, 45 and 60-degree ramps, steel ball bearings, four tubs of flour and black sand. It can be done with two groups of students (at most 10 students each) and one organizer for each group. This activity is related to chapter 13, “Earth, Moon and Beyond” and the lunar theme exploring the formation of craters in the moon.

The last activity, “Friction” takes approximately 45 minutes including set-up and handing out pre-tests. The materials used are 5 penny rollers, 4 dime rollers and 2 aluminum weighing disks. The activity extends the textbook concepts in chapter 18, "Forces," to the lunar theme by discussing how frictional forces experienced by an object vary between the Earth and Moon.

Funding for materials as well as a field trip to WPI for Elm Park's fifth grade students was provided by the New England chapter of the American Institute of Aeronautics and Astronautics (AIAA) in its continuing mission to promote science education among the general public.

We used the following personal descriptions to introduce our team to Elm Park principal, teachers and students:

I am Anibal Ramirez, a junior majoring in Civil Engineering and Management Engineering. I am a native of Worcester, Massachusetts and graduated from North High prior to attending WPI. I chose this IQP because I believe it is essential for those who have managed to advance in life to help others. I see the enhanced science curriculum as a way to help the children get a strong science background that will help them become scientifically literate citizens one day, regardless of whether or not they enter into STEM fields. When I was a small child, my favorite book was "I Didn't Know that the Sun is a Star" a book that I still keep on my shelf today as a reminder of how space can act as a catalyst for engaging children in learning science and mathematics.

I am Seiichiro Ueda, a Robotics Engineering/Electrical and Computer Engineering double major in my junior year. I chose this IQP because I always had a fascination with space (and dinosaurs), it's so vast that the things we could discover are endless. My favorite and best subjects when I was younger were science and mathematics.

I am Tashi Sonam, my major is Chemical Engineering and I graduate in 2015. I was born in Tibet but I have spent most of my life in India. I was brought up in a rigid school system where learning is not focused on student centered learning. I am interested in student centered learning and how elementary students can build a strong understanding of science and mathematics.

I am Tenzin Kalden and I am physics major. I was born in Tibet and did my schooling in India. I like to explore nature, play music, and analyze and discuss philosophical implications as well as paradoxes of natural and psychological phenomena. I chose this IQP because I was educated in India with almost the same academic curriculum as in Elm Park school and I had an understanding as well as experience of how challenging this curriculum is to students, how teachers can help students understand better, how students can study more efficiently to get good marks, and how students can actually become interested in the subject they learn. I think I can contribute to Elm Park School by sharing my experience.

2. Elm-Park Elementary School:

2.1 School History:

Elm Park Community Elementary School was established in Worcester, Massachusetts in 1971. Charles Burack was its first principal. It functions under the Massachusetts Department of Elementary and Secondary Education (ESE). The school was originally operated with open classrooms. Two full time physical education teachers, a librarian and a nurse were employed at that time. The school is known for diversity and it attracts students from both the county and the state of Massachusetts. Many of the students are from the neighborhood that surrounds the school.

2.2 The Mission of the School:

The institution focuses on improving students' writing skills and understanding of text along with the ability to summarize and articulate subjects (Elm Park). Elm Park uses both formal and informal assessments to measure the achievements of the students. The school offers academic programs in Art, Music and Physical Education. It also offers extracurricular activities for students such as after school programs and book fairs. These extracurricular activities play a vital role in developing and enriching the knowledge of the students outside the classroom. Moreover, Elm Park has special partnerships with schools and colleges in Worcester, such as Worcester Polytechnic Institute (WPI).

2.3 School Enrollment:

The school has classes ranging from pre-kindergarten to 6^{th} grade with a total enrollment of 494 students in 2012-2013 (Massachusetts). The faculty consists of 32 teachers licensed in teaching assignment (Massachusetts). Elm Park has a student teacher ratio of 16.3 to 1 which is larger than the other schools of the district (15.6 to 1) and the state of Massachusetts (13.5 to 1). The school is known for being ethnically diverse with 49.4% of its student body being comprised of Hispanic students, followed by 22.4% being Caucasian students, 14.5% being African American students, 6.7% being Asian students, and 6.7% being Non-Hispanic, Multiethnic students(Massachusetts).

89.3% of the student body is from low-income families (Massachusetts Schools and Districts Profiles) with 85.3% receiving free lunch from the school. The number of students receiving free lunch is much higher than that for the other schools in Worcester and the State of the Massachusetts. 16.28% of Elm

Park students are under the poverty level. The school currently spends $14,436 per student (Elm Park Community).

2.4 The Problems of the School:

At Elm Park, many students do not speak English as a primary language. This is one of the challenges that the teachers face. The school offers a special program, English as Second Language (ESL) for students whose native language is not English and have difficulties in understanding and speaking English.

3. Project Sponsor: AIAA

The New England chapter of the American Institute of Aeronautics and Astronautics, also known as the AIAA, has graciously supported the lunar themed space enriched curriculum. The AIAA was founded in January of the year 1963 after the American Rocket Society, founded in 1930 as the American Interplanetary Society (AIS), and the Institute of the Aerospace Sciences, founded in 1932 as the Institute of the Aeronautical Sciences, merged together into a single organization.

The AIAA is divided into several regions within the United States and has over thirty five thousand members worldwide, with most being located in the United States. The group was founded to not only connect members of the aerospace field of professionals, such as aerospace engineers, scientists, and policy makers, but also to advocate for and advance the field of aerospace and its associated fields. Additionally, the organization has helped to shape standards and policies throughout the industry. The AIAA currently publishes the AIAA Journal along with several other specialized journals such as: the Journal of Aerospace Information Systems, the Journal of Aircraft, the Journal of Guidance, Control, and Dynamics, the Journal of Propulsion and Power, the Journal of Spacecraft and Rockets, and the Journal of Thermophysics and Heat Transfer. The AIAA has been a strong advocate for hands on activities to directly engage each of the students.

The New England chapter of the AIAA has helped to support the lunar themed, space enhanced science curriculum across multiple grade levels to ensure that the youth involved are kept immersed in the program and are able to receive the maximum benefit from the improvements made.

The project aims to enhance the current fifth grade science curriculum with a space enriched, lunar themed science curriculum that aims to actively engage the students as they learn the required scientific topics. The team will utilize the current science materials to avoid a duplication of effort and to hasten the process of bringing the lessons to the level that would be expected from a state with as rigorous academic standards as Massachusetts. The enhanced curriculum includes both hands on activities and demonstrations as well as lectures designed to not only actively engage the student in the classroom but to help them retain the information after the lesson as well.

The theme of the enhanced science curriculum for the fifth graders revolves around the concept of a lunar base and the needs and challenges that base would be faced with. Each subject within the curriculum is placed within the context of the lunar base and what its practical applications are. The lunar base theme provides a versatile platform from which to teach the entire fifth grade science curriculum. From topics such as motion to biology, the lunar base concept can be utilized to teach any of the required science subjects in a way that can be hands on and interesting to the student.

4. Elm Park 5th Grade Textbook:

The fifth grade class at Elm Park School uses the *HSP Science* textbook to learn ("Worcester Public Schools", 2013) and to prepare them for the MCAS. The book contains pictures and diagrams on every page and regularly asks questions and states interesting facts to the readers to try to keep them engaged. The book contains an introductory chapter that informs the students of the basics of being a scientist. The chapter goes over the scientific method, as "ask a question, form a hypothesis, plan, investigate and draw conclusions and communicate". The end of each chapter contains a chapter review and test preparation section which reviews the chapter and asks questions that test whether the students understood the content; the reviews also contain questions to test the student's critical thinking abilities.

The book is separated into three sections that cover nineteen different chapter topics. The sections were Life Science, Earth Science and Physical Science. Each science was then separated again into two different units which consist of two to four chapters each. Every chapter consists of lessons that ask questions that are relevant to understand the main topic.

The first section of the textbook was Life Science, which goes over basic biology starting from cells. The first unit covers what cells are, how they work, and how they interact in order to give a sense of how the human body functions. Then it proceeds to living things (multi-cell), their different classifications like the differences between vertebrates and invertebrates, and other general descriptions. As the chapters progress the text goes into more detail about plants and animals, explaining how they grow and about hereditary characteristics. The Life Science section concludes by teaching about the ecosystem, how plants produce their own food through photosynthesis, the food web and that organisms compete to survive in such an environment, that all organisms in an ecosystem have a niche, how people can affect it through their actions and how gradually overtime an ecosystem can change naturally.

After the Living Science section, the book goes into Earth Science, discussing topics about how the Earth changes and more. The first unit goes over the rock cycle, minerals and fossils; going over what they are and what we can learn from them, for example, how we can learn about the past and even the present through fossils. The book then discusses about landforms, and different resources; how people use said resources. Then it moves onto the weather, the water cycle and the ocean, teaching what the causes of weather are, and about ocean currents. Lastly the unit goes over the Earth in a more astronomical sense and the Moon, teaching about how the Earth's orbit affects the seasons and comparing the Earth and the Moon. It also mentions the Moon's phases and eclipses. The book finishes this section by discussing the solar system and what it consists of.

The last of the sciences covered in the textbook is Physical Science. The first unit in Physical science goes over matter and energy. It discusses what matter is and the distinction between physical and chemical properties and the changes that occur because of them, such as different states of matter. Then the book goes on about different forms of energy like heat, and sound, their properties and how they can be used; another example is how electricity relates to magnetism and what electric circuits are. The last unit covers forces and motion. The book goes over the everyday forces that act on an object, what balanced and unbalanced forces are, and what work is. To finish up, the textbook goes over motion and factors that affect it and teaches the Laws of Motion.

The content will be taught to students in a different order from the order of the book. The students started with Earth science, adding space afterwards, and then they would learn physical science and end with Life Science ("Worcester Public Schools", 2013). Using the material taught in the book as a guide, we wish to let the students enjoy science and to improve their results on their tests and exams.

5. Massachusetts Science and Technology Curriculum Framework:

The Massachusetts Science and Technology/Engineering Curriculum Framework guide teachers and curriculum coordinators on specific content to be taught from Pre-K through high school. The framework involves three main sections namely Philosophy and Vision, Science and Technology/Engineering Learning Standards, and Appendices and References

5.1 The Philosophy and Vision:

This chapter talks about the purpose and nature of Science and Technology/Engineering and their interrelation, inquiry, experimentation, and design in the classroom and the guiding principles including the ideals of teaching, learning, assessing, and administering science and technology/engineering programs. It says "The purpose of science and technology/engineering education in Massachusetts is to enable students to draw on these skills and habits, as well as on their subject matter knowledge, in order to participate productively in the intellectual and civic life of American society and to provide the foundation for their further education in these areas if they seek it." (Massachusetts Science and Technology/Engineering Curriculum Framework, *October 2006 page 7*)

5.1.1 Nature of Science and Technology/Engineering:

The goal of science is to observe patterns in nature and to provide a clear, rational and succinct account of these patterns. These accounts should be based on collected data and analysis and other evidence obtained through direct observation or experiments and should convey inferences that are broadly shared and communicated. On the other hand, technology/engineering strives to design and make devices or materials, which help to boost our efficacy in the world, and to satisfy the physical needs of people and society. However these fields are interrelated as science employs the technologies to investigate and experiment scientific phenomena and engineering and technologies derive the basic principles or theories of their manufactured devices from the science.

5.1.2 Inquiry, Experimentation and Design:

Inquiry-based Instruction:

Facilitating students in inquiry-based instruction is considered one of the ways of building conceptual content knowledge and scientific skills. Students should have curricular chances to learn about and understand science and technology/engineering through participatory activities, specifically laboratory, fieldwork, and design challenges. Inquiry, experimentation, and design should not be taught or tested as exclusive skills. Rather, students should be given opportunities for inquiry, experimentation and design through a well-planned curriculum.

Asking questions:

An inquiry-based approach encourages students to ask questions and pursue answers. This can be done in the class by exploring scientific phenomena in a classroom laboratory or an investigation around the school. Students may choose what phenomenon to study. Projects are selected and guided by the teacher. Students can also examine questions pursued by scientists in their investigation of the processes and phenomena as displayed in textbooks, magazines, videos, the internet and other media.

Investigation:

An inquiry-based approach engages students in hands-on investigations that feature their prior knowledge and builds new understanding and skills. Students should have various opportunities to share, present, review, and critique scientific information or findings with others. Characteristics of investigation evolve through grades. For example, in grade 3-5 students can plan and carry out investigation as a class, in small groups or individually, often over a period of several class lessons. The teacher should first organize the process of selecting an answerable question, formulating a hypothesis, planning the steps of an experiment, and finding the most objective way to test the hypothesis. Students should use the mathematical skills of measuring and graphing to display their findings.

The Engineering Design Process:

Just as inquiry and experiments guide investigations in science, the Engineering Design Process guides solutions to technology/engineering design challenges. A hands-on, active approach that allows students to engross in design challenges and safely work with materials to model and test solutions to a problem can significantly enhance students' understanding of technology/engineering content and skills.

5.1.3 Guiding Principles:

(Massachusetts Science and Technology/Engineering Curriculum Framework, *October 2006 page. 13-17*)

1. A comprehensive science and technology/engineering education program enrolls all the students from PreK through grade 12. Approximately one quarter of PreK -5 science time should be spent on technology/engineering.
2. An effective science and technology/engineering program develops students' knowledge of the fundamental concepts of each domain of science, and their understanding of the relations across these domains and to basic concepts in technology/engineering.
3. Mathematics is integrally related to Science and Technology/engineering.
4. An effective program in science and technology takes care of students' prior knowledge and misconceptions.
5. Investigation, experimentation, and problem solving are integral to science and technology education.
6. An effective science and technology program builds upon and enhances students' literacy skills and knowledge.
7. Assessment in science and technology/engineering helps to inform student learning, guide instruction, and evaluate student progress.
8. An effective program in science and technology/engineering gives students opportunities to collaborate in scientific and technological endeavors and communicate their ideas.
9. A coherent science and technology/engineering program requires district-wide planning and on-going support for implementation.

5.2 Science and Technology/Engineering Learning Standards:

The learning standards are exhibited by strand, grade span, and subject area topic. (Massachusetts Science and Technology/Engineering Curriculum Framework, *page-3*)

5.2.1 The Strands:

The learning standards are categorized into four strands:

- Earth and Space Science
- Life Science (Biology)
- Physical Sciences (Chemistry and Physics)
- Technology/Engineering

Each strand section starts with an outline of the strand

5.2.2 Grade Spans and Subject Area Topics:

Each strand's learning standards are grouped into four grade spans:

- Grades PreK-2
- Grades 3-5
- Grades 6-8
- High School

Learning standards are sub-grouped within each grade span under subject area topic headings that are specific to that grade span.

Grade PreK through Grade 8

In the Massachusetts Curriculum framework**,** learning standards for grades PreK-8 are displayed in tables that contain ideas for grade-appropriate classroom investigations and learning experiences for each standard. (Massachusetts Science and Technology/Engineering Curriculum Framework, P25-29)

Our team has focused on the fifth grade Earth and Space Science standard and the Physical sciences standard among the four learning standards listed on section 5.2.1.

Earth and Space Science has five chapters (*Fifth Grade textbook, HSP Science*)

- Chapter 7, The Rock Cycle
- Chapter 9, Changes to Earth's Surface
- Chapter 11, Weather and the Water Cycle
- Chapter 13, Earth, Moon and Beyond

Physical Science has five chapters (*Fifth Grade Textbook, HSP Science*)

- Chapter 14, Properties of Matter
- Chapter 15, Energy
- Chapter 16, Electricity
- Chapter 17, Sound and Light
- Chapter 18, Forces

The team focused on chapter 13, which focuses on the Earth and Space Science strand, and Chapter 16, which focuses on the Physical Science strand. The ideas for classroom investigations and learning experiences listed in the Massachusetts Science/Engineering Curriculum Framework (Massachusetts Science and Technology/Engineering Curriculum Framework, P29-54) for these two chapters are displayed in Table 1 and Table 2.

The Earth and Space Science (chapter 13, Earth, Moon and Beyond)

Learning Standard	**Ideas for developing investigations and learning experiences**
13. Recognize that the earth is part of a system called the "solar system" that includes the sun (a star), planets, and many moons. The earth is the third planet from the sun in our solar system.	Create a proportional model of the solar system starting on the school playground and extending as far as possible. Demonstrate the size of objects (use a pea for the smallest planet, and different sized balls for the others) and the distance between them.
14. Recognize that the earth revolves around (orbits) the sun in a year's time and that the earth rotates on its own axis once approximately every 24 hours. Make connections between the rotation of the earth and day/night, and the apparent movement of the sun, moon, and stars across the sky.	Observe and discuss changes in the length and direction of shadows during the course of a day.
15. Describe the changes that occur in the observable shape of the moon over the course of a month	Observe the sky every night for 30 days. Record every night the shape of the moon and its relative location across the sky (record the date of the month and the time of observation each time as well).

Table 1: Ideas for developing investigations and learning experiences

Physical Sciences (Chapter16, Electricity)

Learning Standard	**Ideas for developing investigations and learning experiences**	**Suggested extensions to learning in Technology/Engineering**
6. Recognize that electricity in circuits requires a complete loop through which an electrical current can pass, and that electricity can produce light, heat, and sound.		1. Using graphic symbols, draw and label a simple electric circuit. 2. Using batteries, bulbs, and wires, build a series circuit.
7.Identify and classify objects and materials that conduct electricity and objects and materials that are insulators of electricity.	Provide a collection of materials that are good conductors and good insulators. Have students determine each material's electrical conductivity by testing the material with a simple battery/bulb circuit.	Select from a variety of materials (e.g., cloth, cardboard, Styrofoam, plastic) to design and construct a simple device (prototype) that could be used as an insulator. Do a simple test of its effectiveness.
8. Explain how electromagnets can be made, and give examples of how they can be used.		

Table 2: Ideas for developing investigations and learning experiences (2)

5.3 Massachusetts Comprehensive Assessment System (MCAS):

Our team studied the Massachusetts Comprehensive Assessment System before we designed the activities. We collected past 10 years MCAS tests and analyzed how often topics from our activities were asked in those past tests. We also designed pre and post-tests based on our study of MCAS.

The Massachusetts Comprehensive Assessment System follows the requirements of the Education Reform Law of 1993(Massachusetts Department). This law emphasizes that the testing program must

- Test all public students in MA, including students with disabilities and English Learner students
- Measure performance based on the Massachusetts Curriculum Framework learning standards;
- Report on the performance of individual students, schools, and districts.

  The Education Reform law stipulates students must pass the grade 10 tests in English Language Arts (ELA), Mathematics and one of the four high school science and Technology Engineering tests in order to be eligible to get a high school diploma (in addition to fulfilling local requirements).

  Moreover, the MCAS program measures whether the schools and districts have made progress yearly towards the objective of the "No child Left behind Law" (Massachusetts Department) that all students be proficient in Reading and Mathematics by 2014.

  MCAS tests three main subjects:

  - English Language Arts (ELA)
  - Mathematics
  - Science and Technology/Engineering

  Types of questions used on MCAS tests

  - Multiple-choice question (MC)
  - Short-answer question (Included only on Mathematics test)
  - Short-response question (included only on the grade 3 English language Arts (ELA) tests)
  - Open-response questions
  - Writing prompts (included only on English Language Arts (ELA) composition tests)

5.3.1 Graphs of the past 10 years of MCAS questions:

Within the Massachusetts Science and Technology/Engineering Curriculum, the topics from each chapter (from each of the four strands) are categorized into different learning standards. For example learning standard 1 of Physical Sciences strand is: “differentiate between properties of objects” and it comes under the chapter, “Properties of Objects and Materials”. The details of the rest of the learning standards for the four different strands can be found in Massachusetts Science and Technology/Engineering Curriculum (Massachusetts Science). In order to get ideas of which topics from which chapters (strands) are featured in MCAS, we collected released MCAS exams from the past ten years. Questions include multiple choice and open response. These released items relate each test question with the learning standard it belongs to. Our team checked how many questions were asked from each learning standard belonging to its corresponding strand, and then plotted the graph (of the total numbers of questions asked vs. the learning standard) for each of the strands. Our team focused on graphs of Physical Sciences strand and Earth and Space Science strand. Future teams who wish to plan curriculum for other strands can use the graph of the respective strand.

The graphs visualize how often questions related to our designed classroom activities appear in past MCAS tests. We would accordingly design pre and pro-tests based on these questions. For example, “Phases of the Moon” activity (section 6.1) is related to Standard 15 of Earth and Space (table 1). If we refer to figure 3, standard 15 is above average questions asked in MCAS.

We note that the distribution of MCAS questions belonging to different learning standards is not uniform. For example if we look at figure 2, the Physical Science learning standard 7 and 11 have the highest frequency. If we refer to the Massachusetts Science and Technology/Engineering Curriculum Framework, learning standard 7 and 11 correspond to electricity and sound energy respectively.

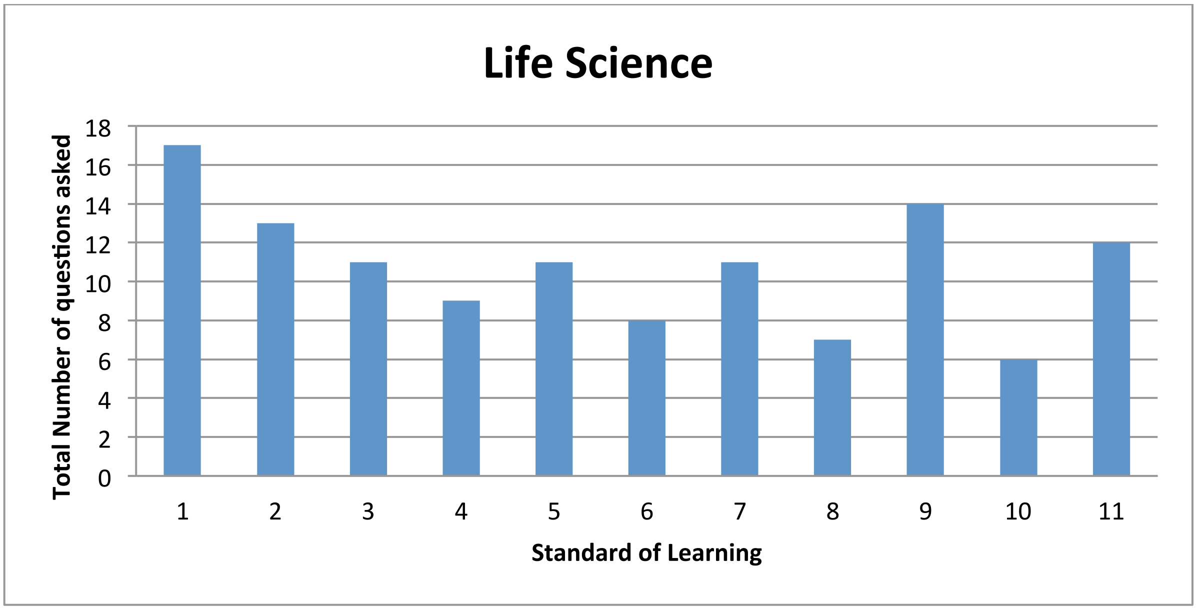

Figure 1: MCAS questions asked from each learning standard over the past 10 years in Life Science

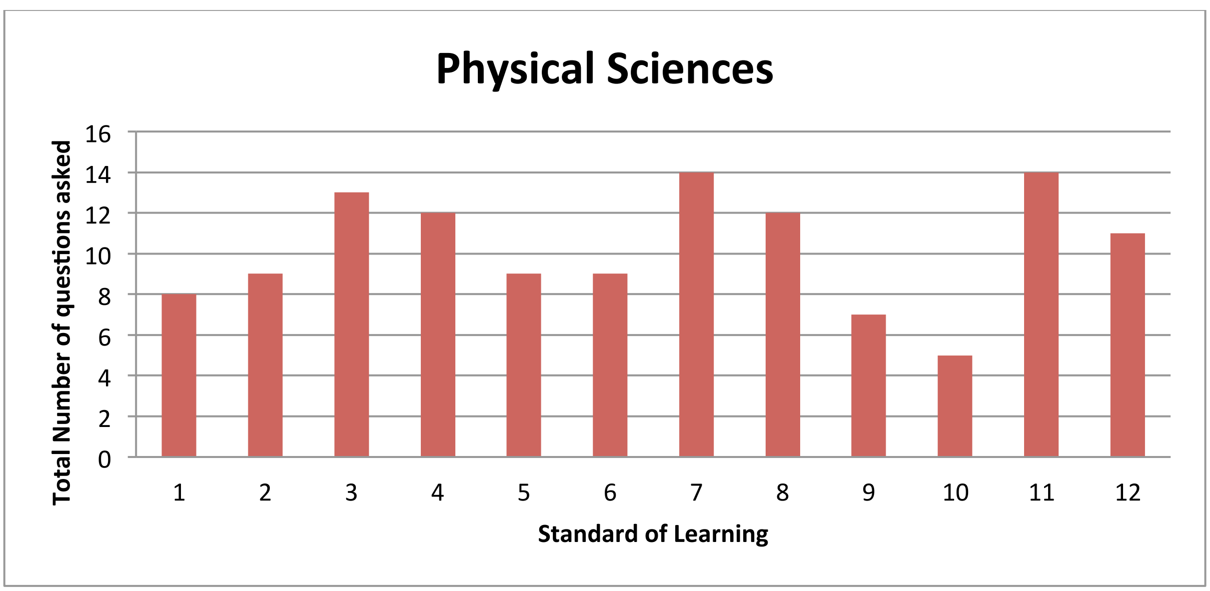

Figure 2: MCAS questions asked from each learning standard over the past 10 years in Physical Science

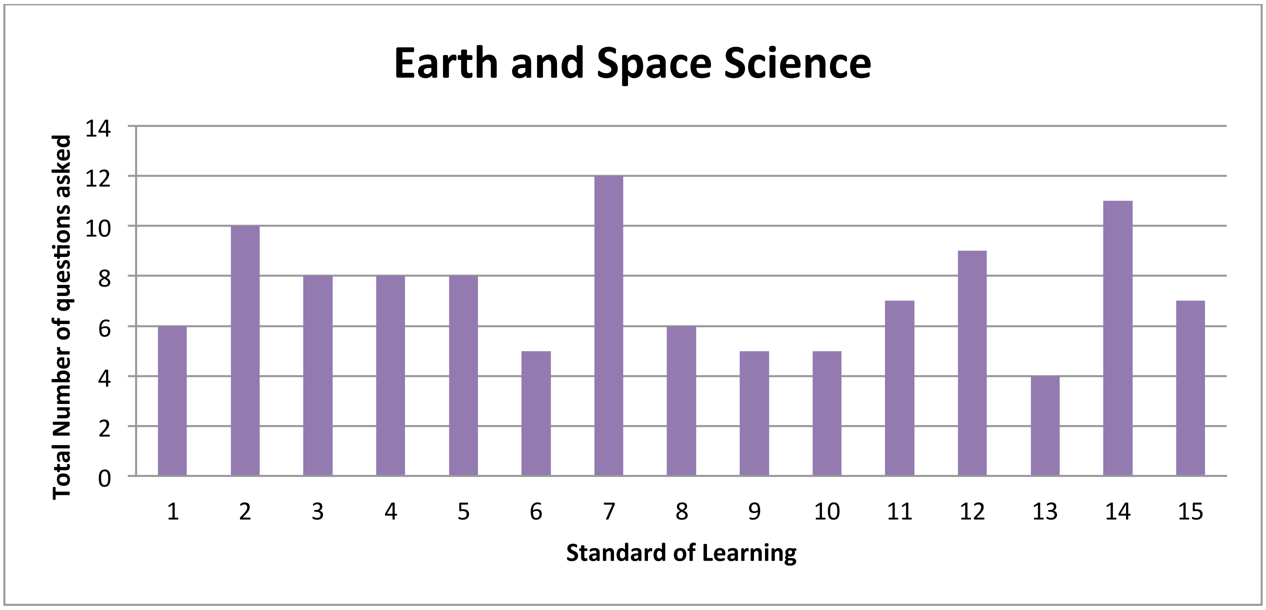

Figure 3: MCAS questions asked from each learning standard over the past 10 years in Earth and Space Science

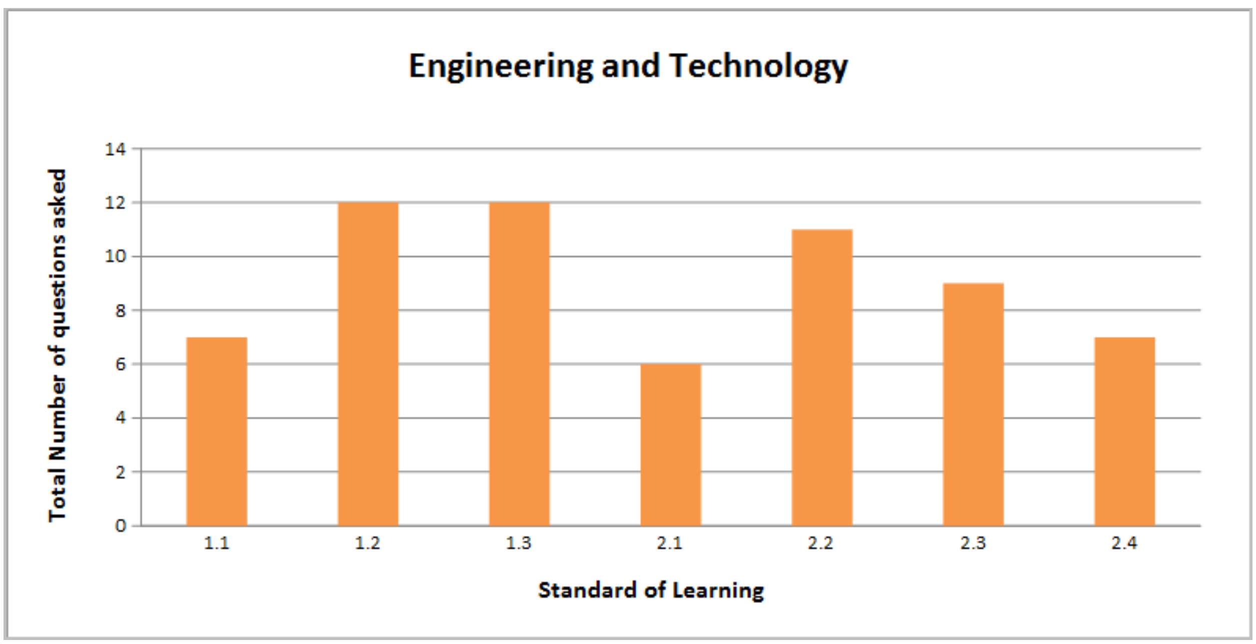

Figure 4: MCAS questions asked from each learning standard over the past 10 years in Engineering and Technology

5.3.2 MCAS Results of 5th grade Elm Park Community:

The learning and performance of the students and the school at large are measured yearly by the state standardized test scores. The Massachusetts Department of Education of Elementary and Secondary Education (ESE) has categorized the performance of students on MCAS into four achievement levels (Massachusetts):

1.Advanced Level

2. Proficient Level

3.Needs Improvement Level

4. Warning level

Elm Park School has struggled in recent years to improve its MCAS scores and avoid slipping into level four status, the point at which the state becomes involved in the management of the school.

The following graph (*figure 5*) shows the achievement level percentage of Elm Park Students in Science and Technology/Engineering section of MCAS (2010-2013). We received the data from the official website of Massachusetts Department of Elementary and Secondary Education (ESE) (Massachusetts). There were 40 percent of students in warning level during 2010, 46 percent during 2011, 49 percent during 2012 and 44 percent during 2013. Thus the average percentage of students in "Warning" level was 45 percent with a standard deviation of 4 percent. The average percentage of students in "Needs Improvement" level from 2010-2013 was 42 percent with a standard deviation of 6%.

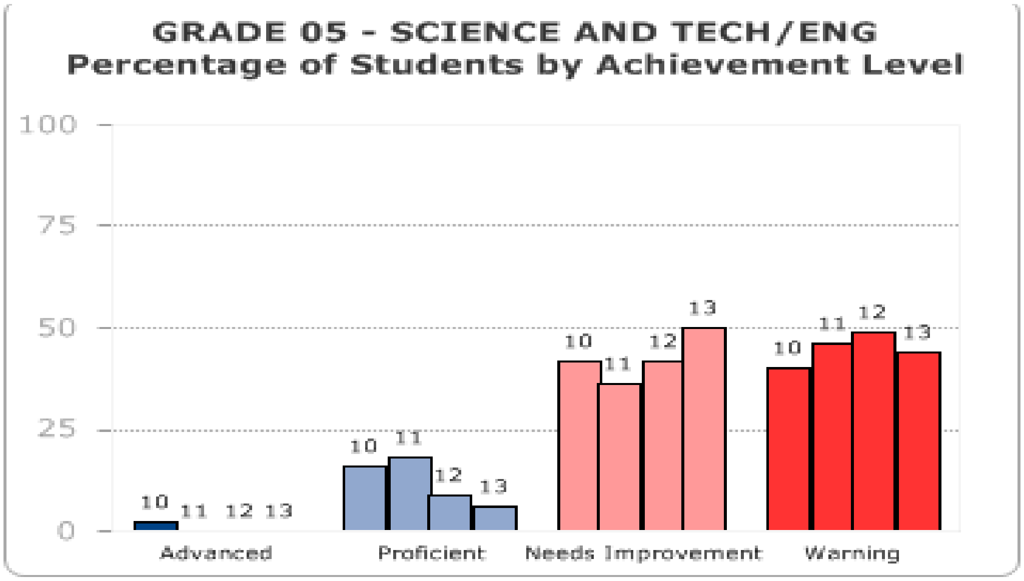

Figure 5: Percentage of Elm Park Students by Achievement Level

ELM PARK 5TH GRADE SCIENCE AND TECH/ENG ACHIEVMENT LEVEL				
Achievement Level	**2010**	**2011**	**2012**	**2013**
Advanced	2	0	0	0
Proficient	16	18	9	6
Needs Improvement	42	36	42	50
Warning	40	46	49	44

Table 3: Elm Park Achievement Level

5.3.3 Average Item score of 5th Elm Park Community:

Year	Item	Type of question	Standard	Number of Students included	Percentage of students getting right answer *(average item score)*		
					Elm Park Community	Worcester	State
2007	3	MC	6	45	84	88	93
	9	MC	7	45	60	83	87
2008	31	MC	7	43	67	78	84
2009	11	MC	7	54	41	43	50
	37	MC	7	54	57	64	74
2010	16	MC	6	54	35	42	53
	37	MC	7	54	52	62	74
	19	MC	15	54	43	42	47
2011	11	MC	7	50	48	58	71
	13	MC	15	50	84	78	84
2012	20	MC	6	57	51	60	70
	30	MC	7	57	56	60	73
	27	MC	15	57	33	37	51
2013	1	MC	15	48	42	60	71
	39	MC	6	48	75	78	86

Table 4: Average Item Score of Elm Park Students in the MCAS

Table 4 shows average item score of the Elm Park students (vs. the city of Worcester and the state of Massachusetts' Students) in Science and Technology/Engineering section of MCAS (from 2007 to 2010). We obtained these results from the released items published by the Massachusetts Department of Elementary and Secondary Education (ESE).

Average item score correlates to the average number of students getting the right answer to a particular item. Each item corresponds to a question from different standards relating to different chapters in the 5^{th} grade textbooks. We have included items of standard 6, 7 and 15 only since our classroom activities are closely related to these standards.

According to Massachusetts Science/Technology Curriculum Framework (Massachusetts) given in *Table 1* and *Table 2.* Standards 6 and 7, covering electricity and physical science, correspond to chapter 16, "Electricity," and standard 15, under Earth and Space Science, corresponds to the Phases of the Moon topic from chapter 13, "Earth, Moon and Beyond.

Standard 6: Recognize that electricity in circuits requires a complete loop through which an electrical current can pass, and that electricity can produce light, heat, and sound.

Standard 7: Identify and classify objects and materials that conduct electricity and objects and materials that are insulators of electricity.

Standard 15: Describe the changes that occur in the observable shape of the moon over the course of a month

We can conclude from the *Table 4* that the average item score of Elm Park students, for the standards, was less than that of both its city and state, Worcester and Massachusetts, with the exception of item 15 in the 2010 MCAS.

Therefore our team found it important to help the current fifth grade Elm Park students to better understand the concepts from these standards and consequently improve their achievement in future MCAS tests. We designed classroom activities, "Phases of the Moon" and "Electrify the base" that cover topics directly from these standards. The details of the activities are found in the following sections**.**

6. Classroom Activities:

Classroom activities are directly linked to Chapter 13, "Earth, Moon and Beyond," Chapter 15, "Electricity" and Chapter 18, "Forces," of the current fifth grade textbook. We designed pre-tests and post-tests for each of these activities using MCAS questions as a guide. Each of our activities follows the lunar base theme. Taking our pre-test, doing the activities and then taking the post-tests should help students to get prepared for MCAS. The following table (table 1) shows the activities, the venue, date, audience and the teachers at the time we performed our activities.

Activities	Venue	Date	Audience	Teacher at the time
Phases of the Moon	Mr. Mahoney's classroom, Elm Park	February 03, 2014	Mr. Mahoney's 5th grade students	Substitute Teacher
Electrify the base	Mr. Mahoney's classroom, Elm Park	April 01, 2014	Mr. Mahoney's 5th grade students	Mr. Mahoney
Shackleton Crater	Riley Commons, Worcester Polytechnic Institute (WPI)	April 11, 2014	60 students from Elm Park 5th Grade.	Elm Park Fifth grade teachers and Professor Wilkes from WPI

Table 5: General Information of Activities

6.1 Activity 1: Phases of the Moon

6.1.1 Introduction:

This activity, the phases of the Moon, relates to the chapter, 'How Do Earth and the Moon Compare'? We demonstrate the phases of the Moon to help the students to better understand the chapter's scientific terms such as 'Moon phases', 'lunar eclipse', 'solar eclipse', and 'refraction'.

The Moon is the only natural body that revolves around the Earth at a distance of about 384,000 km from the Earth. The Earth's moon is the fifth largest moon in our solar system. The diameter of the Earth's moon is 3,474 km and the Earth's diameter is 12,724 km. The Earth and the Moon have many similarities between them. Both of them are composed of aluminum, oxygen, silicon, calcium, and iron, they are both dense and have rocky surfaces. Craters are common on the Earth and Moon's surfaces. However, the craters on the Moon are more prominent than on the Earth. Craters on the Moon last for millions of years because the Moon lacks an atmosphere and water, which are causes of erosion. A crater is a large hole in the surface of a planet or moon, formed by the falling of celestial objects such as meteorites.

The Moon doesn't produce light; instead it reflects the light that reaches it from the Sun. The Moon rotates about its own axis and revolves around the Earth, which changes the visibility of the Moon from the Earth. The phases of the Moon are described as the different shapes in which the Moon appears to an observer on the surface of the Earth as it orbits. The Moon rotates about its axis in the same time it takes for it to revolve around the earth, about one month. It is for this reason that the same side of the Moon constantly faces the Earth.

The word 'eclipse' is another scientific term that is used in the chapter to describe both solar and lunar eclipses. A solar eclipse occurs when the Moon passes in between the Sun and Earth, thereby casting its shadow onto the Earth. Total solar eclipses are rare occurrences; they can only be observed during the New Moon phase of the cycle, when the Sun is near one of the nodes of the lunar orbit, so that the Earth, Sun and Moon form a straight line.

A lunar eclipse occurs when the Earth blocks the Sun's light from reaching the Moon. A total lunar eclipse occurs only when the Sun, Earth, and Moon are exactly aligned with the Earth in between the Sun and the Moon. The Moon is completely within the darkest part of the earth's shadow, called the "umbra". During a lunar eclipse, the moon appears a bright copper color due to the gas particles in the earth's atmosphere refracting some of the Sun's light.

6.1.1.1 Scientific Terms:

Moon: The Earth's only natural satellite, which orbits the earth at a mean distance of 384,400 km.

Rotation: The motion of an object about an axis

The Lunar phase: The shape of the portion of the Moon illuminated by sunlight as seen by an observer on Earth.

Eclipse: A total or partial eclipse is the total or partial obscuring of light from a celestial body as it passes behind or through the shadow of another body.

Solar Eclipse: An eclipse that occurs when the shadow of the Moon falls on the Earth.

Refraction: The bending light experiences as it travels between mediums.

6.1.1.2 Relation to Massachusetts Framework:

- According to the Massachusetts Science and Technology/Engineering Curriculum framework, Phases of the Moon comes under learning standard 15 of Earth and Space Science. Students are encouraged to observe the sky every night for 30 days and record every night the shape of the moon and its relative location across the sky.

- In the appendix II (Additional Learning Activities for Grade PreK through Grade 8, P 117) of the framework, Standard #15 says "Demonstrate the various phases the moon using a model (light source and sphere)

6.1.1.3 Relevance to MCAS:

If we refer to the *figure 3*, showing the past 10 years of MCAS questions asked from each of the learning standards, we would find that, on average, learning standard 15 (Phases of the moon) appears on the MCAS more that most of the other learning standards.

6.1.2 Description of the Activity:

The activity was designed to help students understand the phases of the Moon observed from the Earth. Before the activity began, students are given a pre-test (Figure A: Pre/Post test of activity 1, phases of the moon) containing questions relevant to the activity and the past MCAS tests. Students then perform the activity and are introduced to the scientific terms given in section 6.1.1.1 while working through the activity.

Figure 6: Phases of the Moon Activity

6.1.2.1 Equipment:

- Polystyrene spheres,
- A bright source of light
- Pencil and paper

6.1.2.2 Procedure:

1. Use a sheet of paper *(given in figure 8*) containing eight circles each representing a polystyrene sphere at a particular position from the source of light. Move counterclockwise around the source of light exactly following the ordering of these circles starting from the 1st that is closest to the source of light.

2. Turn on the source of light.

3. Make the room completely dark so that the students can observe the illumination of the sphere by the projector.

4. Stay at the first position, keeping the sphere between yourself and the projector. Observe the surface of the sphere. Note which part of the sphere is illuminated. Now shade the portion of the first circle (representing the sphere at position 1) where a shadow is casted on the sphere. This is the first phase of the moon (the new moon).

5. While keeping the sphere at an arm's length away from yourself, move counter clockwise towards the second position. Repeat the above procedure for the remaining seven positions.

6. Now compare your drawing with the actual phases of the moon on the board as given in the figure 7.

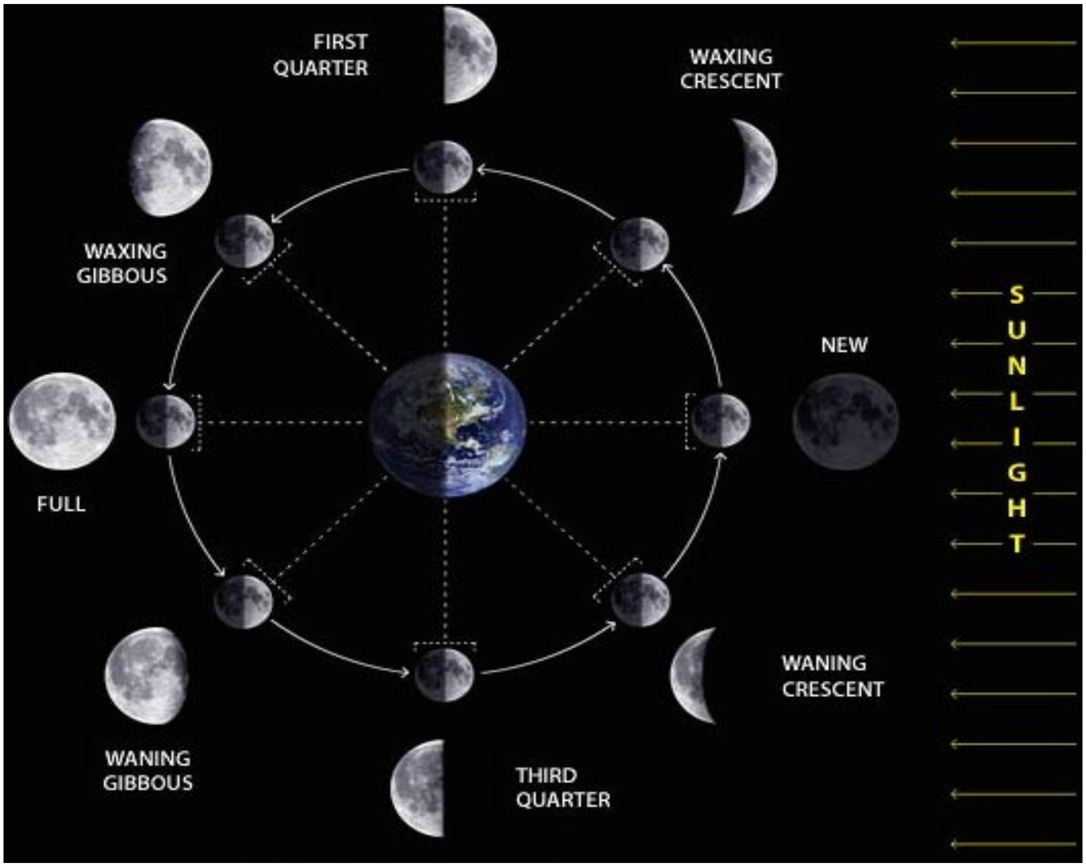

Figure 7: The Different Phases of the Moon (*MoonConnection.com*)

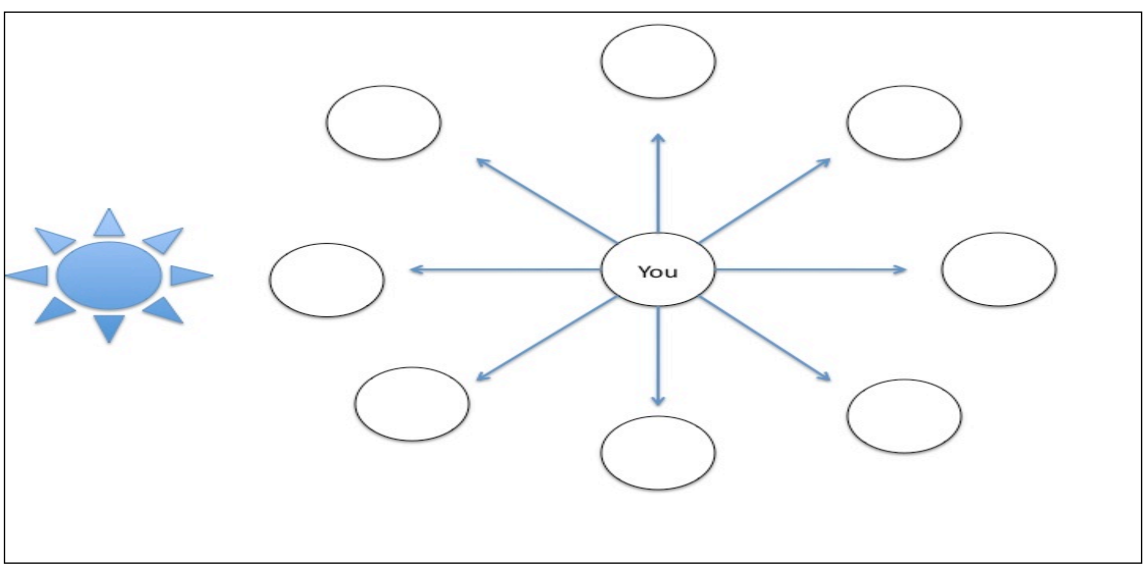

Figure 8: Phases of the Moon Worksheet

6.1.2.3 Activity and Time Organization:

- We give the introduction on the activity to the students, which should not take more than 10 minutes.
- Then we have two groups of students. Each group of students is then divided into pairs. We give a ball to each group. One student holds the sphere and other student draws the picture with the help of his partner. We expect everyone to finish in less than 20 minutes
- At the end we give a conclusion and check their drawings.
  Estimated time needed: 10 minutes
- In total 40 minutes

6.1.2.4 Observation:

- We observe that the surface area of the sphere illuminated by the projector varies when we go from one position to another position.
- The area of illumination increases when we go from position 1 to 4. It then begins to decrease when we move from position 4 to 8.
- At positions 2 and 8 the sphere has the same area of illumination but the diametrically opposite part of the sphere is illuminated.
- We observe the same phenomenon at positions 3 and 7, and at positions 4 and 6.
- At position 5, the area of illumination is at its maximum.
- At position 1, the observed portion of the sphere is dark.

6.1.2.5 Discussion:

The projector acts as the Sun and the sphere act as the Moon. Observer is on the Earth.

- The increase in the area of illumination on the sphere from positions 1 to 4 is called the waxing phase of the moon
- The decrease in the area of illumination on the sphere from positions 4 to 8 is called waning phase of the moon
- When the sphere is at position 1, a solar eclipse is observed since the sphere blocks the light coming from the projector towards an observer
- When the sphere is at position 5, a lunar eclipse is observed since the observer blocks the light coming towards the sphere

Position of the sphere	**Term used for the illuminated area of the sphere**
1	The new moon
2	Waxing crescent
3	First quarter
4	Waxing Gibbous
5	Full Moon
6	Waning Gibbous
7	Third Quarter
8	Waning Crescent

Table 6: Scientific Terms used in the Phases of the Moon Activity

Expected time to complete the experiment: 40 minutes

Description of materials used

Professor John McCamy Wilkes' 2012 IQP group had already made the polystyrene spheres. They purchased the polystyrene and the pencils used to hold the polystyrene spheres for less than 20 dollars in total. We used Tashi and Tenzin's table lamps as the sources of light.

6.1.3 Pre-Test:

6.1.3.1 Methodology and Objectives of Pre Test:

We distributed a pre-test based on the activity, the Phases of the Moon, and chapter 13, "Earth, Moon, and Beyond". The pre-test includes four questions (Figure A: Pre/Post test of activity 1, phases of the moon). The pre-test was designed to measure the students' knowledge of the terms and concepts contained in Chapter 13. The pre-test was handed out while we were setting up the activity and the students were allowed five minutes to complete the pre-test.

6.1.3.2 Observation:

We evaluated the pre-test by plotting the frequency of students' score out of 8 as shown in figure 7.

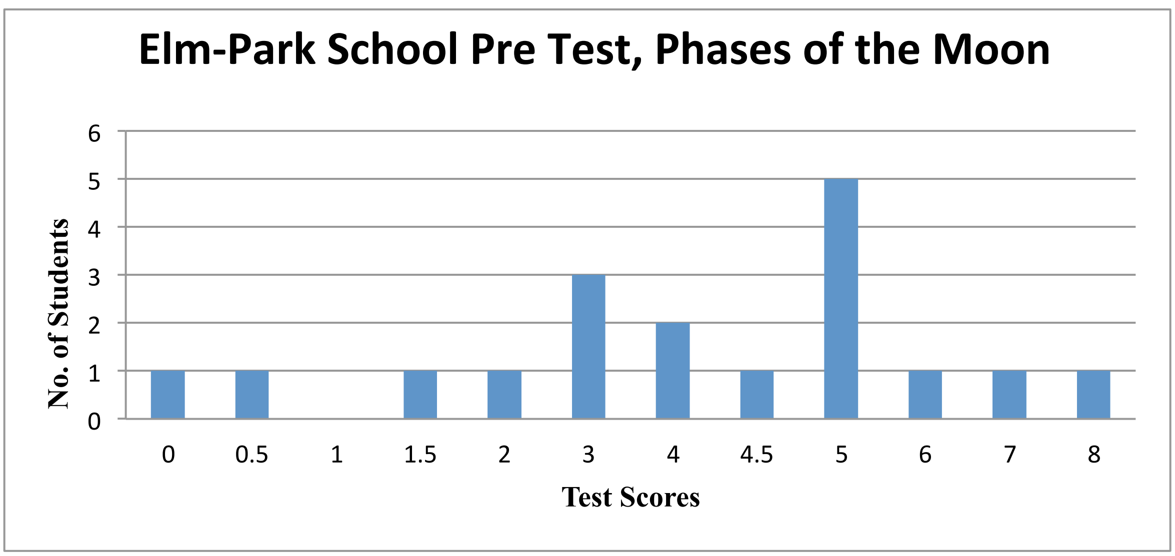

Figure 9: Pre-test Results for Phases of the Moon

No. of students in the class	21
No. of students appeared	18
Mean	3.97
Mode	5
Highest Score	8
Lowest Score	0

Table 7: Summary of Class Performance

6.1.3.3 Results:

The students did well in answering the definition matching problems. However, only two students received a full score in the conceptual problem 1 (Figure A: Pre/Post test of activity 1, phases of the moon) which was to arrange the order of the phases of the Moon. The average score of the students was 3.97 out of 8. The mode of the class was a score of 5.

6.1.4 Classroom Observation:

We performed the activity in one of Elm Park School's fifth grade classrooms. The classroom lacked enough shades for all of the windows. We could not find any curtain in the classroom to block the light coming through the sheet. Tashi fetched a bed sheet from his apartment. We used the bed sheet and the bookshelves in the classroom to block the light coming through the windows. Initially we planned to use a projector available in the classroom as the source of light, but its light was too dim to overcome the strong background light in the classroom. Tashi brought two table lamps and they worked better than the projector. The students however, had a hard time distinguishing between the quarter and gibbous moon stages since the classroom background light killed the light from table lamps reaching beyond the quarter sphere. After doing close observation of the dim light reaching beyond the quarter sphere, they could tell the difference. Some students were very keen to do the activity and they had some interesting questions for example, "Why does the Moon pictured on the chart have no stars around even though the Earth on another chart has many stars around it?" One student asked, " Which one is bigger, the earth or the moon?" When we asked whether they knew about refraction, one student came forward and he put his pencil near a lustrous table leg to show the bending appearance of the pencil. Even though that was not due to refraction, his method of approaching to answer was wonderful. Most of the students in the classroom actively engaged into the activity.

We strongly recommend schoolteachers organize classroom activities that encourage students' participation and to keep curtains in the classroom if possible, to allow the room to be darkened as needed.

6.2 Activity 2: Electricity

6.2.1 Introduction:

The Electrify the Base activity relates to chapter 16, electricity, in the 5^{th} grade textbook. There were two separate activities carried out in order to help the students understand the chapter's content such as conductors and parallel circuits. The main focus of this activity was to go over the material while relating it to the issue of powering a lunar base. The activities covered the topics of what conductors and insulators are and how parallel and series circuits differ.

6.2.1.1 Scientific Terms:

Electricity: A form of energy produced by moving electrons.

Electric Current: The flow of electrons.

Conductor: A material that carries electricity well.

Insulator: A material that does not conduct electricity well.

Parallel Circuit: An electric circuit that has more than one path for the current to follow.

Series Circuit: An electric circuit in which the current has only one path to follow.

6.2.1.2 Relevance to Massachusetts Framework:

- Under Physical Sciences under the Science Technology/Engineering Learning Standards (Additional Learning Activities for Grade PreK through Grade 8, P 65) of the framework, Learning Standard 6 says, "Recognize that electricity in circuits requires a complete loop through which an electrical current can pass, and that electricity can produce light, heat, and sound". Learning Standard 7 says "Identify and classify objects and materials that conduct electricity and objects and materials that are insulators of electricity."

6.2.1.3 Relevance to MCAS:

If we refer to Figure 2: MCAS questions asked from each learning standard over the past 10 years in Physical Science in section 5.3.1, showing the MCAS questions asked over the past ten years from each of the learning standards from Physical Sciences, we will notice that learning standard 7 and 11 appear in the highest number of questions on the MCAS, while learning standard 6 appears in an average number of the questions, compared to the other ten learning standards.

6.2.2 Description of the Activity:

This activity was meant to cover a few different topics in the electricity chapter of the 5th grade science textbook and give the students a better understanding of the material. The students were to figure out a way to supply electricity to a lunar base. The students need to figure out what source of energy would work best then determine what materials on the Moon could be used to create wire; wire will require a conductor and an insulator. They will also learn about parallel and series circuits so that they know how different wiring will affect the rest of the base.

6.2.3 Equipment:

- Assortment of flashlights
- Assortment on conductors
- Assortment of Insulators
- Light bulb demo circuit
- LED circuits
- Model of a lunar dorm
- Solar charged lamp

- Solar powered musical circuit

6.2.4 Procedure:

As a class (approx.10min):

1. Discuss the different sources of energy available on Earth and determine which one is the best choice to power a base on the Moon.
2. Observe the solar powered music circuit and the solar charged lamp and how they function.

Split into groups

Circuits (approx.15min each):

1. Observe the different types of flashlights available and determine how each one completes its circuit (there are three different kinds).
2. Turn on the light bulb demo circuit. Hypothesize how removing different light bulbs would affect the others.
3. Test the hypotheses by actually removing the different light bulbs and observe the changes to the circuit.

Conductors and Insulators:

1. Hypothesize which materials are conductors and which ones are insulators.
2. Using the different materials try to complete the LED circuits.
3. Observe the results from using the different materials, which ones were actually conductors and lit the LED and which ones didn't.

The activity should take one hour to complete. A total of 10 minutes is allocated to completing the pre/post-test. The activity itself, including explanation of the different vocabulary should take 40 minutes to complete and then another 10 minutes to conclude.

Figure 10: Circuit Setup

6.2.5 Pre-Test:

6.2.5.1 Objective:

The students were given five minutes in the beginning of the activity to complete the pre-test handed to them. The pre-test consists of five questions based on chapter 16, and the Electrify the Base activity (Figure C: Pre/Post test of Activity 2, electricity). This was done to get a measurement of the class' understanding of the material before starting.

6.2.5.2 Results:

Figure 11 is the results of the pre-test. Each question was worth one point, looking at the graph most of the students are spread evenly between zero and three points.

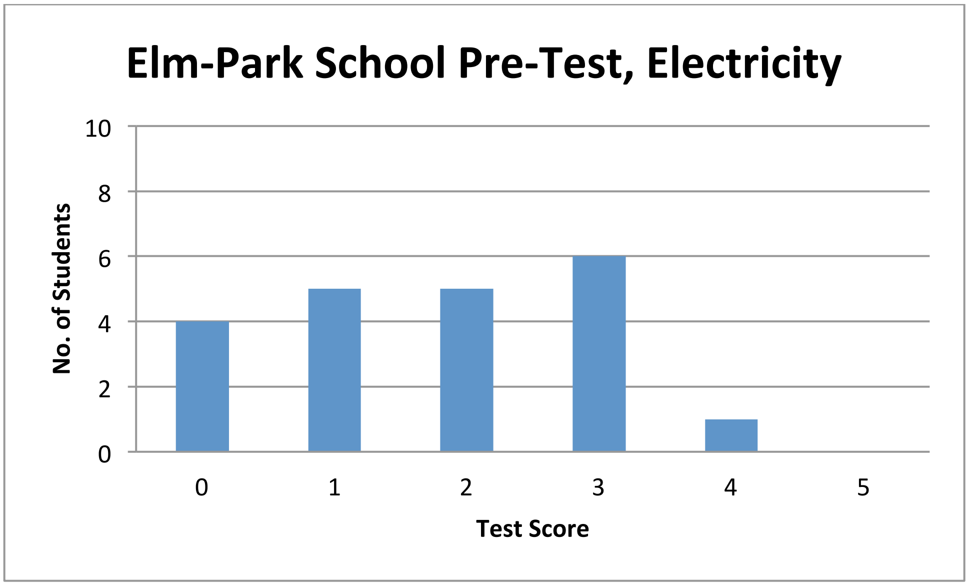

Figure 11: Pre-test Results for Electrify the Base

6.2.6 Post-Test:

6.2.6.1 Objective:

After the completion of the activity, the students were given a post-test consisting of the same questions to determine whether the 5th grade students were able to learn and take away anything from this experience.

6.2.6.2 Results:

Looking at the post-test results in *figure 12* and comparing it to the pre-test results, it is clear that although they don't show full mastery on the subject there is a significant improvement in the student's performance. Most of the students are now concentrated between two to four points with only a few still scoring one point or below.

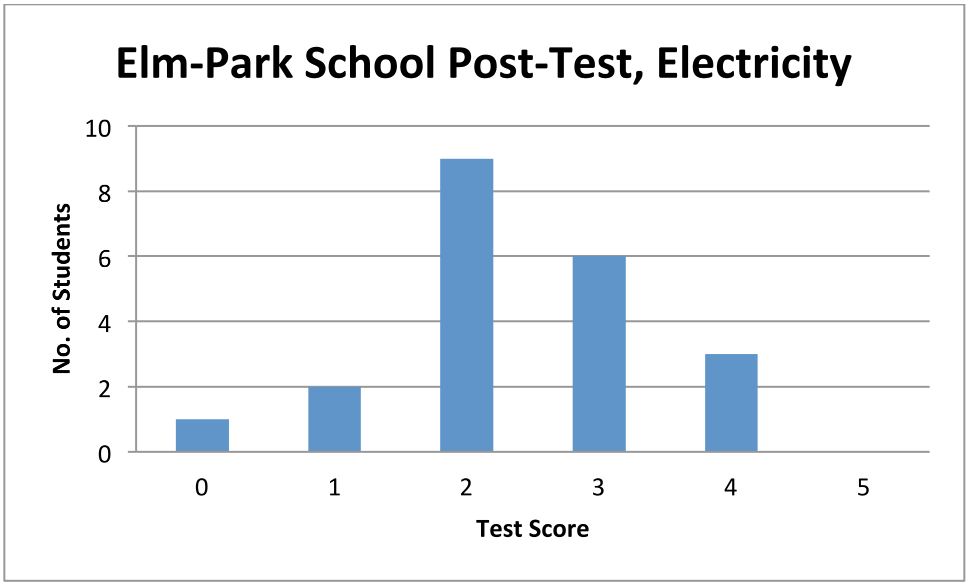

Figure 12: Post-test Results for Electrify the Base

6.2.7 Hypothesis Test:

A hypothesis test was conducted on the pre and post-tests. The results given in *Table 8* indicate that there was a statistically significant improvement in the student's average test score on the subject. The students answered an average of 1.76, out of 5, questions correctly on the pre-test. This is only slightly higher than an average of 1.25, out of 5, correct answers that we would expect had all of the students been guessing completely at random. After the activity was completed and the students were given the post test, the average number of correct answers increased to 2.77, out of 5, indicating that the students had indeed learned from the "Electrify the Base" activity, covering conductors/insulators as well as series/parallel circuitry, with a statistical certainty of over 99%.

Hypothesis Test ***(One-Sample)***	**Post Test Scores**	
Sample Size	21	
Sample Mean	2.381	

Sample Std Dev	1.024	
Hypothesized Mean	1.762	Pre-test Mean
Alternative Hypothesis	> 1.762	Checking whether the results improved in the Post Test
Standard Error of Mean	0.223	
Degrees of Freedom	20	
t-Test Statistic	2.772	
p-Value	0.006	Significant to 0.6%
Null Hypoth. at 10% Significance	Reject	
Null Hypoth. at 5% Significance	Reject	
Null Hypoth. at 1% Significance	Reject	The data strongly indicates an improvement in the students' scores with over 99% confidence

Table 8: Hypothesis Test

6.2.8 Observation:

It seemed like the 5th graders had a hard time understanding the concept behind series and parallel circuits. Unfortunately with the given time, a more proper explanation could not be given. However, overall the students were excited and interested in the subject matter. There were some students that were very active, asking questions and actively engage in the discussions. The 5th graders were shocked to find out the various forms glass could take, they never imagined that the same material as their windows could be woven into a cloth. In addition the students were all intrigued by the solar powered music player and light bulb demo circuit regularly asking to see it or to have it turned on.

6.3 Activity 3: Shackleton Crater:

6.3.1 Introduction:

This activity, Shackleton Crater, relates to the chapter 13, "Earth, Moon, and Beyond". The activity was designed to help the students understand the formation of craters on the surface on of the moon. The moon and the earth have many craters on their surfaces due to volcanic eruption and the impact of falling asteroids. This activity focused more on the formation of craters on the surface of the moon due to impact of falling asteroids from the space. A crater is a large hole on the surface of a planet or moon, formed by falling of celestial objects such as meteorites. The size and shape of the crater can be different depending on which angle the celestial objects strike the surface, the speed of the falling celestial object and the size of the celestial object. This activity was performed during the field trip for the Elm Park 5th grade students.

6.3.1.1 Scientific Terms:

An impact crater: An approximately circular depression in the surface of a planet, moon or other solid body in the Solar System, formed by a very high velocity (approximately over 3000 m/s) impact of a smaller body with the surface.

Shackleton Crater: An impact crater that lies at the south pole of the Moon. The peaks along the crater's rim are exposed to almost continual sunlight, while the interior is perpetually in shadow.

6.3.1.2 Relevance to Massachusetts Framework:

This activity falls under the learning standard 15 of Earth and Space Science of Massachusetts Science and Technology/Engineering Curriculum framework.

6.3.2 Description of the activity:

This activity was designed to help the students understand the formation of craters on the Moon. Students would learn how meteorites falling at different angle could create craters of various shapes and dimensions. Extending that concept, students should determine the side and angle at which the meteor that formed Shackleton Crater would have struck the Moon.

6.3.3 Equipment:

- 15, 30, 45 and 60 degree ramps
- Four tubs of flour
- Black sand
- Steel ball bearings.

6.3.4 Procedures:

- The four tubs of flour and black sand, representing the top two layers of the moon, the ramps, each set up at either 15°, 30°, 45°, or 60°, and the steel ball bearings representing meteors were brought out.
- The fifth grade students were divided into two groups roughly proportional to the number of ramps at each table.
- The students were told that the objective of the demonstrations would be to determine the side and angle the meteor that formed Shackleton Crater would have struck.
- In ascending order, the various angles were shown to the students and the impact craters were then measured with rulers for depth and length in order to demonstrate the effect the various angles would have on the shapes of the craters (the lower the angle, the longer and more shallow the crater).
- After the students had seen each of the craters, they were then asked to identify which side the Shackleton meteor most likely struck from, after noticing that the ball bearings would push up the flour on the opposite end of the crater, and the angle, based upon the shape and length of Shackleton.

Figure 13: Students Performing the Shackelton Crater Activity

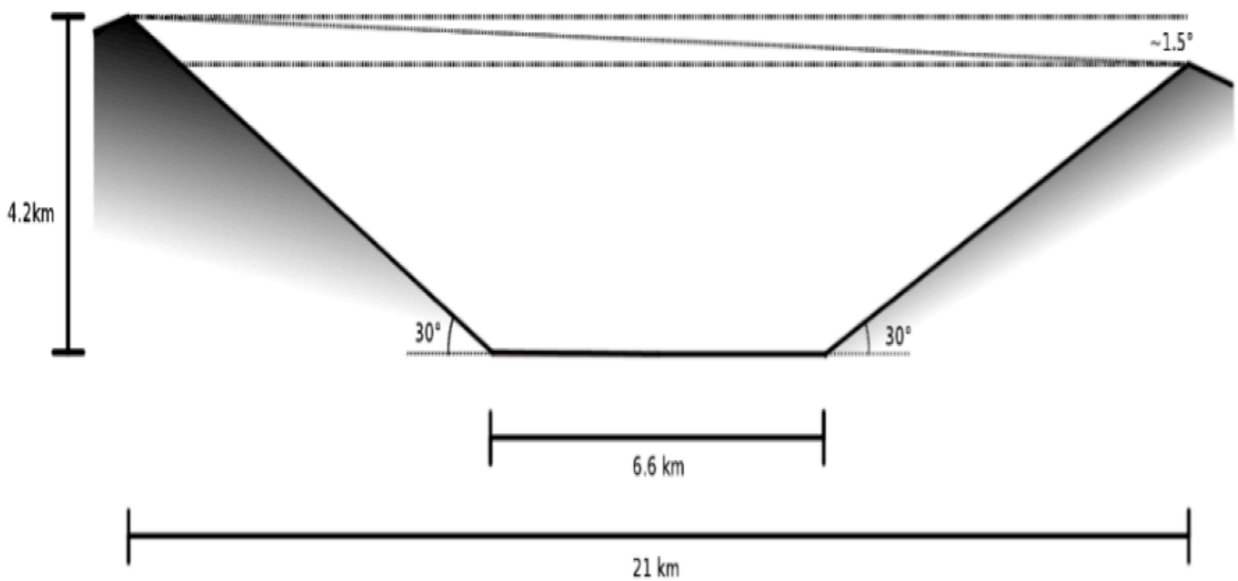

Figure 14: Scaled Diagram of Shackleton Crater

6.3.5 Measurement:

Table 6 shows the measurement of each crater created by the ball bearing rolled down the ramp at different angles.

Angle (in degree)	**Depth (inches)**	**Length (inches)**	**Width (inches)**
15	0.5	4.5	1.5
30	1.5	4	1.5
45	2	3.5	1.5
60	3.5	3	1.5

Table 9: Crater Measurements

6.3.6 Desired Outcome:

Students were expected to get an answer that Shackleton meteor most likely hit the moon at an angle 30^{o} with respect to the base of the crater. They should find that the ball bearing rolled on the ramp set up at 30^{o} would push up the flour on the opposite end of a crater. The shape and length of the crater so formed would most closely represent the shape and the dimensional proportions of the Shackleton crater given in *figure 14.*

6.3.7 Observation:

While the team was rolling a ball bearing on the ramp with a 15-degree angle of elevation, students were curious to know what would happen when the ball bearing hit the flour in the tray. They jostled for the position to be next to roll the ball bearing down the ramp, measure the crater, and level the flour to repeat the activity. One student asked, "What would happen if a ball bearing is dropped from straight above?" The team was impressed by her curiosity because the team had planned to do that (even though asteroid, comets or meteorite would hit the moon obliquely) to show how the crater's dimension would appear? Students were told that the ball bearing acted as an asteroid, the flour in the tub with black sand spread on it represented the surface of the moon with different layers, and the pit made by the ball bearing when it hit the surface of flour represented the crater. One of the team members asked what the students thought the dimension of the crater depended on. The students replied that the size and mass of the asteroid would affect the crater, though they neglected to recognize the effect the asteroid's velocity would have on the crater as well.

6.4 Activity 4: Friction:

6.4.1 Introduction:

The force of gravity on the Moon is roughly 1/6 as much as Earth. Due to the lower gravity, objects would weigh only 1/6 as much on the Moon as they do on Earth. Frictional force is dependent on the surfaces of contact and the weight of the object on top. This activity looks to demonstrate the differences in friction caused by the lower gravitational force on the Moon compared to the Earth.

6.4.2 Materials:

- 25 Penny Rollers
- 20 Dime Rollers
- 5 Aluminum Weighing Dishes
- 5 Spring Scales (1 kg with an accuracy of 20 grams)
- 1400 Pennies
- 1 Roll of Drywall Joint Tape
- 2 Cans of Spray Paint

6.4.3 Concept:

The activity is intended to be part of the Force unit and demonstrates that friction is dependent on gravity. Objects on the Moon weigh only 1/6 as much as they do on the Earth. Since friction depends on the roughness of the surface and the object's weight (as determined by the strength of gravity), decreasing the weight in the weighing dish simulates the difference in weight an object experiences by traveling from the Earth to the Moon.

6.4.4 Assembly of Materials:

It is more cost effective to use pennies as weights rather than standard physics weights. The accuracy of the pennies suffices for the experiment and provides a ninety percent cost reduction. Since each penny weights 2.5 grams, 40 were used to create each 100 gram weight and 20 for each 50 gram weight. Five 100 gram and four 50 gram weights were grouped together with each spring scale.

1400 pennies were counted out and placed into penny rollers and dime rollers. The tops were then glued shut and had books placed on top until the glue had dried. Next the rollers were painted according to the colors of the rollers, the 100 gram penny rollers were painted red and the 50 gram dime rollers were painted green.

In addition, the tabs of the aluminum weighing dishes had a hole-puncher used on them to allow the spring scales to have a place their hooks could connect. Finally, to account for the smooth surface of desks in the classroom, the aluminum weighing dishes had drywall tape added onto their bottom to increase their surface coefficient of friction.

Figure 15: Designing the Activity

6.4.5 Procedure:

1. After a brief introduction to the forces discussed in chapter eighteen of the textbook, such as gravity, magnetism, and friction, the materials can be brought out.

2. Each of the five spring scales receives the following:

- 5 penny rollers
- 4 dime rollers
- 2 aluminum weighing dishes.

3. Load one dish with 600 grams and the other with 100 grams.

4. Attach the spring scale's hook to the 600 gram dish's tab and have the students record the force required to pull the weight. This is also a good time to note the difference between static friction and kinetic friction.

5. Next, pull the 100 gram weight and have the students note that difference between the force required to pull the 600 gram and 100 gram weights, respectively.

6. Allow the students to experiment with various weights by loading the dishes differently and recording their results.

7. The dishes can also be pulled up various inclines using the Shackleton Crater activity's ramps to demonstrate the effects of inclines on friction and record the required forces.

7. Elm Park 5th Grade Science Fair:

Mr. Mahoney requested that our team judge the fifth grade science fair projects for his class and decide which one would be declared the winner. One of our team members along with our IQP advisor, Professor Brigitte Servatius, were able to make it to the school and judged science projects. The judging was done on the basis of judging guidelines provided by Mr. Mahoney (Figure B: Elm Park 5th grade science fair score sheet guideline). There were a total of eleven projects. Some of the projects were individual and some were team projects. All the projects were simple and relevant to 5th grade science topics such as buoyancy, sound, and electricity. The equipment that the students used was simple and easy to obtain. Most of the students had good visual presentations on display such as figures and graphs. Some of the projects for example, the tornado chute and battery power had demonstrations. However, most of the project write-ups and graphs were obtained with help from their parents. The students did not know the science and concepts behind their projects.

The tornado chute was chosen as winner for the 5th grade science fair. The student did a fantastic job in explaining the procedures and the concepts involved in her project. She struggled a bit in answering some questions regarding tornadoes but she did a fabulous job compared to her peers. Though, she was helped by her parents in organizing and writing her report, she put lots of effort in her project.

The following are the science fair projects presented by Mr. Mahoney's fifth grade class:

1. Project Title: ***The Tornado Chute and Parachute***

   Student Name: Shakyra

   The overall presentation of the project was informative and well prepared compared to the other projects. Her project was based on parachutes as well as the causes and effects of tornadoes. On her mother's advice, she decided to explore both the topic because as she could not decide between them. She did a simple demonstration of a tornado using a bottle filled with dyed water. She had a working model of a parachute made from a shopping bag. The write ups and display were very relevant to her knowledge. She had no difficulties in explaining the properties that are essential to making a parachute.

2. Project Title: ***Naked Egg***

Student Names: Taylor and Jessalyn

Taylor and Jessalyn's project was on how eggshells can be dissolved using vinegar (*figure 16)*. The visual presentation was good and they had pictures of eggs after they were treated with vinegar. They knew what the procedures were and how they are performed. However, they did not know what chemical reaction was taking place within the eggshells and why bubbles were being produced when the shells were treated in vinegar. They did not take into consideration the composition of the shell and struggled to explain the reaction occurring between the eggshells and vinegar, though the experimental procedure and observations were good.

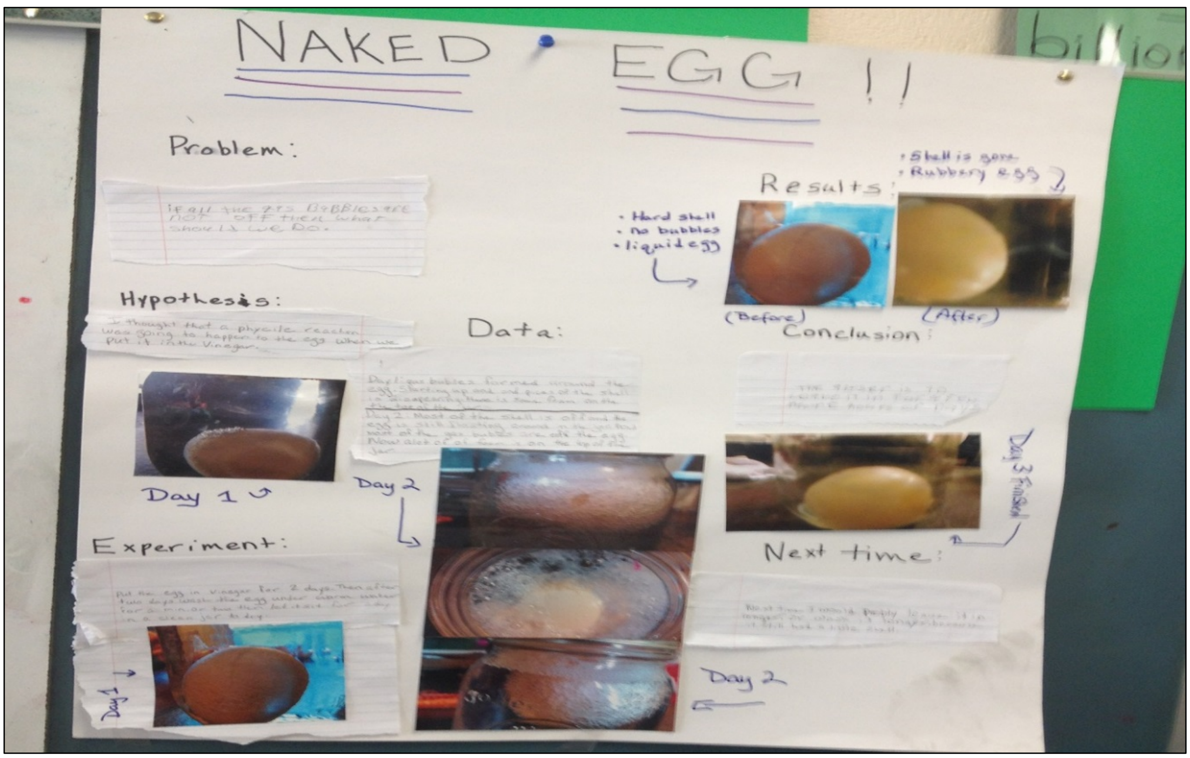

Figure 16: Naked Egg Experiment

3. Project Title: ***Sound Vibration***

Student Name: Binayak

The project setup was simple and he had informative descriptions on display (*figure 17)*. He came up with his project on his own. However, he did not understand the concepts behind sound. The student barely understood how sound travels and in which medium sound travels the fastest. He had a simple demonstration consisting of sound propagating from a spoon in his hand; however, he did not perform the demonstration.

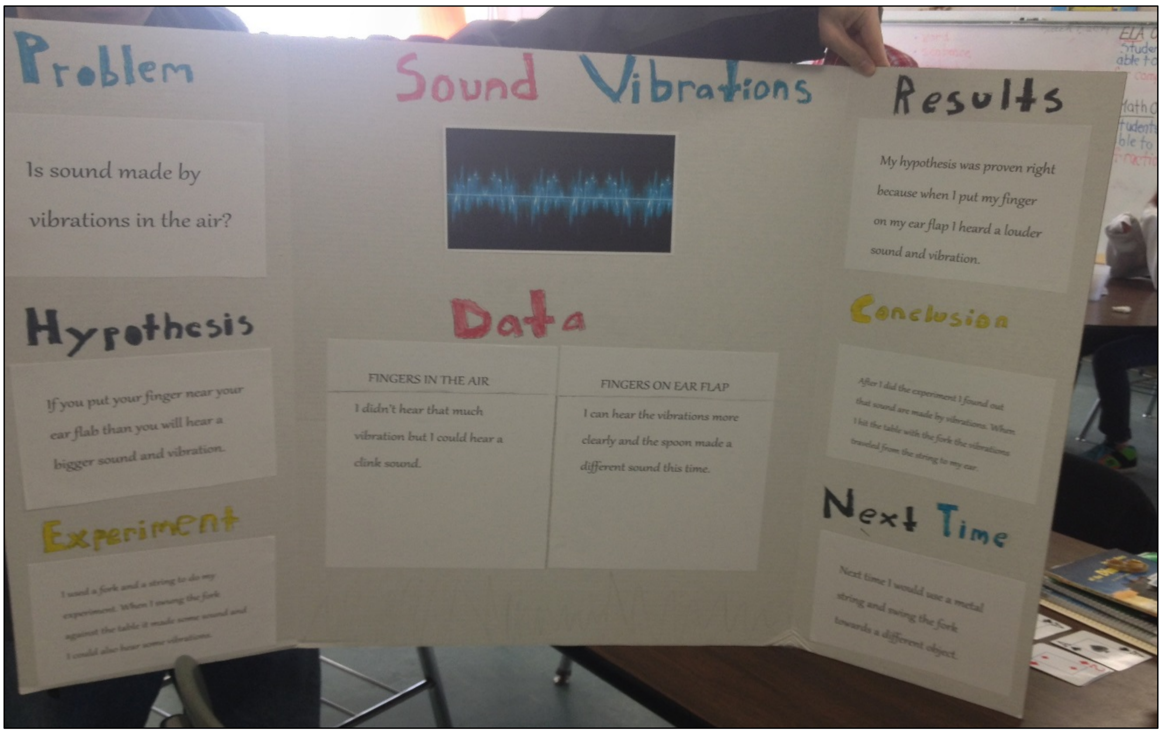

Figure 17: Sound Vibrations Experiment

4. Project Title: ***How a Rock Forms?***

   Student Name: Synsaya

   The visual presentation of the project was good and the student had a demonstration of the project (*figure 18*), which was related to the formation of sedimentary rock. Sedimentary rocks are formed by the compaction of particles that settle at the bottoms of water bodies and accumulate together. Unfortunately the student was unable to describe how rocks are formed.

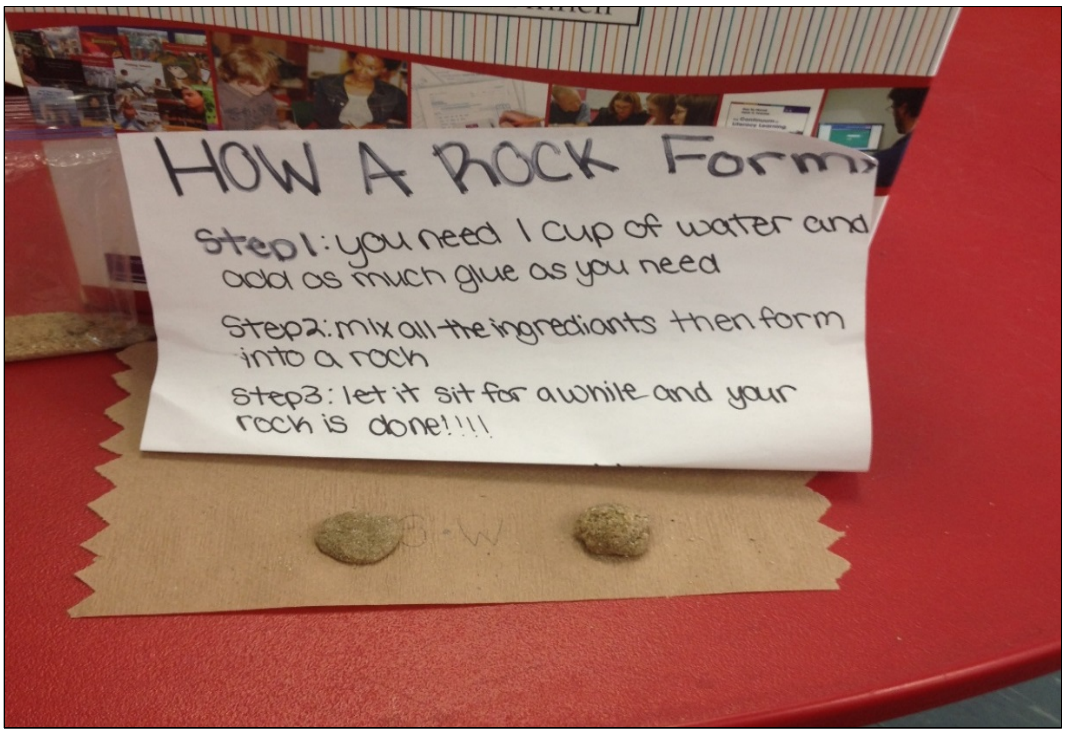

Figure 18: How a Rock Forms Experiment

5. Project Title: ***Oil and Water***

   Student Names: Brenda and Jayda

   The project was about oil and water (*figure 19)*. The students had a good visual presentation on display. They had a consistent scientific approach. However, the report was weak and they struggled greatly in explaining the science behind water and oil being immiscible. They had graphs on display but they did not know what do to with them.

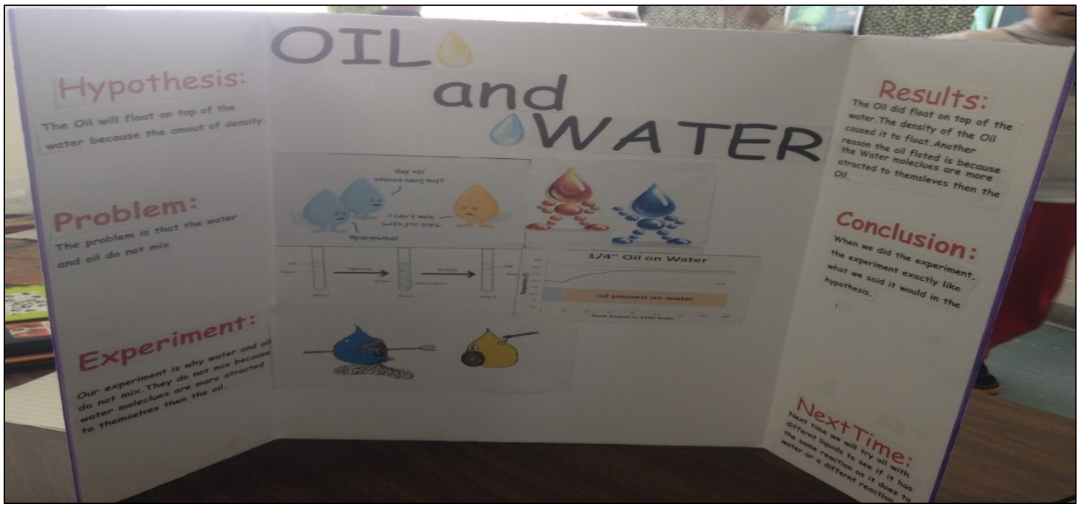

Figure 19: Oil and Water Experiment

6. Project Title: ***Battery Power***

Student Names: George and Cristian

The project was done in a creative way and the students used a scientific approach on their project, Battery Power. They set up the demonstration in a simple way (*figure 20)*. They connected a circuit in series to a battery to light a bulb. However, they didn't know the concepts behind the circuit arrangement. The students found it amazing that the light bulb continued to glow despite one of the batteries being removed from a parallel circuit.

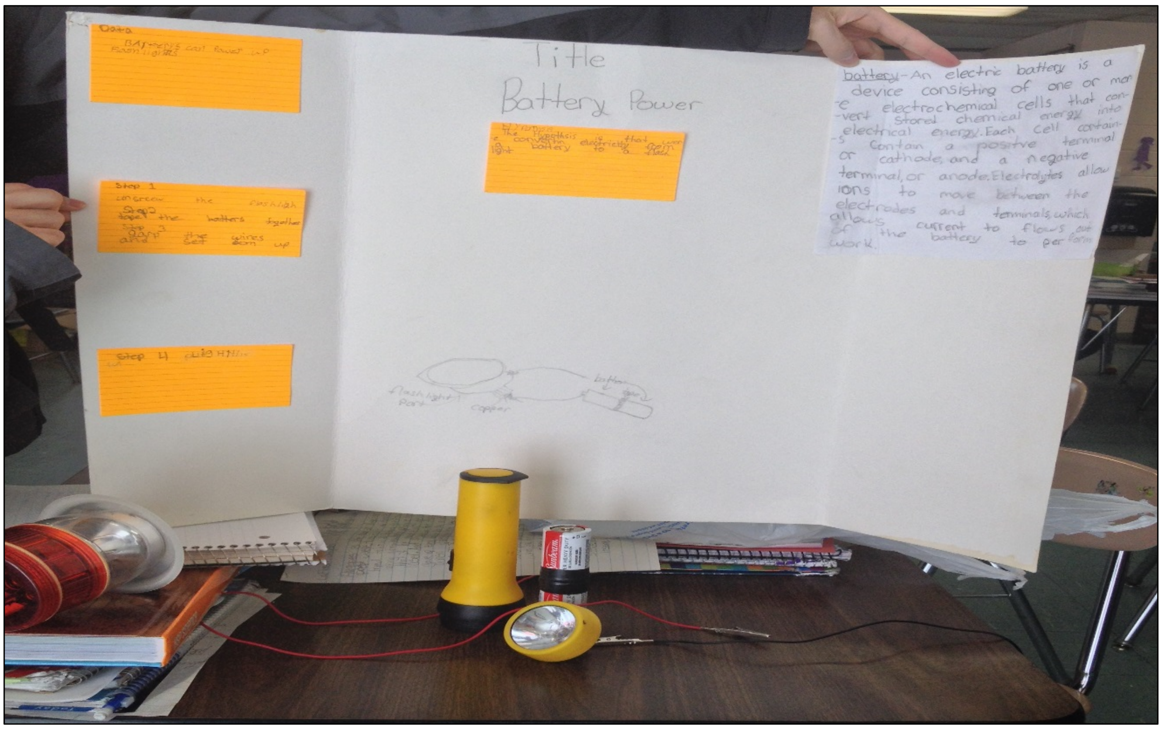

Figure 20: Battery Power Experiment

7. Project Title: ***Buoyancy***

Student Names: Kalu and Isaac

The project was about the effect of weight on the buoyancy of a boat. The students did not take into consideration size or material of boat. They continued to add weight and recorded how long the aluminum foil boat could stay afloat with different weights. The group knew the procedures they followed but not that buoyancy was the reason the boat continued to float.

8. Project Title: ***Sink or Float***

Student Names: Nonh and Eli

The project was not set up properly. The students did not have any displays other than a simple demonstration of a cardboard boat in a tub. They did not know about the forces that keep a boat floating. They did not know the definition of buoyancy. They did not consider the importance of the size and material of the boat. The cardboard boat absorbed a substantial amount of water and subsequently began to sink.

7.1 Conclusion:

Most of the projects except sink or float have write-ups and figures on display, which were up to the expectation for 5th grade students. The students knew the procedures of their projects; however, most of them did not know the concepts and science behind their projects. The sources of most of the students' project ideas and information came from their parents and the internet. None of the students considered using the textbook to either choose or provide information for their science fair projects.

8. Field Trip:

A field trip to WPI was held for the Elm Park 5th grade student body, consisting of 60 students, on April 11, 2014. Professor John Wilkes organized the trip for the students; this is an event that he has organized before. The plan for the trip was to have students come to WPI and take part in different activities throughout the day. The activities were related to either a lunar or Mars base and to the 5th grade curriculum. The activities were primarily held in Riley Commons and were scheduled to start at 9:00 AM and end by 1:50 PM; the students were separated into their classes (a total of three) and followed different schedules (Figure E: Field Trip Schedule). The 5th grade IQP team was left in charge of two of the activities, Shackleton Crater and Electrify the Base.

The Shackleton Crater activity was done exclusively for Mr. Mahoney's class because they had already participated in the Electrify the Base activity on April 1st. The students simulated the formation of craters by dropping ball bearings onto flour and measuring the craters using rulers. The details of the activity will be found in section 6.3.

The Students were told that the ball bearing represented an asteroid, the flour, covered by a layer of black sand represented the surface of the moon and the mantle underneath, and the pit made by the ball bearing when it hit the surface of flour represented the crater created by an asteroid impact. The students were asked what they thought affected the dimensions of the crater. They answered the size and mass of the asteroid (ball bearing). The students were informed that the angle at which the asteroid hit the surface also had an effect. While the ball bearing was rolling down the ramp, the students intently, curious to know what would happen when the ball bearing hits the flour. The students were eager to get a chance to roll the ball, measure the depth and length of the “crater” formed in the flour and level out the flour to repeat the activity again. One girl asked what would happen if she dropped a ball bearing from straight above? It was interesting to see the students’ curiosity and the different thoughts they have. There was actually a vertical drop planned in the activity already, to show what it would look like.

Electrify the Base (6.2 Activity 2: Electricity) was an activity that was already done by Mr. Mahoney’s class but it was decided that it would be a good activity for the other two classes to experience and was added into the schedule. When setting up the activity we discover that most of the nine-volt batteries used to power the LED circuits were dead, despite being brand new. Instead of allowing students to perform the tests by themselves, this part of the activity became a demonstration. The students were separated into two groups; one group did conductivity and the other did circuitry, they swapped places after finishing each topic.

In the conductivity portion, the students were provided with different materials categorized as either conductors and insulators. The LED circuit was used to demonstrate whether a certain material could complete the circuit. The 5th grade students were all pleased when they said that iron was a conductor and saw that the LED circuit lit up when it was tested. However, many students guessed that aluminum was an insulator and their faces were filled with amazement when they saw that aluminum was a conductor and lit up the LED.

In the circuit portion, the students were tasked with understanding how different circuits worked. When presented with the different flashlights, the students were able to quickly identify that the metal contacts inside were functioning as wires to complete the circuit. However, it took them a little longer to figure out that the metal body of one of the flashlights was what completed the circuit. The students were very curious of the circuit demo board and were regularly asking for it to be turned on (similar to Mr. Mahoney's class). The students were all interested in how unscrewing one or even two light bulbs affected the entire circuit and found it fascinating how the brightness of the remaining bulbs became the same when one of the bulbs in parallel was removed from the circuit.

Some students looked little tired near the end of the trip but most of the students seemed like they enjoyed the activities, they were deeply interested and found the entire day to be fun.

John, will you please share:

To John and all members of today's field trip team.   Thank for an exciting and productive day for the 5th graders at Elm Park Comm. School. We could tell many hours went into the planning and implementation of today's activities.

Fran Mahoney, Pam Ford, Tracy Holt

Figure 21: Elm Park School Teachers' Comments

9. Conclusion:

The goal for this project was to enrich the learning process for the fifth grade students of Elm Park Elementary School. The Lunar Enhanced Science curriculum team analyzed the school and its Science and Technology/Engineering MCAS performance in section 2 and section 5.3.2 respectively. Elm Park's Science and Technology MCAS scores have had some fluctuations with percentages of students in the “Needs Improvement' and 'Warning' categories from 2010 through 2013. However the average percentage of students in “Needs Improvement” level was 42 with a standard deviation of 6%. The average percentage of students in “ Warning” level was 45% with a standard deviation of 5%. The percentage of students in the Needs Improvement category has decreased from 52% in 2010 to 42% in 2013. However, the number in the “Warning” range has increased from 37% to 49% (Refer to Section 5.3.1), indicating a decline in scores. In an effort to combat this significant percentage of students in the “Warning” and “Needs Improvement” levels, the enhanced curriculum has been designed to emphasize areas in which the students have struggled.

The results from the 2012 through 2007 Science and Technology MCAS were used to target areas where Elm Park students were under-performing compared to their district and statewide peers. For example, on the 2012 Science and Technology MCAS shown in Table 4 (section 5.3.2), only 51% of Elm Park students, compared to 60% of Worcester students and 70% of Massachusetts students, could answer item 20, which shows a picture of a light bulb along with two nails connected to a board and asks “When the student connects the two nails using a wire, the bulb lights up. Which of the following must be underneath the board?” The question requires a rudimentary understanding the components of a circuit and is covered in detail in the “Electrify the Base” activity.

Question 30 had similar results to question 18, with 56% of Elm Park students, along with 60% and 73% of Worcester and Massachusetts students, able to answer it correctly. Question 30 asked students to “Identify and classify objects and materials that conduct electricity and objects and materials that are insulators of electricity.” Insulators and conductors are also covered in the “Electrify the Base” activity.

Elm Park students fared much worse on question 27, in which they were asked to “Describe the changes that occur in the observable shape of the moon over the course of a month.“ Only 33% of the students, compared to 37% of Worcester and 51% of Massachusetts were able to give the correct answer. The enhanced curriculum includes an entire activity dedicated to this subject.

The team also analyzed the fifth grade textbook in section 4. Since the textbook is based on the Massachusetts Science/Technology Curriculum framework, the team studied the framework in section 5 in order to provide appropriate resources for teachers to adequately prepare students for the MCAS topics in need of extra attention. After analyzing Elm Park School, the textbook, MCAS and the framework, the team performed lunar themed activities such as “Phases of the Moon” and “Electrify the Base” in Mr. Mahoney’s fifth grade class. Each activity has pre and post-tests. The questions and activities in the tests are directly related to and emphasize the scientific terms and concepts used in the textbook, as well as recent MCAS tests. These activities should help to improve students’ comprehension of the topics taught in class and prepare them to take the MCAS. At the end of the school year students were given the opportunity to visit Worcester Polytechnic Institute (WPI) and participate in hands on lunar and Mars themed demonstrations in order to provide a capstone experience for the curriculum, along with a tour of the campus. The students were very responsive to the activities at WPI, as well as the many sights on the campus, they were more than happy to ask questions and paid close attention to the team when they were being instructed.

Besides the development of the pre/post-test done for all the activities carried out this year, the Phases of the Moon and Shackleton Crater activities were largely unchanged from last year’s IQP. Electrify the base was primarily the same, the previous conductivity test circuits were replaced with LED circuits, some of the materials in the kit like Christmas lights weren’t used and the activity was condensed into two stations from the original four. In addition the friction activity was a newly devised activity to supplement the friction chapter. All these activity kits are assembled and are ready to be used by subsequent IQP groups or interested teachers.

The activities were well received by Mr. Mahoney’s class; many of the students were very interested in the contents of the kits like the light bulb demo circuit and found the activities interesting and fun as well. Students helped each other answer the questions asked by the team members. Students were inquisitive and they asked wonderful questions when the team was performing the activities. All these interactive conversations between students and the team member and the observations made by the team are found in the “classroom observation” section following each of the activities. We hope the

Elm Park principal and teachers will read these classroom observation sections and find the recommendations informative.

The pre/post-tests hypothesis test analysis conducted after the "Electrify the Base" activity indicates that there was a statistically significant improvement in the student's comprehension of the subject. The pre-test answers had an average of 1.76 questions answered correctly, out of 5, only slightly higher than the average of 1.25 correct answers that would be expected had the students been guessing completely at random. After the activity was completed and the students were given the post-test, the average jumped to 2.77, indicating that the students had indeed learned the material covering conductors/insulators and circuitry.

The team had a chance to judge the science fair by Mr. Mahoney's class and noticed that most of the projects except sink or float have write-ups and figures on display, which were up to the expectation for 5th grade students. The students knew the procedures of their projects; however, most of them did not understand the concepts and science behind their projects. A majority of the students received their project ideas and information from either their parents or the Internet. None of the students used the textbook as a resource for their projects.

10. Suggestions:

- More time for each activity or divide the electricity chapter into the separate topics of circuitry and conductors and insulators.
- Current kit equipment requires minor alterations to improve durability and ease of handling.
- Organization of materials in the kit would allow for easier storage and use.
- Producing a written procedure for the activities would allow for more uniform instruction as well as improved time management.
- In the crater activity, we recommend to add a magnet for each tub to pull the ball bearing out of the flour (avoids having the students fingers altering the crater shape and helps keep their hands clean).
- In the Phases of the Moon activity, we suggest future teams to bring a good source of light. The classroom we attended had no good source of light. Both LCD and the projector in the classroom could not give enough light for the activity.
- The classroom we perform the activity in had no curtains and we could not produce an adequate dark environment for the activity. We recommend Elm Park School to keep curtains in each classroom so that they can be used when needed.

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12. Appendix:

Figure A: Pre/Post test of activity 1, phases of the moon

Fifth Grade Pre/Post Test — Worcester Polytechnic Institute IQP

Earth, Moon, and Beyond

Name: .... Date:...........................

1. Arrange following in the correct order

New Moon, Waning Phase, Waxing phase, Full Moon,

1 ....

2. ....

3 ....

4. ....

2. Match the following

1. Moon — occurs when the moon passes in between the sun and the earth.
2. Rotation — is any natural celestial body that revolves around a planet.
3. Solar eclipse — is the bending of light as it passes from one substance to another.
4. Refraction — is a process of the Earth turning on its axis.

3. True or False

a. The moon produces like the sun. (True / False)

b. Half moon is one of the phases of the moon. (True/False)

4. Approximately how often do the phases of the moon repeat?

a. Every 48 days

b. Every 12 days

c. Every 29.5 days

d. Every 15 days

Figure B: Elm Park 5th grade science fair score sheet guideline

Judging Guidelines

The judging process will focus on what the student has learned about his or her chosen project and the process used in completing the project. In addition the project will be judged on the basis of the student's ability to discuss intelligently the overall scope and significant results of his or her work. Judging criteria for team and individual projects are identical.

1. Scientific Approach (25 points)

   A. Did the student start with a clearly stated hypothesis, purpose, or statement of an engineering goal?

   B. Was the student orderly and logical with the setup and follow through of the project?

   C. Were the student's conclusions consistent with the data he or she collected?

2. Knowledge of Project Area (20 points)

   A. How effectively did the student conduct preliminary research?

   B. Is the explanation of the project clear and precise?

   C. What was the extent of the student's knowledge of materials related to the project?

   D. Is the student aware of both the scope and limitations of the project?

3. Thoroughness (20 points)

   A. Is there evidence that the student used multiple sources in the literature search?

   B. Has thorough use been made of data and observations?

   C. How successfully has the original plan been followed through to completion?

   D. Was there complexity to any aspect of the project?

4. Written Records and Reports (15 points)

   A. Has the student kept an original day-by-day notebook with all plans, procedures, observations, and conclusions for failures as well as successes?

   B. Has the student put together an accurate written report, complete with a bibliography?

5. Ingenuity and Creativity (15 points)

   A. Did the student show originality of thought, design or implementation of the experiment?

   B. How well has the student used his or her materials in the solution of problems?

   C. Does the student present any new or unique ideas or interpretation of the data?

6. Visual Presentation (5 points)

   A. Is the project displayed in a logical and organized manner?

   B. Have charts and graphs used where needed?

   C. Did the display and posters effectively convey the message in an understandable manner?

Figure C: Pre/Post test of Activity 2, electricity

True or False (Circle the correct answer.)

1. Solar energy a good option to power things on the moon?

True False

2. A conductor blocks the flow of electricity.

True False

Multiple Choice

3. Which one of these is an insulator?
a. Copper
b. Aluminum
c. Iron
d. Glass

4. A series circuit is a circuit in which:
a. Current flows in multiple paths.
b. Current flows in one path
c. Current does not flow.
d. None of the above.

Look at the the parallel circuit on the right.

5. What will happen to Bulb B if Bulb A is unscrewed while the lights are turned on?
a. Bulb B will go out.
b. Bulb B will stay lit.
c. Bulb B will become dimmer.

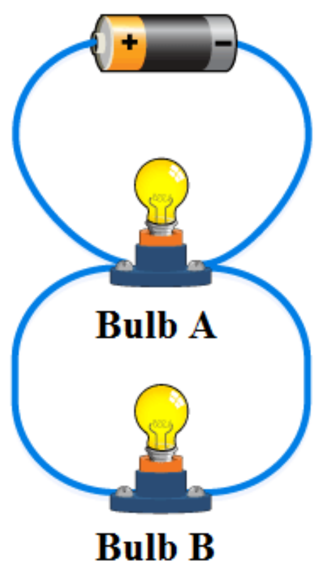

Figure D: Pre/Post test of Activity 3, the moon and craters

Fifth Grade Pre/Post Test   Worcester Polytechnic Institute IQP

The Moon and Craters

Name: ______________________

Date: ______________________

1. **Why is the Moon covered in more craters than the Earth? (chose one)**
   a. Because the Earth is covered in water
   b. Because the atmosphere burns up most of the objects from space
   c. Because the Moon is smaller
   d. It isn't, the Earth has more craters than the moon

2. **If an object hits the Moon at an angle, what would the shape of the crater be? (chose one)**
   a. Circle
   b. Triangle
   c. Tear-shaped
   d. Star-shaped

3. **Arrange the following objects in order based on the size of the crater they would create from largest to smallest.**

   Golf Ball, Bowling Ball, Balloon, and Soccer Ball

   1. ______________________________
   2. ______________________________
   3. ______________________________
   4. ______________________________

4. **True or False**
   a. Marks like craters and foot prints last longer on the Earth than on the Moon. (True / False)
   b. Faster moving objects will create deeper craters than slower moving objects. (True / False)

Figure E: Field Trip Schedule

Fifth Grade Field Trip to the Moon at WPI Schedule –4/ 11 /14

An event to be held at Riley Commons under the Riley Dorm

	Mahoney	Ford	Holt
9:00-9:30	*The Lunar Base*	*Design Review*	*For all 3 Groups*
9:30-10:10	Light the Greenhouse	Mars Base built using Robots/3D Printers	Campus tour & *Moonraker*
10:10-10:50	Mars Base built using Robots/3D Printers	Campus tour & *Moonraker*	Light the Greenhouse
10:50-11:30	Campus Tour & *Moonraker*	Light the Greenhouse	Mars Base built using Robots/3D Printers
11:30-Noon	*Bag Lunches*	*and*	*Tesla Coil Demo*
Noon-12:35	Shackleton Crater	Water and Energy	Design Expedition/LEGOS
12:35-1:10	Water and Energy	Design Expedition/LEGOS	Electrify the Base
1:10-1:50	Design Expedition/LEGOS	Electrify the Base	Water and Energy

Lead Presenter or activity manager

Design Review –Wilkes

Robots/3D- Ciaraldi (Moonraker), Ryan and MacKenzie–(Mars Exhibit Robot) et al.

Light- Beal

Campus tour- Krach and Tour Guides from Admissions

Tesla Coil- Beal

Shackleton Crater – Ramirez, Kalden, Sonam, Ueda

Electrify the Base - Ramirez, Kalden, Sonam, Ueda

Design Expedition/LEGOS- Picchione

Water and Energy-Wilkes