# Grade 5 Space Enhanced Science Education

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## Contents

## Authorship

Taymon Beal wrote the text of the “Special Activities” section.

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This report is based on the work done by the team of Taymon Beal, Zackary Couture, Amber Desjardin, and Elise Mariolis.

## Acknowledgement

We would like to thank everyone at Elm Park Community School and each advisor that has helped this project over the past few years. The 5th and 6th grade science is getting better each year, and it wouldn't be possible without their willingness to depart from the standard curriculum and experiment with thematically integrated hand's on science education. They truly know what they want, and that is a school that offers a consciousness raising experience in science as the fun subject and gets 10-11 year olds dreaming about technical careers and a better future as a possibility through the mastery of math and science. Yes, there is also a state exam, and the students need to learn specified concepts, and the staff is there to help them over this hurdle every step of the way, but it goes so far beyond that. The team effort of English and Science teachers to do the Space Oriented Essay contest this year was a labor of love leading to brilliant success at the 6th grade level, and a success at the 5th grade level as well.

We would also like to acknowledge the contributions of Martha Cyr and Shari Weaver from the WPI STEM Education Center, of Reach for the Stars volunteers Mark Lerret and Kerrin Beovich, and, of course, of our advisor, Dr. John Wilkes, without whom none of this would exist.

## Abstract

The goal of the overall project was to elaborate moon based themes to augment the required 5th grade science curriculum as defined by the Harcourt School Publishers science text. Our team enhanced previous 5th grade team of Rodgers, Lu and Hilario projects with more, better (or in one case less messy) activities and piloted an essay contest conceived of by the prior team, but which they could not get approved and executed. We also worked toward creating a service club of WPI students to help teachers institute hands on education in 5th grade classrooms and started the process of planning a 5th grade field trip to WPI.

The central project goal is to produce well documented kits for the classroom that contain materials necessary to have group activities and hands-on demonstrations in class for 6 text chapters, solar system, matter, energy, electricity, light and sound, forces, and possibly a plan for a 7th on motion. These activities happen on a bi-weekly basis (since 2 classes experience them as part of reading and mastering a text chapter) and in the future are to be run by volunteers and the teacher as necessary. This paper outlines the near complete project including most activities that were run in class, the field trip to WPI, and the essay contest, stressing the 6th grade essay contest on Mars Rovers, since Amber was a judge in that activity. Taymon was a 5th grade essay contest judge. The rest of the team did not read the essays, but the students they worked with read about the search for water on the moon as part of the essay contest.

At the end of this project, 5th grade students should be able to understand and apply basic science ideas from those chapters based on the activities we took into their classroom. In addition, they should see science as the fun course with amazing implications for the future

since all their activities had a lunar theme based on solving the problems associated with living and working on the moon using what they learned each week.

## Introduction

As in the previous reports, this project is geared towards 5th graders because of their age. By the time they are astronaut age, these 10 year olds will be the generation in charge of designing and building a second generation base on the moon, which is expected to happen 40-60 years from now. This base would allow for people to live on the moon and it would be largely self-sufficient. At the least it would be able to feed itself and pay for itself. This is a big task, but it lies in the hands of our current 5th graders. Some parts of the task have already been completed, while others still have more work required before it can be a reality.

Our team worked with the New England chapter of the AIAA as a sponsor, which is a professional organization very interested in students and helping schools improve science education. Their budget is about $5000/ year in all yet they put $1200 of it in our hands for a field trip and class enhancements. They allotted us $50 to enhance each chapter kit, money for a field trip, and money to run the essay contest. Half of that, $600, was for a field trip, but we did not have to spend that much as we just had the students walk over to WPI with their own lunches for a day of activities. The other half we spent about equally on the essay contest and the activity kit materials.

The last team developed activities for the chapters on the Solar System, Matter, Energy, Electricity, Light, and Forces. However, the teacher's reviews of Energy and Friction were negative. He also made it clear that Buoyancy and Gravity were mediocre at best. The students didn't even learn all of the concepts necessary when it came to Light. The chapter on motion was also skipped the previous year. Another misfortune was the failed attempt to start an essay contest and a service club to identify WPI student volunteers to help the teachers do special activities and small group activities in the classroom.

# Background

## Last Year's Report

This project continues on what previous projects began, but expanded on key elements. The goal of the past few years has been to increase the student's interest in science and technology, and give them the confidence, experience, and knowledge they need. This will allow them to the opportunity to solve problems and design things to one day should they decide to go into the science and engineering fields. The overall goal was scientific literacy for the whole class, but also to encourage the budding technologists and scientists by giving them a taste of design and application activities. The previous team went into the classroom of Fran Mahoney on a weekly basis because the science teacher had the same students for a week, then a different class the next. Our team had the challenge of a new schedule. Students now have science every other day, so this required us to be in the classroom twice a week, at least every other week, and sometimes more often. Also different team members were free at the time of the 5th grade science class on a Wed and a Thursday due to scheduling considerations.

The previous team created kits based on a lunar base theme applying the concepts in a chapter of the book. However, they were selective, not covering all the concepts. We tried harder to try to incorporate all of the key words and principles covered even if it meant moving some to another activity. For example, we covered buoyancy and gravity well before the chapter on forces. That gave us time to do their excellent unit on magnetism justice and figure out how to do friction far better. The students needed an effective grasp of all the concepts on which they would be tested and they would remember those they used and applied best. Hence, we ended up creating a second solar system activity kit after the one they did on craters, since the text stressed how the moon looks for Earth, and the phases on the moon that did not interest the prior team. They were setting up to put a lunar base in a specific crater on the moon- and introduced it in their activity.

These activity kits and tied into a lunar base theme to both keep the students interested in what they were learning and so that the separate ideas came together around a common set of problems. The space theme also secured the support of the AIAA as a sponsor for special activities. In combination one gets a lively and engaging ("funner" as the 5th graders said in their thank you letters) hands-on way to experience science in a problems solving applied environment.

Two years ago, in 2011, an essay contest was proposed and run at Elm Park school, but there were very few entries (12) from the 120 5th and 6th grade students at Elm Park because the teachers felt the reading level of the school wasn't up to grade level and the reading (a chapter by Fred Bortz on the search for water on the moon) was too challenging for most students. This was a big disappointment to all involved, but a goal was established for the next year because of it. The proposal was ambitious, to scale up the event to cover 8 schools in Worcester, and it arrived in December, late in the year. The administration saw it as clashing with their plans for a science fair. Elm Park considered doing it anyway, but then decided to do a 5th grade science fair instead.

Since that effort went poorly, Elm Park Principal Paula Proctor reversed her decision when we re-proposed the Essay contest event for this year. All 5th and 6th grade students were required to try, the English teacher would take the lead supported by the science teacher and only the 6th grade would enter the Science Fair if the teacher decided she wanted to do both activities. (She did, and wanted a $600 field trip to Tower Hill Botanical Garden for her 60 students.) However, it was going to be a stretch given all the level 3 vocabulary words in the reading and the science teacher was called on to help prepare them for the challenge. We were also told we had to do it in November at the latest, before state testing began in the second semester. The 6th graders, veterans of the 5th grade lunar unit last year, surprised their teachers with how far they stretched and what they produced when discussing Mars Rovers. The 5th graders saw the close connection between what they were reading about in English and studying in science class.

The book that the students were to read for the contest has become an experiment over the past few years and is made possible by the author, Dr. Fred Bortz. He made a presentation at Elm Park in Jan of 2011, and furthered the student's excitement of learning. Since that talk was video recorded we were in a position to reuse it for a royalty of $100 as part of the Essay contest awards ceremony. Lunar themed field trips have also been arranged the past ( 2011) related to what was being taught in the classroom and were a success once implemented. We recre4ated a similar event on a smaller scale for our class of 5th graders.

One thing that last year's team didn't accomplish was good documentation of the use or makeup of the kits. Documentation will have to be excellent at the level of goals and procedures when the activity kits are in the hands of a volunteer club instead of an IQP team putting a lot of time into developing suitable activities. This was touched upon in this year's project so that the kits can continue and the new club, "Reach for the Stars" can pick up where the IQP teams over the years have left off. The drill seems to be one team to prove the theme, one to develop specific activities for each chapter, one to refine and embellish the promising activities and develop new activities to cover lapses and then final team ( next year) will assess and if it is worthy, disseminate the curriculum materials to other schools via workshops. After that there is no case for an IQP team to work in the classroom, though hopefully the kind of science teaching that was done with the theme and kits will continue. The purpose of the club is to improve the odds of that happening. Iif the club can provide assistants on the days a teacher wants to do special activities, there is a good chance the change will be sustainable.

The major mission for this year was to make improvements in the curriculum linked activities, which got good reviews the prior year and showed promise from the year before. Was It was easy to use and comfortable for the teacher, given their teaching style? If this was not the case it would not be used in the future. Hence, everything started with the review of each unit by the teacher. Mahoney considered three activity unit to have been unsuccessful, meaning Mr. Mahoney would not use them in the future for some reason. These were the energy section which got excellent reviews form students and the prior group, but the teacher thought to be messy and potentially dangerous. The friction section he considered to be a failure compared to what the prior group had done with water, plastic bags and pencils. In their defense, the second team had made a lunar base contention and the activity he liked did not do so.

Mahoney also noted that in the matter section there was too much last minute improvising, and the students lost sight of the main concepts trying to be conveyed. Specifically, they were supposed to make a mold using play dough and pour in wax to mimic metal formation into tools. However, in the classroom at the last minute one does not have hammer heads, pliers, chisels and other hardware. Hence students had copied everything from scissors to pencils and plastic calculators and sort of missed the analogy to metalworking. The wax also did not cool fast enough. They did not have ice water to speed things up or instruction to keep the mold level and roller to enforce that so that the wax would not dribble out the low end. The unit was promising but didn't nail all the concepts to be covered or consistently make its point. Thus, this unit could be tweaked a bit to improve its overall effectiveness. The prior team never got to thinking about a motion activity and thus never came up with any ideas for us to consider, good, bad or indifferent.

Mr. Mahoney did however give strong reviews to the units on craters ( an improved version of what was in the text) , light, and particularly the magnetism activity out of the forces unit. His concern was that the forces unit took two and half days in all. In terms of the electricity unit, he liked it but not comfortable with running it on his own. He would dedicate class time for WPI students to run but not run by himself using the lunar base theme. He would just fall back to a simple demo of series and parallel circuitry. Electricity had to be reworked to streamline core concepts if the lunar base connection was to stay in a sustainable way. He was most concerned with conveying the distinction between serious and parallel wiring but liked the idea of making batteries and telegraph keys. The problem was partly that the electricity equipment used by the prior team was flaky kits with missing parts that could be made to do things like conductivity testing, but we wanted lights and sounds and stuff to happen when a circuit was made, not just an electromagnet to make a telegraph key go click.

We didn't feel that the previous team reported their information that well and some activities were difficult to recreate. In some cases had our advisor not been there or we had not had access to Jonathan Rodgers, we could not have recreated even the highly successful magnetism unit. It seems that the report was rushed since Hilario was a senior and to graduate had an early deadline to meet. In conclusion more than half units needed reworking. Our team ended up elaborating on pretty much every activity that was previously designed. This included modifying the apparatuses or activities for every unit and we created an entirely new unit on the phases of the moon. The Galveston flood activity was completely re-envisioned and is now something quite special.

## 5th Grade Key Words from Text Book

The following key words and concepts are taken from the 5th grade text, by Le Yu to compensate for the fact that the students could not take their texts home. He wanted them to be able to study for the MCAS and be exposed to the things not covered in the demos and activities done by the team in class. The lunar theme made it difficult to teach all of the concepts. The following is what the previous team used to be sure that their kits and activities covered the necessary concepts from the text, but in a more engaging manner. It is split into chapters and covers most of the important material that 5th graders will see on the science portion of the MCAS but is just a list highlighted by the text itself. The lunar base was tied to these key concepts to the best of the team's ability. Last year had a few holes and some of the connections were improved this year. Our job was to assess, enhance, and fix some problems noted by the teacher and ourselves.

**Chapter 13: Earth, Moon, and Beyond**

Lesson 1:

**Sun**: The star at the center of our solar system

**Rotate**: To spin on an axis

**Axis**: An imaginary line that passes through Earth's center and its North and South Poles

**Revolve**: To travel in a closed path

**Orbit**: The path one body takes in space as it revolves around another

**Equator**: An imaginary line around Earth equally distant from the North and South Poles

Lesson 2:

**Moon**: Any natural body that revolves around a planet

**Crater**: A low, bowl---shaped area on the surface of a planet or moon

**Moon phase**: One of the shapes the moon seems to have as it orbits Earth

**Eclipse**: An event that occurs when one object in space passes through the shadow of another object in space

**Refraction**: the bending of light as it moves from one material to another

Lesson 3:

**Star**: A huge ball of very hot gases in space

**Solar system**: A star and all the planets and other objects that revolves around it

**Universe**: everything that exists, including such things as stars, planets, gas, dust, and energy

**Galaxy**: A grouping of gas, dust, and many stars, plus any objects that orbit those stars

**Chapter 14: Properties of Matter**

Lesson 1

**Volume**: The amount of space an object takes up

**Atom**: The smallest particle that still behaves like the original matter it came from

**Molecule**: Two or more atoms joined together

**Nucleus**: A dense area in the center of an atom that contains protons and neutrons

**Element**: Matter made up of only one kind of atom

**Periodic table**: A chart that scientists use to organize the elements

Lesson 2

**Physical change**: A change in which the form of a substance changes, but the substance still has the same chemical makeup

**Density**: The measure of how closely packed an object's atoms are

**Mixture**: A combination of two or more different substances

**Solution**: A mixture in which all the parts are mixed evenly

Lesson 3

**Combustibility**: A measure of how easily a substance will burn

**Reactivity**: The ability of a substance to go through a chemical change

**Chapter 15: Energy**

Lesson 1

**Energy**: The ability to cause changes in matter

**Kinetic energy**: The energy of motion

**Potential energy**: The energy an object has because of its condition or position

Lesson 2

**Solar energy**: Energy that comes from the sun

**Light**: Radiation that we can see

**Chemical energy**: Energy that can be released by a chemical reaction

**Mechanical energy**: The combination of all the kinetic and potential energy that something has

**Electric energy**: Energy that comes from an electric current

Lesson 3

**Heat**: The transfer of thermal energy between objects with different temperatures

**System**: A group of separate elements that work together to accomplish something

**Conduction**: The transfer of heat from one object directly to another

**Convection**: The transfer of heat through the movement of a gas or a liquid

**Radiation**: The transfer of energy by means of waves that move through mater and pace

**Reflection**: The bouncing of heat or light off an object

Lesson 4

**Fossil**: The remains or traces of past life, found in sedimentary rock

**Resource**: Any material that can be used to satisfy a need

**Nonrenewable resource**: A resource that, once used, cannot be replaced in a reasonable amount of time

**Conservation**: The use of less of a resource to make the supply last longer

**Renewable resource**: A resource that can be replaced within a reasonable amount of time

**Pollution**: A waste product that harms living things and damages an ecosystem

**Chapter 16: Electricity**

Lesson 1

**Electricity**: A form of energy produced by moving electrons

**Electromagnet**: A magnet made by coiling a wire around a piece of iron and running electric current through the wire

Lesson 2

**Static electricity**: The buildup of charges on an object

**Electric current**: The flow of electrons

**Current electricity**: A kind of kinetic energy that flows as an electric current

**Conductor**: A material that carries electricity well

**Insulator**: A material that does not conduct electricity well

Lesson 3

**Electric circuit**: The path an electric current follows

**Series circuit**: An electric circuit in which the current has only on path to follow

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

## Chapter 17: Sound and Light

Lesson 1

**Vibration**: A back---and---forth movement of matter

**Volume**: the loudness of a sound

**Pitch**: How high or low a sound is

**Frequency**: the number of vibration per second

Lesson 2

**Reflection**: The bouncing of heat or light off an object

**Opaque**: Not allowing light to pass through

**Translucent**: Allowing only some light to pass through

**Refraction**: The bending of light as it moves from one material to another

**Concave lens**: A lens that is thicker at the edges than it is at the center

**Convex lens**: A lens that is thicker at the center than it is at the edges

## Chapter 18: Forces

Lesson 1

**Force**: A push or pull that causes an object to move, stop, or change direction

**Friction**: A force that opposes motion

**Gravity**: The force of attraction between objects

**Gravitational force**: The pull of all objects in the universe on one another

**Magnetic**: Having the property of attracting iron objects

**Magnetic force**: The force produced by a magnet

Lesson 2

**Balanced forces**: Forces that act on an object but cancel out each other

**Unbalanced forces**: Forces that act on an object and don't cancel out each other; unbalanced forces cause a change in motion

**Net force**: The combination of all the forces acting on an object

**Buoyant force**: The upward force exerted on an object by water Lesson 3

**Work**: The use of a force to move an object through a distance

**Simple machine**: A device that makes a task easier by changing the size or direction of a force or the distance over which the force acts

**Lever**: A bar that makes it easier to move things

**Fulcrum**: The balance point on a lever that supports the arm but does not move

**Wheel---and---axle**: A wheel with a rod, or axle, in the center

**Pulley**: A wheel with a rope that lets you change the direction in which you move an object

**Inclined plane**: A ramp or another sloping surface

**Chapter 19: Motion**

Lesson 1

**Position**: The location of an object in space

**Speed**: The distance an object travels in a certain amount of time

**Velocity**: A measure of an object's speed in a particular direction

**Acceleration**: The rate at which velocity changes

Lesson 2

**Inertia**: The property of matter that keeps it at rest or moving in a straight line

## Kit Development

Kit development was a major priority during the course of this project. We found that to really have an effective lesson and activity experience for the kids, the right materials were needed usually multiple sets of them for small group work or stations for groups to visit. The materials that have aided the space enhanced projects in the past have been a very important aspect to the project, but the development of robust 5th grader proof kits was not a priority to the team that was prototyping.

With the focus of our team making the space enhanced education project a sustainable project, the development of functional kits became an important aspect of that goal. To have robust fully functional, sustainable kits to go alongside with the 5th grade curriculum was a major goal for our team. The focus was not only making the kits fully functional but to also document them enough to make them accessible and easy to use by anyone with a basic science background. The problem again and again was the lunar base scenario was unfamiliar to each new group entering the project and it took time to get up to speed, unless the details were worked out and you could look at the activity sheets the students were to use as well as get an overview.

To clarify, there were kits developed by past 5th grade teams. We found these kits to be all inclusive but they would reuse some things and so it was not like there was one kit for one chapter. It was more there were 4-5 totes and things were put where they fit or were last used. There was almost no distinction between materials by chapter, and not labels. It was hard to figure out which activity they really belonged to unless you had both the text and the report. Even them there were puzzles. This made the use of these kits difficult and time consuming before the actual activity could be carried out. This became a motivation for our team to put more emphasis on these kits and make them functional. In practice we made them more robust but it became harder to cross use things like the ramps which were part of both the crater and energy units.

The job of making these kits fully functional was the main focus of my (Zack's) project experience. It was my goal to not only make these kits robust, functional and sustainable but to also create and enhance the previous materials of the past. This included purchasing materials that needed to be replaced or gathering new materials that benefited the activities.

As the person in charge of the kits and there development, it was also my job to improve on the materials used in the past. One of the major improvements of the past materials was improving the ramps use for the energy activity. These ramps consisted of wooden stands with vinyl tracks that rested against them to form a functional ramp. What we received was aluminum pans that were cut to form a V to hold one end and thus the ramps were barely stable enough to hook onto the stands. My team wanted sturdy plastic containers with tops to hold the flour. They could not be cut.  I wanted to deliver the “asteroids” from above and at the right angle.  A very different point of attachment would be needed if the stands were to be retained.

The problem with these ramps reported to us was that they were unstable and fell apart quite easily due to the point of connection between the stand and the ramp. This required the students to hold the ramps together while they used them. This was not an ideal solution because it made the students focus more on the ramps than the outcome of the experiment.

They also did not hold the top of the ramp steady and thus the bottom was moving in an arc as the ball bearing was delivered to make an impact crater.  That situation made the pattern in the flour hard to measure and interpret. The average ruler was also too long to fit into the flour container.

To correct the situation, there were several steps that were taking to improve the ramps and make them independently functional. The first step was to make a better connection between the ramp and the stand. This was achieved by making a mold out of polymer clay. The polymer clay mold was designed to not only provide a strong connection between the stand and ramp but to also make it function on its own. The molds were also designed to represent different angles. This was achieved by molding the polymer clay so that when the connection was made between the ramp and stand it would create the desired angle needed for the experiment.

After the polymer clay was molded to fit each individual ramp, and then the molds were baked for 45 minutes. The baking processed hardened the molds and made them permanent. After the molds were created then they were glued to the ramps. The benefit of this was that the ramp and stand were not permanently connected so that when it came time to storage, they could be easily separated.

The emphasis was put into the development of these ramps because they were used for not only enhancing the crater activity, but also to be used in the demonstration part of the energy activity. This provides the kits with fully functional ramps that could be utilized for the activities we had intended for them but also for whatever experiment called for functional ramps.

Another important aspect of being in charge of kit development was going through all the materials need before going into the classroom. This would include purchasing materials needed, designing a new aspect to the activity to improve it, delivering materials to the classroom, and setting up the activities.

Another modification to the kits was the addition of the magnetism unit. The state of the unit from last year in terms of images used and activities was not very clear. To make the magnetism unit successful, there was a lot of retooling in order.

The first step was to come up with all of the images needed to convey the core concepts of the magnetism unit. This included: Earth shown as a magnet, a bar magnet with iron fillings surrounding it to show the magnetic field, an image of Earth's magnetosphere during solar wind, and a junk yard magnet, to convey the idea that electromagnets can be turned off.

After the recovery of the necessary images needed, then it was on to improve upon the actual activities from last year. From weak documentation of the magnetism unit, the only activity really discussed was magnetizing iron based objects. This included connecting a magnet to a bolt and then picking up paper clips to show how the magnetic field is transferred.

My focus was to expand upon this idea and add some new apparatuses into the activity to make it more hands on learning experience. The first apparatus was a rather simple but effective one. It was a setup of a glass jar filled with water and paperclips. The idea here was that when you placed the magnet against the glass the magnetic field goes through it and grabs hold of the paper clips. This showed the students that magnetic fields can transfer through materials and still control the paper clips.

The other apparatus developed was again simple to construct but very effective. The setup included two magnets and a chain of paper clips. The way the apparatus worked was by connecting one end of the paper clip chain to one of the magnets. Then the other side of the paper clip chain is strained by the other magnet so it forms a straight line. To make this part effective hold the second magnet slightly above the end of the paper clip to make the chain dance around. The idea being conveyed here is that it's the magnetic field that attracts iron materials not the actual magnet.

These new additions to the magnetism unit proved to be very effective and enjoyed by the students. They conveyed the concepts in a visual and hands on way so that the students could really understand them. Developing the magnetism unit was just one of the many aspects to kit development.

Also in terms of the friction unit, there is an ongoing development for an apparatus that would show how different surfaces affect the friction of a moving object, for instance pushing a box across a carpet instead of an ice track.  The apparatus would consist of a cube with different surfaces on each side. The cube would then be pulled across a track so that the students could feel first- hand the effects of friction. The apparatus is still in the prototype stage and has not been completed.

Another important aspect to kit development was to not only provide materials for the activities but to also create new activities. The creation of new activities or the enhancement of previous activities was carries out by Amber, Elise and I, each one of us at some point during the project provided new ideas on how to make an activity better or just flat out make a whole new activity all together. To perform this task took a lot of brainstorming and also the production of new materials and apparatuses. This required the development of completely new kits and also the addition to previous ones.

I found the development of the kits and materials used for the classroom activities, to be a vital part of my project experience. The development of these kits will provide future teams with functional kits. It will also, hopefully in the future provide 5$^{th}$ grade teachers with activities that not only drive home the concepts of the chapters there teaching but also to provide a hands on learning experience.

The future of the kits and were they are stored really depends on a couple of things. The first being the most important, which is the development and recognition of the “Reach for the Stars Club”. If and when the club is approved they will be given control of the kits and ultimately decide where they will store the kits and proceed with a curriculum guide that accompanies them.

Another possible storage site is at Elm Park School. The problem with storage at the school is that they would be set in a storage closet that anyone in the school could have access to these kits. This in theory is not a bad idea but again it falls to whether the club decides to develop a curriculum guide so that the kits can be properly used along-side a working curriculum. The storage at Elm Park also becomes problematic because then the kits would not be in control of the club and would not be readily available to them. This would pose a problem for the club to carry out these activities with other schools or at different club events.

Our recommendations for the future of the kits are to be handled by the club. This would allow the activities to be carried out by club members and also give them the ability to train teachers or other students on how to carry out these activities. This would promote their proper use and improve the effectiveness on the overall concept being portrayed by the activities. The kits being placed into the hands of the club would also allow the activities to be used in another field trip to WPI for the Elm park students. These activities could be used to aid in the development of different activity stations for the students to partake in.

Again I feel that the development of functional kits was an important part of this project. It encourages the sustainability of the curriculum and it also provides solid hands on learning experience for the students. I encourage to the club or other future IQP groups to continue the development of the kits and enhance them whenever possible to further the education of the 5$^{th}$ grade students. in the end if just a couple of students are inspired to be more involved in science because of the hands on activities provided by the kits, then the development is a success.

# Classroom Activities

## Where do Craters come from?

**Materials List:**

- Flour (2 lbs.)
- Tupperware containers(5)
- Angled Ramps (4)
- Marbles (5)
- Playdough
- Black Sand (optional)
- Handout

**Method:**

This activity is part of Chapter 13, The Earth, Moon, and Beyond. It covered most of the concepts in the book, and the rest were covered or repeated in later activities. This was one of the first lunar themed activities to be done at the school, but not the first time the team met the teacher and the students since there was a prior unit on Buoyancy built around the Galveston "flood" which was actually a storm surge that engulfed the island. In retrospect, a meeting with the teacher and observation of the classroom is recommended before entering the school for the first time. The goal of this activity was to ascertain the angle of the asteroid impact that created Shackleton crater at the South Pole of the moon. The class was split up into 5 groups with about 7 minutes at each station to get the crucial information that they needed.

Preparation involves modeling the geologic layers of the moon as described by Marianne Dyson in her book Home on the Moon: Living on the Space Frontier. In effect, we approximated deep bedrock with play dough the original lunar surface with flour and the dark basalt volcanic layer on top with a dark sandy soil. The asteroids punch through the dark surface layer and expose the whitish layer below- but also pulverize the rock as the asteroid so that the regolith layer on top is about 3-10 meters deep of “sand”. You want a powdered surface, but it would really not be that deep. On the other hand at 50,000 mph impact speeds it does not matter if it was powder or rock before, it is powder after.

So, in metal pans is a 0.5 inch deep layer of playdough that is rolled flat and covered in flour. A thin layer of the darker powder is spread over the top of that for the first trial, but that will not be renewed for each run of impact. Most trials will be into a flattened layer of flour 2-3 inches deep. A large shooter sized marble is at each station along with a ramp on a stand that delivers it to 0.25 inches above the flour surface arriving at a specified angle measured in degrees.

The students were first required to use a protractor to measure the angle they were working with. They are labeled, but they should double check to reinforce math skills and know how to find out if it was not marked. The next step is to set the marble at the top of the ramp, and let it roll off the end of the ramp into the flour at the prescribed angle of impact—so you can’t let it fall off so high that the angle would change much before impact. If they had the 90 degree angle, there was no ramp. The student simply dropped the marble into the pan from a given height and measured the depth, width and length of the impact “crater” noting if one side is higher than the others, as is the case for Shackleton crater. It is best to use rulers that are short and have no extra wood or plastic on the edge where the first unit starts. You do not want the student digging into the flour to get to make their measurements, as that will skew the results. They then filled out a worksheet with measurements including the angle, length, depth, and width of the crater created, calculated length and width ratio, and noted how elongated the crater looked overall as well as the relative heights of the side walls. The overall look is one of the most important pieces of information for figuring out what happened at Shackleton. The students need to be very descriptive to be able to solve the problem they are to be given.

Once everything (3 trials) for a ramp was completed, the volunteers would move the ramp to the following station so the students weren't required to move around but could get data on each of the angles. An example of the handout for data recording can be found in the appendix.

This was a very successful activity for the students, as it combined math on angles and science, which is something that one of the team members thought very crucial. The students enjoyed seeing the flour fly and splash and what happens when the marble is dropped in the flour, and it truly made learning fun as well as messy. There was as much concern about everyone getting a turn to release a marble as there was about measurement. Set up a system and make sure you know who's "turn" it is to release, record, measure, and smooth the flour.

**Background:**

This activity was to get the students to move from the emphasis on volcanic activity and water as having shaped the Earth's surface to thinking about asteroid impacts as the dominant force shaping the moon. The black layer gives you a chance to talk about volcanic activity on the moon- but it leaves sheets of basalt rather than mountains behind. They should note that there were asteroid craters on Earth and they had important implications for life on Earth. We later found pictures of several nice craters on Earth with the best being in Arizona. Even though they were located after the lesson, we did however make the point that there are impact craters on Earth even if the one we showed in class (Crater Lake) was not an example of one. The activity was inspired by a marble dropping activity that came from the book that involved using a ruler to vary only the height of release. But how many real craters were formed by asteroids arriving at a 90 degree angle? Further, asteroid speeds do not vary as much as their angle of impact or composition. Composition would be key to understand an impact on Earth as size and composition more than affects whether it will reach the Earth and produce a crater or blow up above the surface of the planet, or just burn up completely. However, on the moon there is no atmosphere so they are all going to hit, large or small and whether made of metal, stone or ice.

Hence, as we see it, we enhanced a very dull, boring and misleading activity and made it one that was designed to tell you something about a real lunar crater of interest- and about craters in general. . We would also return to this same crater many times in the next few chapters as we were going to explain why NASA felt it was the best place for a lunar base. The goal was to make this an activity that the teacher was committed to doing. The activity was improved for the class' benefit, but it came out of the text, was enhanced by Mariane Dyson's addition of the dark layer and our own ideas about angle of impact to explain the high and low side of Shackleton crater.

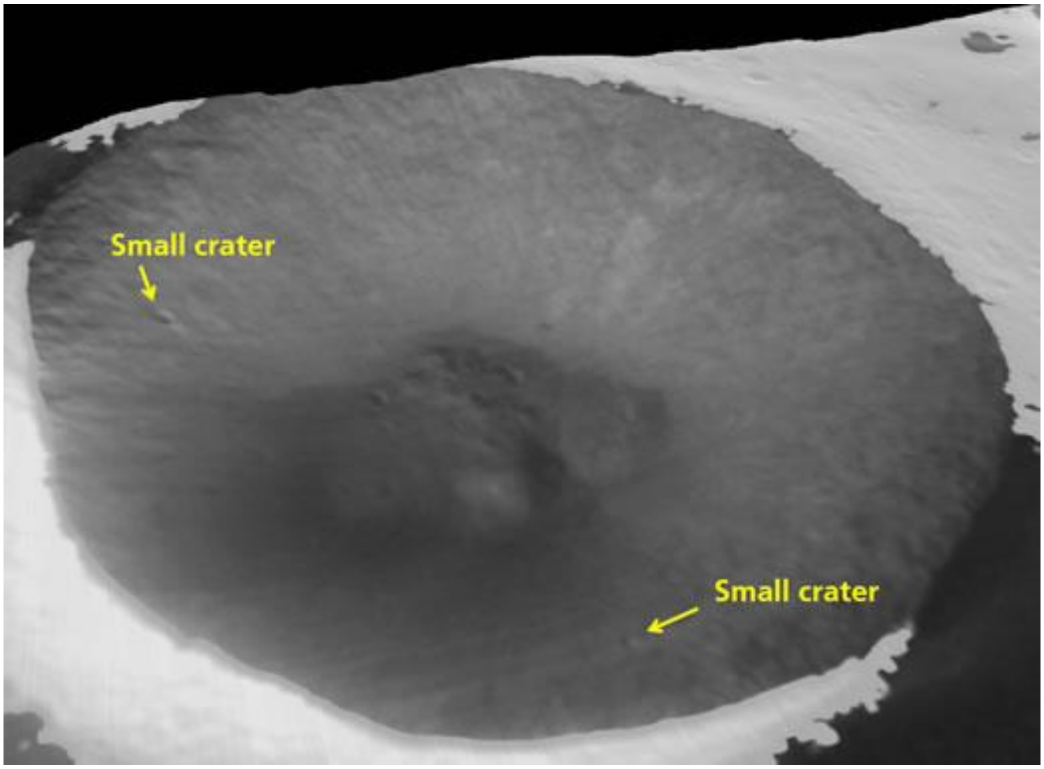
But to really do it right one should return to this question when talking about friction as a "force" and compare landing on Earth to landing on the moon, and the behavior of asteroids hitting each body as well. The fate of the Shuttle Columbia due to having lost a few of its heat shielding ceramic tiles is a case in point. Without protection, the aluminum alloy of the spacecraft structure beneath the shield reached the melting point upon reentry so that the wing fell off and the craft rolled. The side of the craft was without any protection and superheated and it just disintegrated in the sky over Texas while coming in for a landing in Florida. One could not have such an accident landing on the moon as heat shields are needed. This is clear from one look at the Apollo lunar lander called the LEM. You want to do this activity after having done the unit on matter in which we introduce melting point of metals ranging from aluminum to titanium.

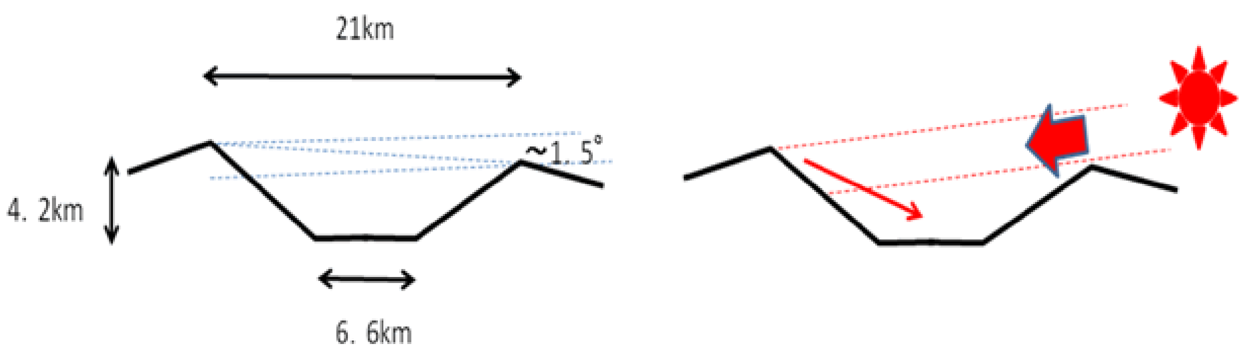
This activity simulates the surface of the moon. A marble that is dropped into the pan resembles an asteroid hitting the moon. Asteroids can hit at any angle, and the activity showed what a crater would look like from various angles. The goal was to estimate the angle of impact that formed a given crater, so it is important for them to see a picture of Shackleton crater at the beginning and the end of class, and explain from what angle an asteroid hit to create the crater. After each station is completed, the students go back into their teams and work out the reasoning for what angle an asteroid hit Shackleton crater to create it since it had one side higher than the other. Although few of the teams did a meticulous job of data gathering and recording, nearly all of the teams could figure out that the angle of impact was between 45 to 60 degrees by noticing the low side of the crater and which way the flour “splashed” since it generally got on the shirt of one of the students standing on the far side of the pan from where the ramp was. They were also surprised to see that it is the asteroid hitting slower and at a lower angle that make the biggest and longest, but not the deepest craters. They glance off the bedrock and plow a trench through the loose surface regolith. While a bit misleading since in the real case the asteroid would probably be going fast enough to pulverize the bedrock, the students really like seeing that unexpected affect, and it gets them thinking. Leave it in.

Below are the pictures that correspond to the activity and should be shown on a projector while the students are working. The first is of Shackleton crater and is an overall view. The second picture is a bit out of scale given the numbers shown, but it is published and not our work, yet it corresponds to the width and depth of the crater and shows angles. This picture is the defining measurement for how the students are going to solve the problem. Help should be given in the last few minutes of class as the teams discuss what angle they think was used, and their reasoning why. In the end, a volunteer should find out the answer from each team, then discuss the real answer and explain why each team was right or wrong.

A version of this activity by Marianne Dyson talks about the formation of the moon as a light colored bedrock coved by volcanic basaltic sheets of a darker color. Thus, an impact cut through the dark layer and exposed the original bedrock. This was important since it was the original bedrock that had most of the aluminum rather than iron on the moon. There were also rare and valuable things created by the impact heat and stress of the crater impact which she notes in her books. While this was too much to go into all at once, we could at least cover the flour with a dark layer of another powder as recommended by Dyson. Our team tried out the idea of using black sand in a trial run, but decided it was too much for us to handle this year since the flour is useless after being used one since the black sand mixes in with it and is no longer on the top.

The previous team had problems with the aluminum baking pans they used to hold the flour. The ramps were not firmly attached to the stands, which of course varied in height. They had to cut V's into the pans to hold the other end of the ramp in place to hold the unstable ramps. The pans didn't have covers so the playdough had to be rolled out right before the activity to prevent it from drying out. We decided to move to low sided plastic covered trays and could not cut into them. Hence, a team member took it on himself to totally redesign the ramp holders trying to make them kid proof and stand alone. This involved a lot of hardening clay. The redesign also took care of the students having to hold the ramp, and gave more accurate data. However, the cost was not being able to use the ramps for a later activity on energy where they all had to be set at 30 degrees. Store of the ramp holders and breakage became issues, so this system is not yet perfected. We are still improvising. What we need is a pan that holds the ramps in place and close to the surface of the flour and flanges on the high end of the ramp that hook into something on the stand.


Small crater
Small crater


21km
~1.5°
4.2km
6.6km

## Electricity

**Materials List:**

- Christmas Lights
- Flashlights
- Light bulb demo
- Batteries
- Forms of Metal
- Forms of Glass
- Small Light Bulbs
- Conductivity Apparatus
- Light and Battery demo
- Conductive Metals
- Handouts

**Method:**

Chapter 16 of the 5th grade student's text book covers electricity. The activities we developed leaned heavily on the work of the prior team cover the lessons from the text except for static electricity. However, the unit expanded by going over renewable resources and energy which is part of their Energy unit (chapter 1 and this topic was not developed at the time that the chapter activity was carried out, thus, a loose end is covered now. The materials for this activity are contained within the Electricity Kit.

For this activity, the students are split into four different groups by the teacher. There are four stations around the classroom for the groups to each spend about ten minutes each, based on the time frame given. Preparation and a basic knowledge of electricity is necessary before running these activities. The goal of this activity is to teach the concepts needed to be able to complete a homework assignment in which one is asked to rewire a lunar habitation unit which consists of a suite of four rooms using only local materials found on the moon. No copper, plastic or rubber is available, so it may not be used in the activity.

The first station contains Christmas lights, a three light bulb demo of series and parallel circuitry, flashlights, and a handout with the information that the students learn in the demonstration. The light bulb demo shows parallel and series circuit. It is very important to show the students that the electricity comes from the wall in two wires, not one as they will believe. The demonstrator shows how the light bulbs turn off and on and how well lit they are based on where in the circuit they are. They will learn the proper concepts to move onto the Christmas lights. They will think that when you unscrew a light bulb, that all of the lights will go out. This isn't the case because it is made of two wires, something they will realize from the previous demonstration with the light bulbs. Lastly, there are multiple flashlights, and two matching yellow ones that use matching large six volt batteries with both contacts on top. On the inside of one, there are wires connecting the battery, but the other simply has metal contacts. The students are asked how the electricity gets from the positive to the negative pole and pass through the bulb with no wires. An explanation may be necessary with this piece but most groups will figure it out. Next, two smaller flashlights using D cells with the poles on the opposite ends are compared; one having been taken apart, and one still intact. It is important that the students see the positive and negative poles in the different places as well as see the circuit design clearly of the light bulb demo. They should get the chance to put the batteries in backwards, and learn the hard way about things that also affect wiring design when they note how the device they assembled will not work. By comparing this to an identical system that works, they start to manipulate, experiment, and observe more closely until the satisfying moment that it works.

The next activity station the students will rotate to is one involving the various forms of metal and glass. Later they will find out that there is no copper or plastic on the moon to make normal wire so they will need to find other conductors and insulators to work with.  It is essential that the students can understand that they can make wire out of braided steel, and cover it with a textile or paper like glass. The idea is to stretch their concept of what metal and glass can look like.

This station will contain fiberglass insulation which is an insulator, filters that are paper like and patching material that looks like a textile as well as glass beads. All these silicon products are insulators. They will want to touch the glass that looks like cotton candy and that which looks like cloth, but it is very important that the students do not open the bag and touch it for fear of tiny scratches and skin irritation. Melting points and the fact that electricity gives off heat come to play in this activity since they will ultimately have to choose between aluminum, titanium, or steel for the conductor. In essence, a mini power plant needs to be created on the moon before people can get electricity. The posters will come into play for this part, as they show what proposed moon base will look like. This part of the activity shows pictures and examples for what the homework assignment is, which will be discussed in length at the end of class in the last ten minutes.

The third station consists of ways to generate electricity. They are told out right that we have to get a generator turning and normally do that by boiling water to get steam. Fossil fuels and wind, for example, is of course out of the question on the moon- but the students do not start out thinking of coals and oil as the remains of ancient plants and animals and just think of coal as another kind of rock you dig up. When they understand the concept, they will start to think of it as stored solar energy. Other sources like solar and nuclear are the promising sources of electricity to help the future moon base to be self-sufficient in terms of energy fuel imports. Using a small hand held parabolic mirror and test tube the students can see how concentrated solar energy could heat and boil water- even on Earth with only 70 degree sunlight. On the moon where surface temperatures can hit 212 degrees the potential is far greater.

Then we show the direct conversion of light into electricity-by photovoltaic means- in this case using a device that plays a song. In order to be sure they know the light is the power source, they note how much faster the music is as the light intensity increases- and we massively increase it with a hand held electric clear glass 100 watt bulb. By having the cells turn away from the light – though the light is still there, we mimic the impact of the moon's rotation. They see how the energy input declines to zero- a problem at the equator but not the poles of the moon where one can rotate the cells to stay in sync with the sun as it seems to go around you on a 28 day cycle. We note two ways to solve this problem of solar power loss at the equator. One, by putting the solar collector in orbit and beaming down the energy to the dark side of the moon, and the other, by using sunlight to charge a battery when the sun is out and using the stored power when the 14 earth day lunar night hits the equatorial region. Also to be mentioned is photovoltaic cells, - though it fascinated them- but fuel cells, and power satellites are new ideas and illustrations would be valuable.

This activity should turn into a debate that engages the students about the pros and cons of between each source, but you will have to explain nuclear to them as they associate atom energy with bombs rather than power plants- but the idea of fission is something 10% of them have down in very general terms. There are different ways to generate electricity, like steam, and these ways should be discussed by the students. They should learn by the end of this activity that the sun is actually a fusion reactor. Most students won't know this at first, so it is important to explain with enough detail that they distinguish fission and fusion, and know that you release energy both ways and most power plants on Earth are fission plants. Europe, the USA, and Japan (at least ITER project) , and probably Russia as well, are working on how to create the conditions that exist on the sun so that we can have fusion plants too- and it would be a very big deal if we succeed. The best source of the fusion reactor fuel used by the Sun is the moon. It is carried there by the solar wind and there is no atmosphere or magnetosphere to deflect it as there is on Earth. This activity also needs some research to be done before the activity occurs to make sure the key concepts are taught correctly. You will not cover everything in 10 minutes, but do go with the flow of student questions as you take them through a list of courses we use on earth and talk about each as it comes up.

The last station is about conductivity. A demonstration is to be given first to show what happens in the station. Students will be given pre-made set-ups that include a light bulb and will light up if the item they test is conductive. They are to go through the materials found in the lunar regolith, not including sodium or calcium. Ceramic tile, glass, aluminum, titanium, iron and steel should all be present but we missed on the iron, which is a frying pan currently in storage for the first group and got another one temporarily to use for the second group that is too big, but serves the purpose.  Since they have already done the matter unit they will have a melting point list to refer too. It is all compared to copper, which is the Earth standard for wire – so let them test copper too if they want.  There will be a myriad of different items scattered at the station to try out. The students will eventually want to try anything they can get a hold of and they will truly get into this activity while learning what is conductive and not. At the end, a battery and light are used to show how to wire a circuit in series. The light needs a certain amount of current and voltage to turn on, so that is demonstrated through having a series circuit. Parallel can be demonstrated, and it shouldn't work. Since you want everyone to have something to test circuits with and we had only two light bulbs we also used to telegraph keys by turning on the electromagnets.

As an add on, one day we added making a battery to this station, using vinegar and salt copper and zinc.  Getting enough power to turn something on is a challenge, but an LED light can be used for this purpose.  In our case the equipment came out of a kit.  We suggest that the next group use something larger of their own design and more vinegar. This Energy activity kit also had a way to extract hydrogen and demonstrate a fuel cell that would have been a better fit for the unit- but the teacher wanted to have them see a battery made as it was more likely to come up on the MCAS.

**Background:**

The homework for this unit combines what they learned at all of the stations that the students went to, except the battery experiment, so it is essential that they learn and pay attention at each one. In the last ten minutes of class, a handout will go out to each student that shows how lunar bases on the moon may look in years to come.  Cartersville living space is basically made out of fiberglass wrapped cylinders inserted into round holes excavated into the side of Shackleton crater.  In order to help them see the pictures before them as a 3d object, going around is a cardboard tube wrapped in fiberglass that simulates a small scale model of the base space where people will live.

There are 4 units in a cylinder scale model of the picture which indicates cylinders about 8 meters in diameter and 12 meters long. They are stacked one on top of the other and are half the length of the cylinder. A person 6 feet tall as a stick figure is added for perspective. Their problem is to rewire the base. This seems simple, but how do you do that without copper, plastic, or rubber?  In this illustration, all the wires are in the round wall inserted in the middle of the cylinder and they tie into metal bars running the length on at least one side.  They are wrapped in the fiber glass making up the wall- inserted there half way through the construction process.

The students also need to figure out how to even get electricity in the first place. They then need to change the wiring of their room in the base which contains wall plugs, lights, heaters, and computers. It is currently in series with expensive wire imported from Earth, but if it is changed to parallel, other items will still work if one goes out but each will get less power. The lunar residents want to use more power and more wire, but to make their case they have to show how you can wire the base without using imported wire and generate ample electricity to be able to afford parallel circuits. Since parallel circuits use more wire, the students should be able to explain why parallel is better enough to be worth it in a few sentences they attach to their handout once they complete it. This should be collected by the team and graded for the teachers use to measure how well they understood the concepts. Parallel and series circuits are on the MCAS every year, so it is a crucial concept to master. Rewiring involves drawing on a paper where you want the metal wire or rods and indicating what they are made out of and how they are insulated.

The best answer is to use the braided steel wire wrapped in fiberglass- but aluminum would work and one should show aluminum wire too, pointing out the higher failure rate that is likely given the lower melting point of that metal. On the other hand you could use it as a fuse mechanism to be sure you know where the circuit will break if it starts to overheat, and that it is easy to get to and fix.

We are also teaching about how to interpret a diagram with different perspectives and what the drawings represent as a 3-D object. The key is to practice drawing circuits and predicting what will happen if a device failure breaks the circuit at any given point. In series, that would leave them in a dark cold hole without communication system at the South Pole of the moon. In addition, not only their unit would be affected. There are 3 others that are tied into the same circuit. The exercise could be elaborated to figure out how to make sure only one unit is knocked out in case of a serious break in one that cannot be repaired by a simple blub replacement. For an enhancement, there should be fuses in the kit that are either burned out or overloaded to make the points to the students.

## Light

### Materials List:

- Christmas Lights
- Flashlights
- Mirror
- Tape
- Protractor
- Concave / Convex lenses
- Kaleidoscopes
- Binoculars
- Telescopes
- Glasses with mirrors
- Prism
- Slinky
- Color wheel
- Handouts

**Method:**

Chapter 17 covers light and sound. The previous team provided equipment for both, but did not do anything with sound. Mr. Mahoney handled that without trying to tie into the lunar base theme. It is just having them handle a lot of musical instruments and figure out what is vibrating in each case. He was also given a toy that changes the sound of a voice spoken into it and they have to figure out if the sound wave is being shortened or lengthened electronically- like a distorted telephone. The team covered both, and left the sound equipment with Mr. Mahoney and we never even saw it. This team upgraded the Light portion of the activity, and sound was again covered separately later by the teacher.

The light activity we again did in stations set up around the room. Four stations are set up with volunteers manning each one. Each station is also around ten minutes, depending on the time frame. All of the materials for this activity are included in the kits provided from the previous team. Each lesson should be researched before implementation to allow background knowledge. The chapter from the 5th grade text should also be read so as to properly use the key concepts and words.

The first station in this activity is one involving mirrors and 45 degree binoculars. The mirrors are to teach the concept of reflection. The mirror, while small, is taped to the classroom white board and a piece of tape is put on the floor perpendicular to it. The students are then lined up on the tape. The purpose of this activity is for the students to learn about angles. A student that is at a certain angle from the mirror should see a student at the same but opposite angle when looking at the mirror. This takes some adjustment, but when everyone is lined up correctly, the activity works. Protractors let other students do the measurements while two are currently seeing each other.

The next activity is about convex and concave lenses. This is a demonstration that is good with a piece of paper on hand – and indeed the last team had a handout on this concept as the students struggled with which was the different lenses drawn, and thoroughly explained. Diffraction and diffusion through the lenses are explained with each type of lens. How to concentrate and diffuse light is also explained at this station. After the mini lesson, lenses are brought out and shown to the students. Pass one of each kind around and ask what type of lens they are. Once they properly identify them and explain why, more lenses can be passed around. The students should look through the lenses and describe what they see until time is up.

The next station is the favorite of the students. It puts reflection and lenses together. There are kaleidoscopes, binoculars with a side door to shift from seeing straight ahead to seeing sideways., and other toys like telescopes and eye glasses with a rear view mirror that are found in the kit. These toys bounce light around corners, which is a crucial part of this activity. The students will play with these devices and use them try to see around corners and get the idea that they can make light turn corners in a predictable way.   They will try to explain how many mirrors are in each of the toys they use.

The volunteer for this station should be well versed in what is in these toys and the methodology of how these toys work because the students will ask many questions. Background information can be given while this activity is happening, but most likely the students will be too involved in the station to absorb more information.  Everyone will want to handle every device so having 3 or 4 of each is a good idea.

The last station covers light wavelengths and colors. A prism is included in the kit, and the volunteer must explain how the white light is really made up of colored lights running from red to blue and the wave lengths we can’t see as well ultraviolet and infrared are still there. You want to have a table of the ranges handy and a long slinky (put a few together if necessary) to illustrate differences in wave length and speed of travel. This is helpful to show how they work and what they do. A slinky can be used to explain how waves work in the light spectrum. A color wheel can be spun with a basic motor, and this mix of colors will turn white (more like beige) while in motion. Plants only respond to certain wavelengths of light for cooking $CO_2$ and $H_2O$ into carbohydrates. If they look green it is because they are reflecting back the blue and yellow and absorbing the red—but plants do not all look like the same kind of green and some actually look red or blue in color.

Successfully growing plants is critical to a sustainable lunar base. The radiation levels on the surface would kill them, so they must be grown underground in a greenhouse shielded by at least 10 feet of regolith to block 90% of the dangerous cosmic radiation. Also, the sun is too hot without atmosphere to block and reflect some of it, and would evaporate the water and wilt and burn the plants.  So, to grow plants on the moon you have to be able to separate the radiation from the light and get it to go underground and then diffuse it to the ambient levels on Earth. The key to separating radiation from light is that the gamma rays will go right through a reflector (like an X-ray) but the light will change direction.  You need to make it turn a few corners and you have just the light. The plants must not die so it is essential to get rid of the dangerous light in space. This is also a new station that was developed this year, from what was in the past just a slinky demo so further fine tuning is appropriate to make this color oriented activity fruitful and tightly tied to the needs of growing plants.

As 6th graders they will be focusing on the greenhouse problem and what to grow and why, so this activity sets the stage for the whole 6th grade lunar base curriculum and the color section is part of the transition.  There is also a greenhouse design problem coming up and the decision about whether to use grow-lights underground, or make the whole roof glass and water 8 meters deep or see if they can use a small opening and get the light to concentrate, then turn a 90 degree corner and zoom down a hole and then turn another corner before spreading in all directions. This year we do not want the details, just the general concept. In 6th grade they will visit Tower Hill, see a massive greenhouse and then redesign it as it would look if it were to be part of a lunar base 10 meters underground at the lunar South Pole.

**Background:**

As for the relation to the lunar theme, at the beginning of the lesson, the students are faced with the challenge of getting light into a greenhouse. This greenhouse is located in a base dug into the side of Shackleton crater, something the students should be familiar with as they have worked with it before on previous activities. This greenhouse is situated ten meters underground, and a picture of the crater is necessary for the students to understand the situation completely. The solution we are looking for is for the students to take what they have learned in the activities and apply them to delivering enough, and not too much light to the plants. They should first concentrate the light, bend it into the crater, and then diffuse it into the lighthouse. If any parts of this are done incorrectly, there is a high chance that the plants either won't get light, or they will burn because of too much light. A piece of paper should be handed out to each team. In the remaining class time, they are to draw a picture together of how they would come up with their solution of getting light to the plants. Another tricky situation is where the students have the light come into the greenhouse. If it comes from a reflector on the floor or the lower half of the chamber, the plants would have to be on the ceiling and walls since plants will grow towards the light. They also respond to gravity, but that is a much smaller force on the moon than on the Earth, and we are not going to get into the water delivery problem this year. This is something to keep in mind while the volunteers go around and check on each group's progress.

So far no team has announced that they do not need any light underground as they will be growing mushrooms.  However, some day a Smart Alec will do that and we can respond with questions about what temperature the mushrooms will need and since they do produce their own food, but live off of other plants like animals do, what the feed stock will be if it is not going to be rotting trees?  If they come up with human feces as the answer you just shake their hands as the rest of the class is grossed out.

## Energy

Background:

The sun, during its creation of energy releases solar winds throughout space. The solar winds in turn carry hydrogen molecules which collide with the moon. On the moon these hydrogen molecules react with oxygen found in the regolith to produce water. Most of the water that is produced in this process gets loss to evaporation due to the Sun. Due to the position of the Sun relative to the poles of the moon, the sunlight cannot reach to the bottom of craters located near the poles. Because of the absence of sun light at the bottom of craters, the water does not evaporate and one gets a hydrogen signature from the appropriate instruments on satellites orbiting the moon from these locations. Whether the water is ice , dry water or in another form is under debate but the consensus is that there is water and it can be mined and separted from the regolith by melting. I think it turns into blocks of ice mixed with regolith –a dusty iron rich very fine grained sand.

The ice formed at the bottom of the craters will be then harvested by mining robots to be used in the moon base. The problem with the harvesting of the ice is where the base is located. The moon bas will be located on the top edge of Shackleton crater. The base is dug into the side of the crater nearly 3 kilometers from the bottom. This puts only the top third of the ramp from the bottom of the crater to the base in direct sunlight, with the other portion always being in darkness near the bottom of the crater.

In order to get an idea where the processing center will be placed one must first understand how big Shakletons crater is. The crater is roughly 20 kilometers in diameter and has only 7 kilometers of flat surface area located at the bottom. The Possessing Center would be located in the direct center of the crater floor, leaving approximately 3 kilometers for all surrounding sides.

How ice is melted in the processing center is by setting up a parabolic mirror along the edge of the crater. This mirror would concentrate the sunlight and focus it directly on the processing center. This in turn would cause the center to warm up causing the ice inside to melt. The Processing center would be black so that the building would absorb the heat from the mirror. Also the mirrors would be polished and coated with chromium so that the beam of light would be reflected off them would be strong enough to reach the bottom of the crater. The warming of the center would not affect the humans working in there due to their space suits, so safety at this point is not an issue. Most of the work will be done by robots controlled from mission control anyway.

The mining robots mentioned before would carve blocks of ice of the bottom of the crater with lasers. The ice would then be brought to the processing center to be melted using the parabolic mirror setup. The ice needs to be melted in order to remove the regolith form it so that only pure ice is shipped to the moon base.

When the processing plant is absorbing the heat from the beam of light, there needs to be a system in place so that the building does not to get too hot and the water is lost. In order to achieve this, the building's roof would be able to change its color from black to white. The color White does not absorb heat it actually reflects all colors of light.

The process of removing regolith from the ice would work on the effects of gravity on the moon. When the ice is melted to large chunks of regolith and solids would simply fall to the floor of the processing center while the water is the drawn from the top and then refrozen. While being refroze the water would have a metal bar (axle) and hook attached to it so that it can be pulled to the base with a cable. The water can be refrozen by placing them in circular containers and placed in the shade were they would freeze quite rapidly. The frozen ice ball as hard as steel and big as a truck would then be dragged smoothly up a fiberglass ramp.

The fiberglass ramp would probably be made out of silicone likely to be produced from the ice melting procedure. Silicone would be found amongst the raw materials left over from the previously mentioned process, along with the metal hook used as a connection for the ball to be dragged.

The ice is then dragged up the ramps by attaching a cable to the hook that was frozen into the ice ball. The ramp runs flat from the processing center for 3 kilometers until it then moves upward at a 30 degree angle for another 4 kilometers to the lower level processing area of the moon base.

If there was a problem with the ice or cable connection it should in theory break before it reaches the tilted ramp. The problem would be more severe if it breaks while traveling up the thirty degree ramp section. As the ice gets further and further up the ramp, if it breaks it becomes more dangerous because it will slide down the ramp. The higher it breaks the faster it will slide down the ramp. What a fine opportunity to talk about potential energy.

Another issue that arises is the fact that when the ice reaches the near top of the crater it will be in direct sunlight. This will cause the ice and the ramp to heat up. The direct sunlight at this point is why the ramp is made from fiberglass and not metal. The issue with the ice heating up is its potential for failure. If the metal hooks gets too hot it could heat the ice up enough to cause the connection to fail. This would send the ice ball flying down the ramp. The only time the direct sunlight would be an issue would be for fourteen days out of the month were the sunlight is at its strongest. The problem for the students is to experiment with "ice" breaking free at different points on the ramp and seeing how far it travels back down. The important question is whether the processing center is in danger and should they consider shutting it down while the sun is at its strongest point in the month. Also can they figure out how to block or stop the rolling ice ball before it hits the ice plant? It is suggested that they try leaving the next few ice balls standing in the ramp on the level part waiting their turn to go up the slope.

## Energy Activity

Materials List

- Ramp Setups from Crater Activity (2)
- Sturdy Cardboard Rolls (4) ( About the size of a paper towel roll but stronger)
- Large Paper Roll (2) ( for 3 foot long tracks)
- 4" x 4" Wood Squares
- Golf Balls (12)
- Ping Bong Balls (12) or practice waffle golf balls (12)

  ( What you really want is 1/6$^{th}$ the weight of a golf ball- about 3 ping pong balls together give you the right weight)
- Ice Balls (4)
- Ice Cubes (2)

- Small black Plastic Tray (4)
- Towels (6)
- Cardboard carton based backstops (4)

Method:

The first part to this activity is setting up a demonstration on a table for all the kids to gather around. The demonstration consists of the ramps from the crater activity setup to slide the ice balls and ice cubes down to give the students a visual effect of what's happening. The small black plastic tray is setup at the bottom of the ramp to represent the processing center, with towels laid under the setup to prevent water hazards. The ice balls were made with small plastic ball containers the night before and brought to the classroom in a cooler. Regular ice cubes were used as well to show the students how the shape of the ice affects the way it travels down the ramp.

This part is performed as a demonstration because Mr. Mahoney was not comfortable with the children using ice cubes last year. His concerns were that it created a wet mess on the floor and the children could slip and get hurt. In order to appease him we made the ice part a demo run by our team, and simulated ice balls as hard as steel with that for the kids with golf balls and ping pong balls. We could have use marbles or ball bearings.

The ice balls are then rolled from 3 different heights on the ramp to show how potential energy is building and how serious the failure that could occur from the ice balls breaking free depends to some extent on how far they are up the ramp when it happens.  The objective here is to show the students ( potential energy) how the height effects the distance the ice travels down the ramp and also how fast it travels as it crashes ( kinetic energy) into the tray.  Also the object here is to show them by placing other ice balls or cubes on the track or in front of the ice house; one can absorbs energy and could slow them down. However, the energy is conveyed to the last ball in the line and it can take off at a impressive speed.

The activity is then setup for four groups of students. The first step is to set up the equipment. Each group will get a stand, ramp, backstop, plastic tray, 3 golf balls, and 3 ping pong balls. The set up starts with the ramp and stand first. The ramp and stand are set up in a straight line with the ice house. The ice house is placed 3 kilometers away (two tiles length from end of ramp). The backstop is the placed behind the ice house to prevent the balls from scattering throughout the classroom.

First the students are given the ping pong balls to see how far up the 30 degree slope the ball can be raised before is crashes into the ice house causing damage.

The idea is introduced to the students that they can place other ping pong balls in front of the track of ice house to absorb the energy and prevent failure. The students were then able to play with this idea and test different methods on how they could protect their ice house or whether or not it could be protected.

Once the students came up with ideas on how to protect their ice how, then the golf balls were introduced. The golf balls are a lot heavier than the ping pong balls making them roll down the ramp faster and at a greater distance. The students were then encourage to come up with ideas to save the ice house from the golf balls by placing other golf balls or ping pong balls in front of the ramp or house to absorb the energy.

After the students experimented with many ideas about how to save their ice house the experiments were cleaned up. The students then remained in there groups and discussed the best way to maybe save the ice house, as well as how the height and weight of the balls affected how the balls rolled down the ramp and impacted the ice house.

Observations:

This activity has proved to be one of the more popular activities with the students. This activity was also displayed by Professor Wilkes at the New England  Air Museum(NEAM) , Space EXPO representing the AIAA New England chapter and featuring our 5$^{th}$ grade curriculum. It was a big hit with the 1600 spectators there, as about 350 of them stopped by during the day. It has proved to be a very successful activity and is recommended to be kept intact by future 5$^{th}$ grade teams.  Our role was to make it acceptable to Fran Mahoney, who otherwise would have just rolled balls down a ramp and dropped the lunar base connection to get rid of the ice.

There were a couple of key observations made by our team. The first being that when the students saw the demonstration of when the balls were placed in a row in front of the track and were struck by a ball rolling down the ramp, they instantly though of the swinging metal ball apparatus. It resonated with them that when three balls were placed in a row, when struck the middle one did not move. The middle ball in fact transferred its energy into the last ball in the row.

This concept really sparked ideas with the students on how the could setup balls in front of the track and ice house to absorb and transfer energy. It seemed that the most popular was three balls in a line spaced a part from one another. The inspiring thing is that they were actually using the concepts of energy in the experiments.

Another observation was that students all wanted to multiple balls down the ramp at the same time. This would in fact bombard the ice house causing its destruction, which the students really enjoyed. Also another observation made was that the students would place the balls diagonal to the ball rolling down the track to divert its path causing the ice house to be safe.

Overall this activity went over very well with the students and you could see that it spark scientific intuition and creativity which was really rewarding to see. I've learned through this project that you can make really fun but education hands on activities for the students and this activity was amongst the best.

The only thing I would recommend change is the height of the ice house. The plastic trays when using the golf balls was far too short at higher distances. The higher the distance the faster the ball would roll down and sometimes it would skip over the ice house. At NEAM to avoid bouncing black marbles were used with good success but the key to keeping the balls in the track was to not have them hit the stationary balls until they had gone at least 6 inches on the level ramp. Many students thought this was a successful idea but in reality this was almost a false success, causing a little confusion amongst the students. To improve the activity I would find a taller tray or box to stop the balls from bouncing over it at higher distances.

The best part of the activity for me was telling them at the very end that in fact their ice houses would be safe after all due to the effects of gravity on the moon. I happened to get a kick out of this but many students did not. They thought we should have told them at the outset that the ice house would be safe. At NEAM they had things set up so that using practice golf balls you could just barely dissipate the energy before it hit the ice house, missing by about an inch for dramatic effect. The kids there were very excited and cheered when they figured out how to dissipate energy using golf balls, and used it later so that under lunar gravity conditions it would actually work- barely.

## Magnetism

Background:

What is magnetism? Magnetism is an object that creates an area of magnetic force around it known as magnetic fields. The magnetic fields of two objects are what makes them attracted to each other, or repel each other. A magnetic field like the Earth has a north and south pole. If you try to connect a north and north pole of two objects then the result will be that they repel one another. The same goes for a south pole to south pole connection.

The Earth can be said to be one giant magnet, with a massive magnetic field around it. But what makes Earth a giant magnet? The Earth at its core it's made from molten metals such as iron. This molten metal core rotates just like the Earth rotates. The molten core actually rotates much faster than the Earth rotates. This fast rotation of the Earth's core creates a giant magnetic field around the Earth.

The creation and existence of the Earth's magnetic field is quite significant. Earth's magnetic field is what allows there to be life on Earth.  Without the magnetic field in place, solar winds created from the sun would wipe out life as we know it on Earth. The magnetic field acts as a shield against the solar winds and burst of intense energy from the Sun.

Solar winds are continuous streams of electrically charged particles. They are created from magnetic anomalies that occur in the sun. The solar winds are formed when the magnetic fields of the Sun loop out into space instead of back into the Sun. This anomaly occurs in the Suns corona which are called coronal holes, which can last from months to years.

It takes almost five days for the solar winds to reach Earth at a speed of about 250 miles/sec. Due to the fact that these electrically charged particles are emitted from the Sun as it rotates they move across  space in a pinwheel shape.  These solar winds affect the entire solar system but luckily we are protected on Earth and never feel the effects of them. The only visual sense we get those solar winds is from the creation of auroras which can occur on other planets as well.

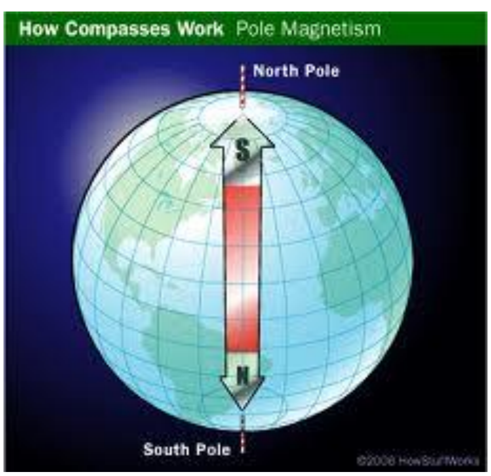
When these solar winds hit the Earth's magnetic field with intense force, they have the ability to distort the shape of the Magnetic field. The magnetic field starts as two giant circles stemming from Earths two poles. When the solar winds hit these two giant circles then become distorted and turn into a tear drop shape. The tear drop shape is significant to point out because the front part acts as the barrier and then the tear drops tail forms as the solar winds are forced around the Earth. This mode of protection is also very significant because not only does it allow life on Earth but it also is the central idea behind this unit. The moon passes through the elongated tail of the Earth's field when it is under pressure due to solar activity but has no other protection.

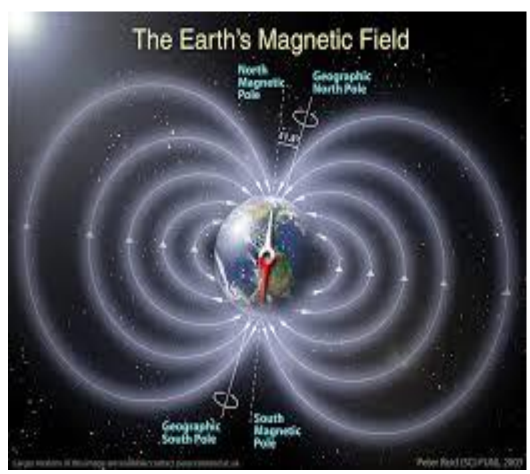
Imagine that you're traveling across the moon, or that you have built a base on the Moon for shelter. There is a major threat that you will face while trying to accomplish one of these tasks.

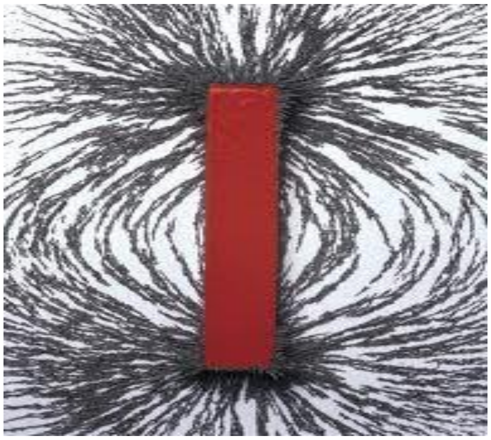
That being solar flares, and of course solar winds. Earth as we know is protected from such effects due to its magnetic field. The Moon however is not that fortunate. The Moon does not have a power magnetic field as the Earth does. It is so small and weak it is practically irrelevant, especially when it comes to protection form solar flares and even the constant solar wind.

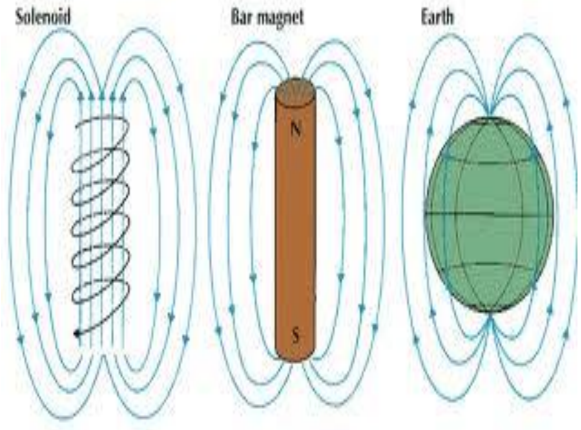
While traveling on the surface of the moon or constructing a moon base, the fact that you will not be protected from solar flare and winds must be the main construction shielding priority  in order to be successful. The main concept while designing the lunar base is whether or not it could be protected during these storms and its ability to be sustainable after them. Also the idea that magnetic fields can be created from electricity and turned on or off at anytime. Could you use electricity in your base to turn the magnetic field on during a storm on shut it off when not needed?  Would it be possible to create a base that could be protected due to the solar flare and winds? How could you protect your base or rover from solar flares and winds? Could creating a magnetic field be a viable solution?

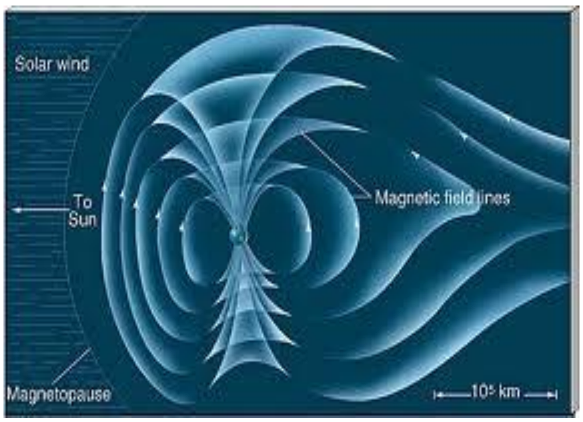
Images Used to Convey Ideas:






Solenoid
Bar magnet
Earth
N
S


Solar wind
To
Sun
Magnetic field lines
Magnetopause
10⁵ km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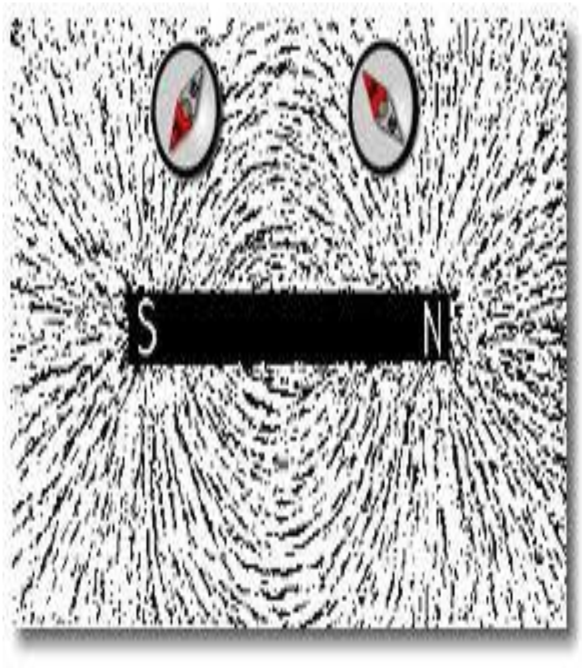
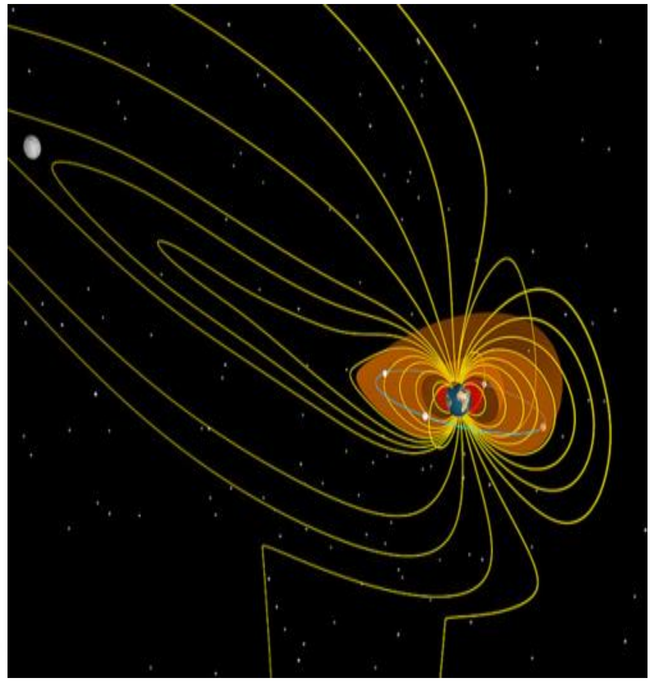


## Magnetism Activity

Materials List:

- Box of Paper Clips (1 box)
- Bar Magnets (16)
- Glass Jar Filled with Water (1)
- Compass (2)
- Assortment of Nuts and Bolts

Method:

The magnetism activity was conducted during the field trip to WPI, and not in the regular classroom setting. However it would carry the same setup and process if were completed in the classroom or as a workshop demo.

First the class is divided into four groups. Each group was then given a mini demonstration on the different aspects of magnets. The first demonstration was how magnets have north and south poles which produce fields. The idea is to show the group that magnets can attract and repel each other depending on with poles you try to connect. Then the students were free to test the magnets out and feel firsthand the effects of the magnetic fields.

The second demonstration to the next group was that the magnetic field can be transferred through different metals. The idea here is to show how a magnet can pick up a bolt. Then by demonstrating that the magnetized bolt can now pick up other materials like the paper clips. The focus here is that magnetic fields can be transferred around certain metals. This allows the students to realize that not only magnets can be magnetized but other metals as well. The students are then free to transfer magnetic field and experiment with the idea.

The third demonstration to the next group also plays on the theme of transferring magnetic fields but it also shows the fact that certain metals can be manipulated by those fields. The setup here is connecting 5 paper clips into a chain. The end of the chain is attached to a magnet, with the rest of the chain being pulled in a straight line. Next a magnet is place just slightly above the other end of the paper clip chain so that it is now in the magnets magnetic field. This will cause the paper clip chain to be controlled by the top magnet without actually being connected to it.

The idea is that as long as the metal is within the magnetic field it can be controlled by it. The students were then asked to recreate this demonstration to get a hands-on sense of how magnetic fields work. The students were then free to make their own setups and convey their own ideas on how it could be done.

The final demonstration to the last group involved a compass and a glass jar filled with water and paperclips. This demonstration conveyed to the students that magnetic fields could be strong enough to not only manipulate metal but to also have their magnetic fields go through things like water and glass.  The way this was achieved was by placing magnets along the side of the glass jar and moving them around to make the paper clips inside dance around. This showed the students that it is possible for magnetic fields to travel though non-magnetic materials and have control over metals contained inside them. The students were then shown the compass on given a quick mini demo on how it works. It was then shown that a magnet placed just slightly above the compass could manipulate the metal arrow making it spin in circles to do the conflicting magnetic fields. The students were the free to experiment with the two objects and how they could manipulate different metals using magnetic fields.

The students were given ten minutes with each mini demo unit and then were rotated to the next group so each got the full spectrum of magnetic demonstrations. Each group was given a demonstration of the concept being conveyed to them and that was followed by a discussion of how we could use these magnetic fields to protect of lunar base.

Observations:

While carrying out this magnetism unit there were key observations made. The first being that must student did not realize that there was a magnetic field around the magnet causing it to attached different metals. They did however understand the idea that magnets had a north and south pole which would attract and repel one another.

Another observation was that the magnetism unit was very popular amongst the students during the field trip to WPI. This conveys to future teams that the magnetism is a good unit to hold onto and incorporate into future curriculums because it was very successful and is proven. Another observation was during the paper clip chain demonstration, many students tried to make the chain very long.

When it did not work, they learned that magnetic fields have certain strength to them. The realized they could make there magnetic fields much stronger by placing more magnets together to carry out the experiment. This was very rewarding to see because it showed you that the students really grasped the concept that certain objects create magnetic fields around them and you could manipulate these fields depending on the application.

## Gravity

Background

The gravity activity was conducted with the Phases of the Moon Activity and was setup as an individual station to compliment the larger Moon Phases activity.

What are the effects of gravity? Gravity is a force that pulls matter altogether. The more matter (anything you can physically touch) the stronger the pull of gravity, such as the planets and stars. To measure the effect of gravity we measure the mass of something. With the mass of something being the total matter that it is made of. The more matter something has the stronger the gravitational force that it is being pulled by.

The Earth consisting of a high volume of matter has an extremely larger gravitational pull. As we walk across the surface of the Earth it pulls on us and we pull back. Due to the fact that Earth is much larger then we are its gravitational force is much stronger so that the gravitational force produced by people is not large enough to move the Earth. The pull from the Earth's gravitational force can cause objects and people to fall the surface of the Earth.

Gravity not only depends on the mass of an object but is also depends on how far you are away from something with gravitational force. This is what keep people on the surface of the Earth instead of being sucked into the Sun, even though the Suns gravitational forces is much strong than Earths. The reason we stay grounded to Earth is due to the large distance between Earth's gravitational force and the Suns.

On the moon the effects of gravity are $1/6^{th}$ the strength of the Earths. The much smaller gravitational force is what causes things to become much lighter on the surface of the Moon and eve float in some circumstances. While on the surface of the Moon the effects of gravity can have serious consequences on the human body. Gravity controls the way blood circulates in our bodies, if the human body is experiencing less gravitational pull then more blood would flow to your head. Your bodies' response to this would be to decrease the amount of blood volume throughout the rest of your body to compensate for the change in gravity. This body response can cause permanent damage to the body.

## Gravity Activity

Materials List

- 5Lb bag of potatoes (1)
- Gallon Jug of Water (3)
- Student text books (3)
- Digital Scales (2)
- Sack of Oranges (1)
- Handouts

Method:

This activity is started by having one group gather around two digital scales set up in one corner of the classroom. The activity starts of like most with a demonstration on how on the moon things would weight 1/6$^{th}$ the weight as they do on Earth. This is achieved by having three water jugs filled with different amounts of water. The amount of water in each is to represent how much a gallon of water would weight on Earth compared to the Moon and Mars. The students pass around the three jugs so that get a feel how much the difference is first hand.

The students were then given a handout that has a chart of different gravitational forces from various planets compared to the Earths. Also on the handout was a chart to record the weight of an object on the Earth and then to convert it to Moon weight. The students were instructed to weight the different items to record their weight on Earth. The students were also given the option to weight themselves to see how much they would way Moon but was not mandatory so that no one felt embarrassed about their weight.

One the students recorded the weights of various objects the next task was to convert them to the Moon weight by either dividing the total weight by 6 or multiplying the weight by $1/6^{th}$. Once everything was weighed and converted we then all reconvened and discussed our findings.

Observations:

During this activity there were key observations made. The first observation and must important one being that the kids really struggled with the math portion of this experiment and really could not preform simple division problems or multiplication of fractions. This really hindered the effectiveness of the overall activity because the students just could not grasp the math concepts. To help the students out with the conversions, we all gathered as groups after the weights were recorded to convert them to Moon weight. A mini lesson on the multiplication of fractions was given and a large amount of time was spent with the students preforming math operations.

## Essay Contest

### Background

The 5th grade Space Enhanced Science Education team (4 WPI students) offered to run a special pilot project for at least the Elm Park School 5th and 6th graders, and possibly a larger group of schools that want to participate. It was the launch event of a proposed WPI student service club, now called Reach for the Stars. In this case we saw ourselves as addressing the problems of public understanding of science and technological literacy. This all occurs while improving science education and trying to carry out phase one of a talent search. The mission of Reach for the Stars is in part, to find the students in the next generation with a knack for science and who should be encouraged to pursue it.

Three years ago an IQP team working at Elm Park pioneered this idea with a smaller scale essay contest, which they called a book report contest. Only 5-6 students from the 5th grade and about the same number of 6th graders from Elm Park participated. The reading level of the chapter from the book selected as a prompt was considered too challenging for most of the 5th and even the 6th graders that year. However, Elm Park has worked hard on English reading levels over the last 2 years and Principal Paula Proctor seemed to think the bulk of the class was probably ready to tackle the same reading used in the prior contest this year. She at least wanted them to try and stretch a bit if necessary.

The book used before was <u>Seven Wonders of Space Technology</u>. The author, Fred Bortz, said that it could be used again under the same terms to support both the 5th and 6th grade contests using chapters 4 " Moon bases and Moon Water" and 5 "Mars Rovers" as prompts for the two grades respectively. Dr. Bortz allowed the last team to distribute copies of chapter 4 to students entering the essay contest. He was even more excited about the proposed event for 110 students, since the prize was to be copies of his book that had to be bought for the winners at his special price of $25.00, rather than $30.00 each from the publisher, and he agreed to inscribe them personally as book awards. A $1.00 royalty fee was also established for each student that entered the contest so that they could have a copy of the text to read and bring home and even mark up. It cost about another dollar to make the photocopies, but WPI contributed to cover that cost.

Chapter 4 fits the theme of the curriculum unit for 5th grade very well. Just reading the chapter about the discovery of water on the moon that changed everything and makes lunar bases feasible was challenging enough for most students.  In essence, this was a glorified book report built around an MCAS like essay prompt. More was required at the 6th grade level, especially since these 6th graders had a space enriched 5th grade science unit last year, focusing on the moon, and the biology part of their 6th grade class will pick up on this theme again.  They were ready to move on to another subject.

Chapter 5 talks about the Mars rovers and even mentions “Curiosity” before it went into space, and everything that went into making it. It goes into a few details about its purpose, and why it is important for space exploration and even explains how it was named.  However, it could not go into what happened next, so the 6th graders weren’t doing just a “book report”. In order to finish the story they had to do some independent current events research for their essays.

It is a very inspirational and detailed chapter of the book that has a lot of potential for an essay. The latest Mars rover has landed on the Mars in a very dramatic way this past summer, and it is still just at the beginning of its long journey. This was a great opportunity where students were able to read what has happened in the chapter, and then go on and do their own research about what the rover is doing now. Students were supposed to use newspapers, the media, and any other form of news source, including those on line, since it is still such a new topic. There were endless possibilities that students were able to write an essay about based on what articles they read in addition to the book chapter offered. They were able to go in whatever direction they find the most interesting. There was to be a myriad of different topics to focus on, and that is what helped make this a great essay contest.

The Principal was enthusiastic to the point of wanting us to let all the students do the Mars essay, and predicted that her 6th grade team would do a lot with this idea, with the English teacher taking the lead and the science teacher covering necessary background materials. She was right, but the teachers were worried about the vocabulary and the length of essay anticipated. They were terrified about the need to support 60 students all wanting outside materials at once, with no librarian to help and only 3 computers in each classroom. Hence, they changed to prompt to one that was on a prior rover mission covered entirely by the distributed materials. Then, when they saw how the students did with that, they selected the top 3 students and supported them in adding a section responding to the original prompt about Curiosity. They also had those 3 papers typed as they figured they were going into the external competition with the other schools. However, there was not outside competition this year as it was not approved by the district. We asked to see all the essays, and took the opportunity to see if we agreed with the teachers as to what were the top 3 essays. This would determine if we could delegate the task of producing the short list to English teachers in the future. Would they see the same things in the essays as the technical minds from WPI –or the author of the book, Fred Bortz?

The leaders of Reach for the Stars chaired the two review committees and the 6th grade committee dealing with this complication was Alec and Danny from the 6th grade curriculum team, Mark, President of the Club, and Amber from the5th grade team.  In the end, it was their job to identify the top 20% and send off to author Fred Bortz for his review.  He would select the winner and they would rank order the next two for book awards, finalist certificates and honorable mentions.

The 5th grade essay review team was to be the rest of the 5th grade team, Taymon, Elise and Zack headed by Kerrin, the VP of the Club. The top essays at each grade level went into a final review by a team of judges that consisted of the 5th grade team, and they faced a different problem.  The prompt had not been changed but was sometimes all but part one (the descriptive part that could come directly from the text) was ignored.  The English teacher got sick for a week and in the end  only about 32 students out of 55 completed the essay even with her collecting 8 more after she got back- some completely new as the originals were lost.  The results were less polished as the students got less feedback.  Some lost their prompts and copies of the chapter before she returned.

Hence the review started late and Elise and Zack were involved in other things by then and never fully participated.  An outside reader was recruited who had worked with this age level before and could handle the challenging hand writing.  So, Taymon, Kerrin, Professor Wilkes and outsider Sandra Ansaldi finally did the judging- Ansaldi focusing on how much of the assignment each student had done, and commenting on what the handwriting revealed, providing a very different voice in the committee. The best 6th grade essays were sent to Dr.

Fred Bortz for final review 2 weeks before the best 5th grades essays. . He looked over the essays, and decided which three are the best and which captured the story he was trying to portray at the 5th grade level and how imaginative the response was at the 6th grade level.

His decisions were a surprise as he was willing to overlook substantial factual errors to reward the most imaginative reactions to his work. At the 6th grade level he went for an essay that seemed to ignore the comment in the prompt that a minimum trip to Mars would take 2 years, 6 months to get there and year on the ground until the planets were realigned for return and 6 months back. This student said that was not good enough and the trip would have to be cut down to 6 days to reach Mars, not 6 months. Bortz responded that many technical people agreed with that assessment and were working on a drive that would cut it to 6 weeks from 6 months and this was the right attitude. At the 5th grade level he overlooked a substantial reading error that was surprisingly common that the students thought we had been back to the moon for new sample in 2009 when he really meant the Apollo samples had be reanalyzed, blaming that on the teachers, who should have known we had not been back and coached on the point. He then went on to reward an essay that was unusually complete in thinking about the implications of the discovery of water on the moon. This student author had clearly picked up on the idea of what agriculture on the moon would mean in terms of making a lunar base feasible.

In the end the assessments of the teachers, WPI students and the author were so different that we dropped the idea of giving first, second and third prize and gave out an Author's award with a small trophy as well as a book, a WPI book award and a Teacher's choice award, representing the radically different criteria in play. The WPI students were looking for the students who “got it” technically whatever their mastery of the English language, the authors wanted imagination and the teachers were looking for essay composition, completeness and presentation taking into account how challenging the assignment was for an individual. Honorable mentions were supported by a specific phrase from the essay that was notable or revealing.

Those students identified as best by any of the three criteria would become the overall winners of the essay contest and they would get an inscribed book. However, in the case of the 6th grade contest there was an essay on everyone’s list- but always in second place. This was arguable the best essay produced, and so a 4th award- and First Runner Up award was created to cover this situation. In the past, the author has signed and delivered his book for the winner to own and bring home. The student that won 3 years ago at the 5th grade level was ecstatic that he finally owned a book, especially one about space exploration that she won by his own efforts. It was a very special book indeed. The 6th grade winner was also noticeably moved to be singled out by the author of the book. He read from her essay and she identified herself as author. This was not her first book ever- but rather her new favorite.

The timeline we used demands a start in the first semester and the student writing has to be done by Christmas since the second semester, when they return after New Year’s is dominated by preparation for testing and the testing itself. There is time later only for an awards ceremony. Given the constraints, the activity worked out well, and the schedule must be followed in order to complete the task and allow for the WPI and Elm Park Community

School's break schedule. It has to start in early November, where students are given a prompt. They then have 3 weeks to work on their essay and submit it to the teachers. The teachers had until mid-December to review the essays, so as to add it to the curriculum and make it count for a grade. The team then received the essay, read each one, and met in person or electronically to create a short list. Then the best must be sent to Dr. Fred Bortz. An awards ceremony is scheduled in the last week of February, which is right after the students come back from spring break and just before the WPI students leave on theirs. Finals week is a hard time to do the ceremony, so moving it up two weeks next year is advised.

## Outcome

This was the first time this was done at such a large scale and it was a great learning experience for everyone, but not everyone was involved. The prompts, shown in the appendix, were changed greatly by the teachers. For lower level reading classes, pieces of the prompt were taken out all together, and the students weren't required to answer each one. The higher level reading classes wrote more and answered more questions. The top students, as the teachers saw it, were given extra help typing their essay and with outside research. This would help the stars in external competition. That did not happen this year, but it is revealing that it was on the minds of the teachers when it was a possibility. This made the contest a bit unfair for some of the students that really had great ideas, but couldn't execute them in the way they wanted to because they didn't have outside help.

It is also revealing how much things unraveled at the 5$^{th}$ grade level when the teacher got sick for a week during draft process. Some papers were lost altogether and two students rewrote from scratch at the encouragement of the teacher, but she feels the second version was not as good as the first. Still, she had to move onto other things. Some 6 students out of 55 are on an IEP and she really never expected more than a paragraph from these students so they were not contenders and she let it go and did not push them. In the end we got 33 (9 late after the teacher returned). We had been expecting 48-50 out of 55. This was an assignment that was assigned and required of all students- a directive from the Principal, but still didn't work out in practice.

The 6$^{th}$ grade English teacher started out believing that the reading was too challenging for their class, and was struck by how completely the class engaged the material and stretched to master it. They needed some help on the level 3 words that are rare and some had not seen before, but the science teacher was on board to help. The class was supposed to be doing more non-fiction- and this fit the bill so the 6$^{th}$ grade team of teachers went for it and the students rose to the challenge. Soon we heard that 6 boys in the 6$^{th}$ grade class were determined to build a model of Curiosity out of LEGOs and had found instructions on line. The teachers supported this effort- and soon found that rare and expensive parts were needed to get past instruction 23 out of 36. We were asked to help out, but delegated the problem to the 6$^{th}$ grade team of Alec and Danny with support for Martha Cyr's collection of LEGOs at WPI. Dr. Cyr once worked for the LEGO Company and her collection is worth over $1000, but is not normally allowed to leave the WPI campus. In this case a few parts were allowed to go to Elm Park.

The 5th grade team did not have a chance to work on this project like the 6th grade team due to the illness of the lead teacher on the effort. Substitutes were not up to the challenge and did not even manage to collect all the first drafts. When we asked for the essays before the teacher had returned she had not read them and there was a general reading comprehension problem affecting even the top essays. The mistake came from reading the chapter incorrectly and a lot of the 5th graders believed that we had been to the moon recently, as in Americans landing on the moon in the 1990 or as late as 2009. This is in fact not true, and made it difficult to judge a lot of the essays when they had incorrectly understood key information. Were we to reward avoiding error or overlook a factual error and look for the ideas? Dr. Fred Bortz decided he would not fault the students for this one and awarded books based on ingenuity and originality since as the line between awarding a good essay that was in one place incorrect and a descriptive essay that got the facts right but had little else to offer was in the end a matter of educational philosophy on which he was willing to take a stand. So, we followed his lead, though one student got an honorable mention for getting all the facts right, when so many of her classmates did not.

At the awards ceremony, Professor Wilkes decided to clarify the question of the last time anyone had been to the moon by explaining that when we quit making Saturn 5 rockets in 1972, we no longer had the means to get people to the moon, and the Russians had never gotten their moon mission rocket the N-1 to work. Since then, one could only get lunar samples with unmanned missions, like the Russians did after the Apollo landings, but so far the USA had not done so.

The last problem came from the $6^{th}$ graders. They didn't do independent research as we had hoped. It was made clear after the contest was over that in order for them to have completed the outside research part of the paper, we would have had to provide them with the means and the materials to do so. The new library isn't equipped for such things as of yet, and each classroom has few computers. The teachers instead gave the students a source or two they found on the sojourner mission, which was also covered in the chapter provided, and the same information was used by about six essays. Others showed evidence of independent data gathering but they were few, about 2-3 out of 90.  This wasn't the intention. We hoped that the students would each go separate ways in their outside research on Curiosity, and have an essay based on what they themselves found interesting in their research and their own independent thinking about what the next mission to mars should try to learn if the long term goal was to prepare for a manned mission. Giving the $6^{th}$ graders more freedom proved to be something that needs to be handled at a much closer level in the future, possibly by having a library tour at WPI or students showing up with laptops and helping the students through the process.

To fix these problems, the IQP team must work more closely with the $5^{th}$ and $6^{th}$ grade teachers. A volunteer should go into the classroom on the first day of the contest to explain the prompt to each class, and answer any questions that may arise. Weekly check-ins should occur, and progress reports should be obtained from teachers so the team running the contests knows whether they need to provide more information to the students or not. By working with the teachers closer, we would have known that the prompt had been changed, and we could have prevented it or changed the overall criteria for everyone so the essays weren't all so different. Collaboration is key for this to be a complete success in coming years.

For the future, it is time to up the stakes, and get more children involved in non-fiction reading, space exploration, and to give them all a chance to write about something they are likely to find interesting. If we are able to get more classes involved, it would be a good thing, but so far the concept is approved only at Elm park school. There the idea is popular because it combined science and English all in one essay effort, hence, with an Elm Pak endorsement, there is hope that the idea can be approved for the whole Doherty Quadrant of 8 elementary schools and there is a book by Bortz (a biography of a female astrophysicist) suitable for use at the 7$^{th}$ or 8$^{th}$ grade level as well where all the quadrant students come together at Forest Grove Middle school before going to Doherty high schools as 9$^{th}$ graders. In future years, the essay prompt should be fine-tuned for the 5th and 6th grade. A book of past winners needs to be compiled for placement in the school libraries. Then students would be able to look at the winners essays from past years to get a grasp for what a good essay consists of. This assumes that the chapter, background, and prompts, would change from year to year.

To work on overall writing abilities for the whole class, after the winning of the essay are announced, students should be sent home with another packet. It would consist of a good essay, a mediocre essay, and an essay that could use some more work and thought. Students would read all three as homework and then describe which the best was and which needed work and what they would add to make the weaker essay as good as the best one, but still being independent and different. This would help the students understand the different writing levels and get to critique something they worked on themselves. It would be a good way to end the project within the classroom and contribute as a capstone to the essay contest and give a real learning value. MCAS preparation takes a lot of practice runs, and this could be one of them. The more experience the students can get, the better. With the correct timing, funds, and knowledge, this contest has the potential to become a great opportunity and learning experience for everyone involved and the AIAA NEC should be thinking in terms of some sort of token gift to all participants, possibly a special pencil. Hence, we would like to see this activity taken to a larger scale, inviting all of the 5th grade students in the Doherty Quadrant of Worcester to participate, so long as the faculty is willing to do the first round of review. In short, an IQP team devoted to running this one event and setting up a field trip to follow at WPI can handle about 5-6 strong essays from each participating 5th grade class, up to 20 classes. The service club at WPI, Reach for the Stars, can help out with both the field trip and working with the top 10 % "stars" identified as the finalists in the contest. A critical thinking afterschool club for these students has been requested by the Elm Park School. That is likely to be a popular idea elsewhere as well if WPI student mentors can be found in sufficient numbers.

The 6th graders of the Quadrant should be offered a field trip to Tower Hill Botanical Garden and also allowed to join the club, but use the time to prepare projects for the district wide science fair.

## Awards Ceremony and Feedback on the Project

. The award's ceremony was part party, part display of the Curiosity model, part the showing of a videotape of a presentation by Fred Bortz, the author of the book, partly a presentation by Professor Wilkes on the space race and moon missions, and a special opportunity for Principal Paula Proctor to have Martha Cyr be a role model to all the students. She would be giving out the prizes on behalf of President Berkey of WPI, while Carol Puskas called up the students and Amber Desjardin of WPI read the citation and Professor Wilkes handed the appropriate prize to Martha, as each book had the name of a specific student written into it.

The students cheered, there were snacks for all, a few parents got there and we understand that the children were blown away and the 5th graders can't wait for a chance to be a winner next year in the 6th grade contest. Fran Mahoney says they want to start now on a Mars project.

The Thanks you notes we were given by the 5th and 6th graders mention Tower Hill repeatedly and include comments like " wonderful lessons, amazing projects", "sharing your amazing talents", "bringing fun to science", " science got much funner with you guys around", " one day I hope to be able to go to Tower Hill again", " thank you for all the cool trips and we get to learn a lot of new stuff and Mars and moon research", "activities that were fun and exciting", " We learned many fascinating and interesting things like the plant botanical gardens and many more facts that I don't know where to start. I still have the plant. It's so big now…" " all the fantastic things and experiments you showed us", " thank you for helping us increase our knowledge", " my class appreciates what you have done for us and we loved when we got to plant plants with the staff at Tower Hill, " thank you for helping us understand our science", You taught us students things about plants and space I never knew and the trip to Tower Hill as a blast", " the biggest thanks for paying for the trip to Tower Hill Botanical Garden. I had a wonderful time there looking at all those fascinating interesting plants, it was so big. I so wanted to eat all those fruit I found there- Ha Ha. Another huge thank you.", "You are a great group WPI, Flowers bloom because of WPI.", "thank you for everything…you really made us learn so many facts about the moon, Mars and from Tower Hill Botanic garden, plants. Without your help we will never had learned, explore and discover those amazing facts and things that we saw…", "thank you WPI for taking the time to talk about science related things like thermal energy experiment or the time of talking to us about Mars and letting us learn about outer space", "thank you for your time and part in helping me realize how fascinating space can be. Also thank you for taking time to look at my writing.", "Space is Amazing", "thanks for all the guidance you told us about science, because some of us get stuck on science, even me, but when you are here everything is just right.", "The trip was the greatest thing ever".

Principal Paula Proctor added the following" Dear Professor Wilkes, My sincerest thanks for the work that you and your WPI students with the AIAA NEC funding provided for use at Elm Park. You have truly made a difference." So, the space enriched science education initiative is showing great promise and it is hard to separate out the impact of the work in the classroom, the field trip and the Essay contest, but in combination they "made a difference" and made science "funner" and "amazing". The picture on the card that just says "thank you for the experiment" leaves no question what "THE" experiment was. It is a drawing of either Zack's or Amber's station (possibly a mix) in the electricity activity unit where bulbs would light up. There seems to have been something for everyone.

There is another dimension to the 5th grade curriculum project besides building kits and running science class activities. There should also be special events and extracurricular activities designed to augment the curriculum. These activities are designed to further inspire and excite students and bring them to the next level of understanding and enthusiasm. The scope of this aspect of the project is large, and covers many different areas of the curriculum. We believe that it offers great promise for enhancing students' science education.

## On Special Assignment

My role in this project was different from that of my teammates. I did not develop the classroom science activities, build kits for them, or take charge of running the activities in the classroom. Instead, I worked to develop special curricular and extracurricular activities designed to enrich students' understanding of and interest in science. For this year, the major activity that was implemented was the book award essay contest. Numerous possibilities have been investigated for other events to run in the future, including field trips, science fair support, and after-school clubs. We have also investigated opportunities to collaborate with other organizations in order to make these activities possible and provide financial support for them.

Although my work was not focused on classroom lessons, I did frequently go into the classroom due to the need for manpower to facilitate the activities. My role was as a largely untrained volunteer. Most of the activities were structured in stations; the class would be divided up into groups which would rotate into different parts of the activity. I would be assigned to a station and would figure out the activity on the fly while guiding students through it. (There were a few activities, such as a demonstration of the nature of light, which I developed myself.) From my experience, it is apparent that future teams will need to develop activities in a way that more directly supports outside volunteers in the classroom. At a minimum, there needs to be established documentation of each classroom activity and how it works; this alone will greatly help volunteers if they are given the opportunity to read it in advance. Naturally, this documentation is more likely to be helpful for well-established activities than for new ones. While the curriculum continues to be developed by IQP teams, if it is going to continue to be used, as intended, in small group activities, the teachers will need assistants. A pool of outside volunteers organized as a student service club should be briefed in advance by members of the curriculum development team about newly developed or adjusted activities that are not yet fully documented.

## The Coordination Role

Much of my work on this project was devoted to finding opportunities for cooperation between the existing teams working on space-enhanced science education and other groups. On multiple occasions, I met with Principal Proctor of Elm Park School in order to gain a better understanding of what Elm Park's needs were and how WPI's supplementary education projects could best meet them. This is how it became apparent that more support was needed for the students who have shown the most promise and interest in the areas of science and technology. Principal Proctor gave us much-needed direction for our development of curricular and extracurricular activities with her concept of a "critical thinking" club. She also endorsed my idea of trying to do a re-run of the field trip to WPI called "Field Trip to the Moon- at WPI" that was organized by an IQP team at Elm Park 2 years ago.

I also met multiple times with Martha Cyr and Shari Weaver of the WPI STEM Education Center, which we hope will be a partner in the work of creating a student service club to support hands on science education that I want to call "Reach for the Stars" going forward. In February, I attended an event sponsored by the Colleges of Worcester Consortium, "Dessert & Discourse on Science, Technology and Engineering Curriculum Initiatives", during which educators in Worcester area schools met with faculty from Consortium colleges to discuss the future of STEM curricula. While there, I made the acquaintance of Kathy Berube, Curriculum Liaison of the Science and Technology/Engineering program of the Worcester Public Schools. She expressed interest in the activities that we were planning for the Club (including the essay contest and a potential field trip) and had heard of the Elm Park lUnar themed curriculum initiative. Coordinating with her program will be important, especially to the extent that we wish to expand activities beyond Elm Park to the rest of the district.

One possibility that we attempted to pursue was working with the WPI Great Problems Seminar "Educate the World". This first-year seminar is devoted to contemporary problems in the field of education, and the instructors wished for their students to go into local elementary schools and work with students there to gain a better understanding of the issues involved. The instructors were aware of our work and were interested in coordinating with us; their students would gain classroom experience, and we would benefit from the newly available personnel power enough to be able to run another field trip to WPI. . Unfortunately, "Educate the World" was not held this year due to a lack of enrollment. Future teams should bear in mind the possibility of collaboration with future offerings of the seminar.

Another potential strategic partner going forward is the Worcester Education Collaborative, a nonprofit organization supported by local businesses, foundations, and Consortium colleges, including WPI. Dr. Jennifer Carey is the founding- Executive Director of the Worcester Education Collaborative and she seems politically well connected. Jennifer received her Master's and Doctoral degrees from the Harvard Graduate School of Education and her Bachelor's degree from Harvard and Radcliffe Colleges. In 1998 she served as Special Assistant to Governor Paul Cellucci of Massachusetts, and a year later she became Director of the Office of Consumer Affairs and Business Regulations under Governor Jane Swift. Before joining Massachusetts state government, Dr. Carey worked at Ohio University, Harvard University and at Bancroft School, an independent K-12 school in Worcester. Martha Cyr seemed to think that she could arrange an introduction to meet her.

This year, the WEC came to my attention when it started the Blackstone Fellowship, an initiative through which college students would support students at Elm Park and other schools in creating science fair projects for the Worcester Science Fair. This is likely to play an important role in the future of extracurricular science education at Elm Park. However, the main reason for wanting to meet her is that the organization has traditionally been more interested in literacy than in science. they have done essay contests, and we have one that might interest them in that it is full of science content but gives practice in writing non fiction prose. As a team effort of the English and science teachers at Elm Park it was very successful this year, but we were not able to afford to bring the author of the book used to Worcester for the awards ceremony. Instead we showed a video recording of him speaking at WPI two years ago. It seems possible that the WEC could afford to do so. It would cost about $2000.

## Reach for the Stars

While the groups that we worked with should be considered as important strategic partners in the future, the previous IQP team concluded that in order for the curriculum and associated activities to be developed as well as they can be by an IQP team, and to survive after the IQP teams are no longer working on them, it is necessary for a dedicated corps of volunteers from WPI to exist who can provide the necessary manpower to run activities in class at the request of a teacher who wants to do hand's on activities with modest equipment needs. On that team's recommendation, we began the work to assemble activity kits and make this "club" a reality. The group has been named Reach for the Stars, and the proposed President and I are currently working to have it become become an official WPI-recognized student organization. We wanted to have it do something before it went into recruitment mode, so officially “Reach for the Stars” ran the pilot version of the 5t hand 6th grade essay contest, this year meaning that they helped do the judging.

The mission of Reach for the Stars is to promote STEM (science, technology, engineering, and mathematics) education at the K-12 level in Worcester. In its unofficial capacity wherein it consisted of the project team and a few other students, Reach for the Stars has already worked to assist in the administration of the essay contest and and a few classroom activities.

We have begun work drafting a governance structure for Reach for the Stars. Under the proposed constitution in progress, the organization will be governed by a board of officers, including a President who will oversee the membership of the organization, and a General Initiatives Coordinator who will coordinate all the initiatives that the organization will undertake. Students will be free to propose new initiatives in accordance with the organization’s mission; each initiative has a coordinator who oversees it and the volunteers working on it. This will allow the group to have a broad mission while still remaining focused in its activities.

Reach for the Stars will have an especially important role to play in the classroom; when the activities have been documented, and evaluated, there is no longer a case for recruiting teams to work on them other than to disseminate the units to new sites.  At that point  the activities will have to be run by volunteers who are trained in workshops run by that organization and scheduled to go where they are needed.. One hoped-for benefit of this is to push the teacher to become more involved in the activities, since the IQP teams that designed them will no longer be directly available. When activities are in development, a single team member could be sent for research purposes, leaving the rest of the team free to work on other things instead of becoming bogged down running the class day to day.

## The Pilot Essay Contest

The major special activity that was conducted this year was, of course, the essay contest. We learned much from this, and it changed form several times during the process. Originally, the plan was to invite multiple schools in the district to participate. Each school would have been required to buy one copy of *Seven Wonders of Space Technology,* by Dr Alfred Bortz, per participating classroom, in order to satisfy the royalty requirements for duplication of the chapters so that each student can take their own copy home. There was still a $1.00/ copy charge for this as well as the copy of photocopying. Each school would then select the best two essays from each classroom and send these to us. (The method of selection would have been left to the discretion of the individual teachers.) The project teams and volunteers from Reach for the Stars would then have selected the single best essay from each school at the fifth-grade level and at the sixth-grade level. These essays would then have been sent to Dr. Bortz, and their authors would have received autographed copies of *Seven Wonders of Space Technology* and been invited to an award ceremony at WPI. Dr. Bortz would select first-, second-, and third-place winners for the entire district at each grade level, and these would be announced at the award ceremony.

Running the contest district-wide proved impossible this year due to scheduling difficulties; the standardized test schedule meant that we would have had to wrap up in January, and this did not leave us with enough time to coordinate and run the contest at a district-wide level. We narrowed our focus to Elm Park, which resulted in some alterations to the purpose of the contest. With only a single school involved, we could read all the papers and evaluate the reading level of the students. In addition, the essay contest now served as an opportunity for us to identify the most promising 10% of students in science suitable to have that interest be nurtured by a club like Reach for the Stars. .

When all was said and done, the students and educators at Elm Park were quite happy with the essay contest ( especially the awards ceremony that involved students getting autographed books inscribed by the author as prizes which were paid for by AIAA NEC. However, I believe that there are changes and improvements that need to be made if it is to be done again next year. In order for the contest to have as wide an impact as possible, it should again be attempted at the district level. It is important to recognize, however, that not everything that was done at Elm Park will scale to that level. Reading all the essays, for instance, will not be possible, and if the teachers change the prompt to avoid having to support outside research by so many students, (as they did in this case) our ability to adapt will be more limited. We will need to recognize this when adapting the contest for a wider audience and stay in touch so that the teachers will not feel they are being left to their own devices. If the prompt must change, we need to make the change ourselves and it must apply to everyone.

For a district-wide contest with competition between schools, it is especially important that the schools and their students know in advance how they will be judged. Therefore, much attention must be paid to the construction of the prompt and the judging criteria. A good prompt should ask a single overarching question that is specific enough to be directly answerable, while at the same time broad enough to support an entire essay. It must be open-ended enough to allow students the freedom to answer creatively, but also settled enough to serve as a filter between students who understand the material and those who do not. The judging criteria must be written for multiple audiences; they must be understandable by students and teachers, but also usable by the judges as their sole guide to judging the submissions, in order to give everyone a fair chance at writing a winning essay.

Crafting a prompt and judging criteria like these is not easy, and the ones for this year's contest were put together in a fairly rapid and haphazard fashion but still went through several revisions.

Two sets of criteria were drafted up; the first was a good description of the pedagogical goals of the contest, but was too full of educational jargon to be of much use to students. The second set of criteria was written more directly for students, but was too vague for teachers; there was also uncertainty about the relative importance of creativity versus technical accuracy. With the time drawing near for the contest to begin, the two sets were combined in a way that did not quite meet any of the goals. Meanwhile, the essay prompts were expanded to incorporate multiple questions in order to allow students who had potentially novel ideas about space exploration to be able to incorporate them. The result, unfortunately, was that the prompts were unfocused and consisted of multiple different questions bolted end-to-end, with some teachers splitting them up into separate writing assignments, and some students being told not to attempt all of them. . A final issue was the minimum and maximum word counts, which were arrived at by guessing; the teachers will have a better idea of what their students can actually write and there should probably be several categories of entry based on reading ability.

In order for this contest to work in the future, the team will need to lay out the requirements for what the prompt and judging criteria need to be, then allow time for them to be crafted properly. It is probably a good idea for them to receive input from teachers while they are doing this. When they send out the prompt, it needs to be definitive; switching things around because the teachers aren't happy with them will not work at the scale of multiple schools.

Another important question is the role of outside research in the contest. The decision was made in this contest to include a research component in the sixth-grade prompt, in order to add an extra dimension of educational value. This was largely inspired by the obvious research potential in the topic matter; the book made reference to *Curiosity*, which had since landed on Mars and resulted in much media coverage. Furthermore, a major purpose of the contest is to promote student interest in space exploration; this necessitates tying it in with current events whenever possible. While there are clear benefits to this research component, there are downsides as well. From the school's perspective, the contest is already a project of immense scope if everyone is going to enter and be stretched by the vocabulary. In the case of Elm Park this was the first time a need for citation of sources had come up, and that needed to be explained as well. Adding a component that requires external research only increases this pressure, and a case can be made for having that be optional, but worth "extra credit".

Furthermore, in the absence of a well-stocked school library, outside research for students is possible only with external support; we had hoped that we would be able to provide this in cooperation with the library team, but this effort fell through as they were occupied with a book drive. These factors combined resulted in the teachers changing the prompt.

Another question is the extent to which the prompt should resemble an MCAS essay prompt, in order to justify the contest in an environment where test scores are given the highest importance. The contest bears less resemblance to the MCAS prompt when outside research is included. All told, the outside research component must be carefully considered when this contest is conducted again. If outside research is again included, it must be determined how this will be supported in a multi-school setting. One possibility is to make each school responsible for the provision of its own outside research material. Another is to provide support for all participating schools, perhaps by sending a representative from Reach for the Stars to each school for a day with research materials.

Finally, it will need to be decided how the award ceremony will be conducted. The one held at Elm Park this year, though quite well received, was nothing like what was originally planned. It had the benefit of allowing students to be recognized in front of their entire body of peers, and inspiring all the students in the fifth and sixth grades. However, aside from the planning issues that cropped up this year (that resulted in the students not seeing most of the Dr. Bortz video), this style of award ceremony has the problem that, once again, it doesn't readily scale to multiple schools. One possibility would be to send a representative from Reach for the Stars to each school to present that school's finalists and semifinalists with awards. Such a ceremony would not have everything that this year's ceremony had; not all of the representatives from WPI would be present, and there would be fewer awards presented. Furthermore, other schools might not be interested in such a ceremony. Still, it is worth considering. Meanwhile, the inter-school award ceremony has its own benefits; it could be made into an event allowing Reach for the Stars to get to know the winning students and encourage them to continue their endeavors in science.

One important proposal regarding the essay contest is the possibility of expanding it outside of Worcester. The McAuliffe-Shepard Discovery Center in Concord, NH is interested in participating in the contest. Reach for the Stars would be in a position to provide guidance to them as an activity is developed there that runs in parallel with ours. This could be important in giving broader reach to the themes of space exploration that we wish to promote.

The essay contest unexpectedly gave rise to another activity. While I was working with the lunar base model at Elm Park, a sixth-grade English/Language Arts teacher came up to me and said that, after her students learned about Mars rovers from the essay contest, she wanted her class to work with a Lego model of *Curiosity*. They found instructions online for building such a model. The class worked with these instructions, but soon found that they were missing parts. We made arrangements with the WPI STEM Education Center to allow the students to use their Legos to finish the model. As the teacher herself said when asking for the model, many students learn better with a tactile learning device; consequently, such a model has educational value.

In addition to the essay contest and Lego model, another activity is currently in the works: a field trip. This is being modeled on a field trip that occurred on the WPI campus in 2011. At that time, students from several elementary schools were brought to WPI for a variety of activities, in what was officially called an "MCAS Review Day "On the Moon" at WPI " (largely out of necessity to justify taking a whole day for science). They were invited to hear Dr. Bortz speak and deliver his talk, "Our Next Planet...", about the long-term future of Earth and the necessity of human space colonization. There was a computer based plate tectonics activity. In Alden Memorial, there were several different lunar-themed activity stations set up for rotation, including "expedition" a convoy of vehicles designed to go to the lunar pole to the equator made out of Legos, Moon Shoes, remote-controllable robots, an explanation of lunar agriculture, and an explanation of the *Moonraker* robot. (The Society of Physics Students explained Fusion Energy reactors and also had a demonstration of a Van de Graaff generator, (which did not particularly have anything to do with lunar science, but was naturally enjoyed by the students nevertheless.) Students were also shown 6 proposed designs for a lunar base and asked to evaluate them. (For fun the WPI students running the design review included a design for a wind-powered base and most of the 5th graders realized why this design was not workable). Some of the students also ate a "lunar lunch", consisting only of foods that could be grown in a lunar base. The event was a major success and was praised by the students, teachers, and principals. I was a volunteer for that event, and gave the Elm Park students a tour of Gordon Library.

We are now trying to conduct an event similar in spirit for the current Elm Park students. As Reach for the Stars is not yet a mature organization, the event needs to be reduced in scope to a single school for the time being. Due to scheduling difficulties, this year's event will have to be held at Elm Park, rather than at WPI. The stations that appeared at the 2011 event will be brought back if possible, and new stations will be introduced; for instance, the West Boylston Apparatus, a device that uses counterweights to allow a person to experience simulated 1/6th Earth (lunar) gravity, will hopefully be brought to Elm Park. This event will allow Reach for the Stars to learn more about what kinds of activities successfully contribute to students' understanding and enthusiasm, which will allow it to improve the events that it runs in future, and hopefully begin running larger-scale events at WPI again the following year. We believe that holding the 2011 event at WPI had important inspirational value for students who may not necessarily have considered college as an option for them, and that this should continue to be done.

Another important aspect of the 2011 event was the presence of Dr. Bortz. In addition to his talk that he gave to all the students, he also came to Elm Park and held question-and-answer sessions with students in the classrooms. We would like to bring him back to Worcester to talk to students; unfortunately, this could not be done this year as there was no source of funding. One possibility for future years would be to connect it to the essay contest; participating schools would be given the option to contribute towards the cost of bringing him to Worcester, in return for which he would visit that school for half a day. With multiple schools contributing, the option becomes economical. Another possibility would be to arrange for Dr. Bortz to go to events in other cities in New England at AIAA expense and then come to Worcester for a day.

Science fairs are another important extracurricular activity; they provide a unique opportunity to learn the scientific method through actual practice, and to develop projects that encourage them to ask the right kinds of questions. The Worcester Public Schools encourages all schools to have their students complete science fair projects for the Worcester Science Fair; however, Elm Park initially decided not to include science fair projects in the main curriculum due to lack of room. Science fair projects ultimately were done at the sixth-grade level; a different IQP team worked with that class, and it seems to have been a success. Meanwhile, initiatives such as the Blackstone Fellowship support science fair projects on an extracurricular basis. It will be important to consider the role of science fairs in the work going forward. In particular, it may be worthwhile to reach out to the WEC for collaboration on the Blackstone Fellowship.

One further event has also been proposed. In order to encourage interest in space exploration, both among Elm Park students and at WPI, a proposal has been floated that Reach for the Stars should sponsor a celebration of Yuri's Night: the April 12 anniversary of the first human spaceflight in 1961. Reach for the Stars could reach out to Student Pugwash and/or the WPI chapter of the American Institute of Aeronautics and Astronautics for assistance with this. Yuri's Night has long been a focal point of space advocacy, and could serve as a recruiting opportunity for Reach for the Stars. WPI as an institution can also play an important role in space advocacy, given the important role of alumnus Robert Goddard in the history of rocket science. In addition, an attempt is currently being made to bring a speaker from the Jet Propulsion Laboratory to Worcester to speak about *Curiosity* for audiences of elementary school students, WPI students, and aerospace professionals. No doubt, such a speaker would be received with enthusiasm.

## A critical-thinking after school club

One of the most important priorities that Principal Proctor expressed at the beginning of the year was ensuring that these enriching extracurricular activities provided options for students at all levels of achievement. Remedial after-school activities already exist, and auxiliary science support for average students is being provided by another group of volunteers from some of whom come from WPI but the leader of the program is paid by Elm Park.. What she now wants to do is create a Critical Thinking Club for the high-achieving students. One initial step is to identify these students; this year's essay contest served that role by allowing us to see all the students' thought processes in action and determine which were the most promising. MCAS scores and techer grades and nomination have also been proposed as ways to identify the "stars". (How this will work if the essay contest is scaled up to multiple schools is, once again, an open question.) Once the students are identified, an after-school club run by Reach for the Stars volunteers can provide them with an opportunity to improve their critical thinking skills. This could also potentially be an opportunity to nurture their interest in space science and technology.

There are many possible directions that such an after-school club initiative could take. The purest critical reasoning exercises are likely to be based in mathematics; the students could be introduced to applications of math different than those they have seen in school, and how to use them to solve problems. If the club wanted to focus more on developing skills of empirical reasoning, it could set up science labs and use them to teach students to make predictions and apply the scientific method. Other possibilities focus on different areas of STEM; continuing with the lunar theme, for instance, students could be given engineering challenges related to the construction of a lunar base. They could do research projects, which might or might not be directly related to STEM. They could learn about something entirely separate from the normal school curriculum, such as computer science. They could do something in the spirit of the growing-in-popularity STEM-to-STEAM initiatives, which integrate the arts into STEM activities. In short, many things are possible, and Reach for the Stars will have to determine what best meets the school's needs.

Overall, we made significant strides over the course of this project in the development of special activities. We executed a successful essay contest at Elm Park that will serve as a pilot for a future contest with a wider scope. We made valuable connections with a wide variety of organizations whose interests intersect with our own, which are in a position to potentially help with activities. We set up the base of an organization which will ensure that these activities continue to be organized. Most importantly, we made an impact on the students we worked with, and worked to ensure that this impact continues to be made for years to come.

In my role on special assignment I was not only planning the special activities but also finding out what would be involved if volunteers from the proposed clube were to take them on next year.

## A Field Trip to WPI

The final event organized by the fifth grade team was a field trip to WPI. This was the final objected and was deemed a relatively successful field trip. The field trip to WPI was not successful for last year's team so it became an important aspect to the $5^{th}$ grade project team. The field trip was a way to show the students the WPI campus as well as give them a first- hand learning experience inside the campus classrooms.

The field trip to WPI was setup and organized as shown in the document from Professor Wilkes:

## Fifth Grade Field Trip Schedule

Wed. April 10

9:00 someone needs to pick up LEGOS from Martha Cyr- 2nd floor SL and take them to the 3rd floor to store near my office. They go to room SL 406 at 10 AM when that room becomes clear.

Also Kevin and Nathan Wilkes will pick up the coolers of lunch at Elm Park School at 9:10 and deliver them to the rear of SL by 9:20. Volunteers needed to take the coolers to the 4th floor- store next to Room SL411

9:10-9:30 Jacob, Elise, and John W(me) meet the 55 fifth graders at Elm Park School (Ashland St) and help the 2 teachers walk the 55 students to WPI, SL 4th floor.

( This is thin. You need 1adult /10 students and we should have one more person ideally. A Volunteer would be welcome.)

The students are organized into 3 Groups of 18 with 6 teams of 3 in each group. These Groups will rotate between 3 stations in SL 402, 411 and 407. SL 406 is reserved as of 10:00AM.

Part 1- Before Lunch

Station 1 for each group is 9:30-10:00

Station 2 for each group is 10:05-10:35

Station 3 for each group is 10:40- 11:10

Lunch 11:15 to 11:40 (Lunch will be in SL 411)

We have SL 402 Expedition Station- Set up by James Castro and Zac Couture- but run by James Castro. James requests assistance "coaching" teams that will plan a strategy to safely travel

From the lunar south pole to the Marius hills (just north of the Equator) to check out some holes that might open into lava tubes. The threat is a solar flare while they are en route. It would kill everyone who is unprotected.

The assistance of Tushar Narayan is requested from 10- 11:10. A volunteer is sought to cover 9:30-10.

We have SL 411 Magnetism Station- Set up by Zac Couture and John Wilkes- and run by John Wilkes at 9:30 and by Zac Couture after 10AM. This will present magnetism concepts and move from that to the Earth as a Magnet- and surrounded by a magnetosphere, and how that protects the Earth from radiation and makes Earth suitable for life though it is made of basically the same raw materials as the moon.

Much of the design of a lunar base is to compensate for the lack of radiation protection on the moon- which lacks an iron core and is not a magnet. However, it passes through the tail of the Earth's magnetosphere.

(Here we pass out magnets and have activities involving paper clips and bolts planned, so we could use some assistants.) Zac has requested backup from Elise Mariolis. I second the motion and want her to support my run too.

We have SL 407 (no tables, just desks)set up for Lunar Base Design Review. This activity will be run by Joshua Fuller- who can be there until 11, probably long enough to do the briefing but not to complete the activity.

Narimane Khaled can cover from 11-12 while he is gone to wrap up this activity and get them through lunch. A volunteer is sought to back her up in that last session when Joshua has to leave.

Part 2 After Lunch

Matt Heverly- Mars Rover Driver's Skype Presentation from JPL on Mars Rover Curiosity is 11:45-12:25 All groups gather in SL 402.

(Taymon Beal will set this up in SL402 but has an interview at 11:00. Someone will need to actually run the equipment.

Taymon tested it today. This event was originally to be at 1PM, when he would have been back. Lyle, the JPL support person is at 818-354-2702 if we have trouble)

12:30-1:00 Fifth graders form into voluntary groups- their choice. They can: 1) go on a brief Library Tour

2) They can go to room SL 406 to play with LEGOS and actually try to build the convoy vehicle that they designed in "Expedition".

1:00-1:40 Rhobetaupilson (Robotics Honors Club) demonstration of ORYZ, a prize winning robot and a robotic arm by Matt DeDonato and Velin Dimitrov presenting on the robots.

They may also have a video of Moonraker- another prize winner- but the actual robot is being prepared for display at the Smithsonian in Washington DC for a few months.

Everyone will gather in one of the largest rooms- probably 411 which we must clean up after lunch and rearrange with open floor space in the central area.

1:45- 2:00 the 5th graders walk back to Elm Park School (at least 3 volunteers are needed to do the walk and others will repack the Legos and put the tables back in order.

## Magnetism Station

The magnetism station which was run by Professor Wilkes and I was said to be most popular amongst the students. The other two stations will be discussed their perspective leaders. The magnetism station was setup and carried out the exact way it was mentioned in the Activities section of this report.

In the magnetism unit the approach was a hands-on activity that would stress the core concepts to the students. The most important concept that was stressed was the fact that magnets have a force area surrounding them known as a magnetic field. This concept was important to convey because most of the students believed that is was the magnet itself that attracted iron objects, when in reality it was the magnetic field that attracts the iron to the magnet.

The magnetism unit was based on the unit done by last year's fifth grade team. However this year's magnetism unit added more hands on experiences for the students. Last year's activity focused on showing the students how magnets repelled and attracted each other. They were also given demonstrations on how you could transfer the magnetic field into a material causing it to become magnetic. These were both useful demonstration which I incorporated them both in the new magnetism unit. The difference though in the new magnetism unit was the introducing a couple new apparatuses on demonstrating magnetic fields and also letting the students have more hands on time with the magnets, to spark their creativity and technical literacy.

The reason I chose a hand-on approach to the students learning about magnetic fields because I thought that if they were only shown pictures and demonstration they would really grasp the concept. I found that the paper clip chain controlled by the magnetic field to be the most popular apparatuses as well as the most effective in teaching the students about magnetic fields. The way the paper clip chain apparatus worked was by connecting paper clips in a chain and connecting one end to a magnet and controlling the other end by placing a magnet just slightly above the paper clip chain to make it dance around. This really sparked the interest of the students and one of the goals of the unit was to have the students recreate this apparatus and come up with their own ideas on how to achieve it affectively.

The students were also showed a power point presentation on magnetism using the projector and drop down screen in the WPI classroom. These went over very well with the students and were highly impressed with the technology that was available to the WPI students. I think that this was also an important side to the field trip. It really showed the student how a college classroom functioned. This was very exciting for most of the students and after the lesson I was asked by many students on how they could attend a college like this. My emphasis too them was to study hard and get good grades, this was a very popular idea with the 5th grade teachers.

The overall effectiveness of the magnetism unit was very successful it was a nice compliment to the other stations during the field trip. It was also as a good start to an educational day for the students and I would recommend making either part of a future event at WPI or just as a classroom activity.

## JPL Skype Presentation on Mars Rover Curiosity

After the students eat lunch they then preceded to one of the larger classrooms to watch a video presentation by Matt Heverly the driver of the Mars rover Curiosity. The presentation included a short video on how they landed Curiosity on Mars. The presentation also included a lot on how the rover was developed from conception to the landing on Mars.

During the presentation we experienced a lot of technical difficulties which hindered the overall effectiveness of the presentation. Everything was running smoothly until the laptop that had the needed program on it was overheating causing the computer to crash. This stopped the presentation smack in the middle of it. After frantic recovery efforts the presentation was back up and running in which Matt gave a shorter presentation showing some interesting pictures as well as having a Q & A session with the students.

My observations of the presentation were that it was very interesting but lost the interest of a good number of students. You could see however that there were a selected group of students who really found the presentation enjoyable.

Despite the technical difficulties the overall presentation can be considered a success. The reason we can consider the presentation a success was due to the fact that the presentation was a bonus for the students and not the center piece of the field trip. The presentation was really intended for the six graders but they were not able to be a part of the field trip. It was intended for the six graders because of their essay contest on Curiosity.

## Rhobetaupilson (Robotics Honors Club) demonstration of ORYX

Another significant event during the field trip was the presentation by the robotics club. The presentation focused on the robot ORYX. The presentation covered the competition the robot was a part of in Houston Texas. The competition entailed Onyx competing against other robots in a challenge was the robots were controlled from their home campuses and explored a rock yard in search of colored rocks. The robot ended up outperforming most of the other robots and did quite well in the overall competition.

The presentation also covered Moonraker, the NASA award winning robot. The presentation talked about the NASA robotics competition. The NASA Regolith Excavation Challenge was one by the WPI robot and beat out 22 other robots. The other robots were created by other colleges, high schools, and professional engineers. It was said that Moonraker outperformed the other robots by a longshot and won the competition hands down. The description of the competition was taking from the WPI website and reads as follows:

The impetus for the Regolith Excavation Challenge was NASA's quest for new ideas for excavation techniques that do not require excessively heavy machines or large amounts of power. The competition called for teams to design and build robotic machines to excavate simulated lunar soil (regolith), a function that will be an important part of any construction projects or processing of natural resources on the Moon. Specifically, the robots had to navigate around a moon-like surface, collect regolith, and deliver it to a collection bin. To qualify for a prize, a robot had to dig up and dump at least 150 kg of regolith within a 30-minute period. The teams that boasted the largest loads would claim the three cash prizes: $500,000 for first place, $150,000 for second place, and $100,000 for third place. Paul's Robotics won the competition by collecting and dumping 439 kg of regolith.

The observations taking from the presentation were very comparable to the observations taking from the JPL presentation. The overall presentation went very well but lost the interest of a large number of students. There was however a small number of students who found the presentation and the robots to be very exciting and captivating. This small group of students moved closes to the robots and was highly interested in the presentation. They were also very interested in the prize money that WPI won ($500,000). They were trying to figure out home many houses you could by with that amount of money and it really amazed them. It also inspired them and gave them the insight that if you build cool things then that equals big money.

Overall the presentation was very effective for a small number of students just like the JPL presentation.  Even though a large number of students lost interest during the presentations but the excitement and interest of even just a few students, In my eyes made the presentations successful. If these presentations lead the selected students down a path of science and mathematics then I think it validates the overall project and is worth repeating to possibly inspire other students.

# Recommendations for the Future

## Future IQP's

For the future, the next IQP team should be given the main task of evaluation broken down to the level of what concepts we adequately conveyed and failed to convey.  Thus the 6th grade year should start with a test of the concepts that were to have been taught in 5th grade through the activities presented in MCAS style.  We have upgraded and documented the activities enough for a volunteer or club member to assist the teacher with the activity in the following years. The club, along with volunteers, should teach each activity to those who are interested, in order to streamline the process and get the program to more schools so students have the advantage when it comes to science and technology.

Parts of larger initiative with goal of curriculum with a lunar theme integrated with an exhibit, a field trip, and activities still need work. Eventually, a good paperback book about space for the students to learn from and enjoy reading would be a major asset. The textbook has serious problems. It is disjointed and scattered in general and the activities are busywork that assume access to no equipment. Worse in the space area there are misleading figures and it gives an inaccurate image of the moon which is resources rich, rather than desolate and forbidding. Teachers need a curriculum that builds toward a field trip as a capstone experience and they need engaging reading that they can do at home as class preparation. Our job was to look at a proposed curriculum theme and set of activities, assess them, and replace or improve those we found wanting. We filled gaps and improved the documentation overall. We also launched the essay contest to look into the outside preparation problem and assess the skill level of the class as a whole. Overall, the students are not in a good place. One has to start where they are at and where they are at indicated either that science education was not a priority in grades 1-4, since no teacher specializes in it or that reading comprehension is standing in the way. It is time to shift to hands on science education in 5th grade while getting some science into English classes so the vocabulary becomes less forbidding.

Clearly, progress was made and the Principal thinks the whole case was made for this approach. On the other hand, she already believed in it philosophically and just needed to have someone field a working example and provide the necessary materials, which we did. In a way, the person who had to be convinced was the 5th grade teacher, who wanted to stick to the text as much as possible but who could hardly miss the joy in the faces of the students when we showed up for “activity” day. Science was not going to be based on the text that day and everyone knew it. The question in everyone's mind is whether he can do it our way after we leave without support beyond what volunteers from a club coming to do something very specific can provide? They will not have an overview or plan of their own. They will be there to help him execute his plan and make small group activities or stations possible.

It is surprising to us that another IQP team has been working on what the exhibit for a lunar base field trip would look like and only the last minute came to us for advice. We found that they had not read the text used in Worcester, but rather have been working off of the state guidelines. Yet it is the classroom teacher who will decide if the field trip is "time on task" or not and worth the time and money. They may use the state rhetoric to justify a trip once they have decided they want to do it, but to decide, they will refer to the concepts in the test that have to be mastered and reviewed for the test. These teams should have read not only the Worcester text- but those in use in other nearby school districts. Alternatively, they have to be working a lot more closely with the IQP teams that are working from a text.

In the future the exhibit and curriculum teams should be running in parallel and talking to each other with monthly meetings of all the teams structured into the plan so they can update one another and critique each other's plans. We never worked out a plan for a field trip as we were too busy. The team planning the ultimate exhibit would have been in a better position to do that for us and try out some of their ideas if we worked together and they knew what the students were learning to plan the exhibit.

Advice to future curriculum team: 6th grade, come find out from us what they did in 5th grade and critique as well as build upon it. Feed to the next 5th grade teams what concepts the

6th graders haven’t mastered so they know where to focus their attention to fix the 5th grade curriculum and focus for the students to learn better. Intergroup communications are the next challenge in getting a coordinated effort. Work with volunteers in the club as much as possible. Teams should meet twice a week, with the first being on their own, and second by sending a representative to an all teams meeting.  Everyone should gather in person monthly. Cross meeting will help keep people on task and help get a report written since there will be regular progress reports to refer to in doing your own report and the group of reports will be better connected and have cross references.

## Conclusion

In conclusion, this project was one of real importance and value for both the students at the school and those of WPI. It was meant to have science curriculums with an emphasis on lunar themes. A well-developed curriculum guide is a very important piece of this project, and will help future teams as well as the club assist the teachers at the school in what they need done. Students like learning when there are fun activities to be done, and they may be learning without even realizing it.

Without a good guide, teachers will shy away from the lunar concepts and teach straight from the book, which isn’t acceptable. The book is a bad example of a text book, and doesn’t explain concepts well. It has a lot of problems, and we want students to learn the most they can with what they are given. Reach for the Stars will help run the activities, since a lot of them require multiple people to handle the equipment and make sure the children are paying attention to the concepts. Once off the ground, it will erase any need for a teacher to avoid the curriculum set before them. We are trying to create future scientists and engineers, and this curriculum does just that.

In the end, this project has been composed of a lot of work and proposes pieces of a curriculum guide, with a promise of more to come from fellow team mates soon. The success of this IQP is essential in order to help middle school students compete with the rest of the country. Being a master of science is an extra ordinary skill, and every student should get the opportunity.

# Appendix

The following pages contain worksheets and visuals necessary to run the aforementioned activities. These are to be used as a guide when running activities for students to use for their own personal learning and background information.

## Crater Handout

| | Angle of Impact | Length of Crater | Width of Crater | Ratio (L/W) | Other Observations |
|---|---|---|---|---|---|
| Station 1 | | | | | |
| Station 2 | | | | | |
| Station 3 | | | | | |
| Station 4 | | | | | |
| Station5 | | | | | |

## Electricity Handouts

**Take-Home Reading & Study Sheet for Electricity Chapter**

**What is Electricity?**

**Electricity** is a form of energy produced by moving electrons (aka. Electric current)

Recall from energy chapter, **Electrical energy** is the energy that comes from an **electric current.**

Moving electrons produces electricity we use in everyday life. There is also another form of electricity, **static electricity** that involves no moving electrons.

**Static electricity** is the buildup of charges on an object. (Note: charges are electrons)

**Current electricity** is a kind of kinetic energy that flows as an electric current.

**How does Electricity Work?**

**Conductor**: A type of material that carries electricity well. (The electrons can move freely through the material)

**Insulator**: A type of material that does not conduct electricity well. (The moving of electrons is constrained through the material, in other words, no electrons can pass through.)

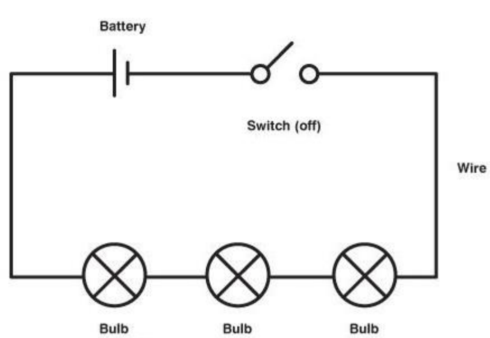
**How to Use Electricity?**

**Electric circuit**: The path an electric current follows

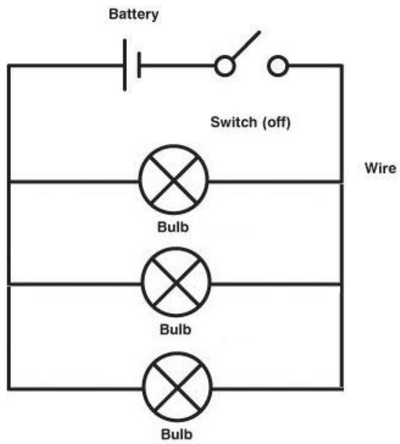
**Series circuit**: An electric circuit in which the current has only one path to follow.

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

Example of series circuit:




Example of parallel circuit:




Disadvantages and advantages of both series and parallel circuit:

Connecting three bulbs in series circuit uses less wire than in parallel circuit

If any one of the three bulbs in series circuit breaks, other two bulbs will not be working simply because there is one way the electric current can flow and the only way is broken.

If any one of the three bulbs in parallel circuit breaks, the other two bulbs will still be working because the electric current has three ways to go in parallel circuit. One bulb breaks meaning only one of the ways in which the electric current can follow breaks and the other two ways are still working.

**What does Electricity do?**

**Turning electricity into magnetism**

**Electromagnet**: A magnet made by coiling a wire around a piece of iron and running electric current through the wire.

Note: The piece of iron itself is not magnetic, but by coiling a wire around it and running electric current through it will make it magnetic.

## Light Handouts

**What is Light?**

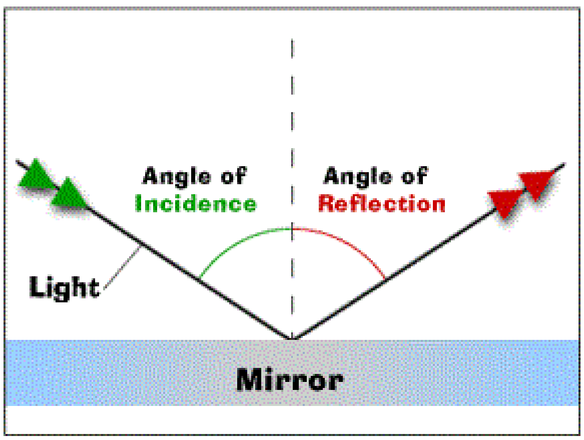
**Visible Light** is electromagnetic radiation that is visible to the human eye.

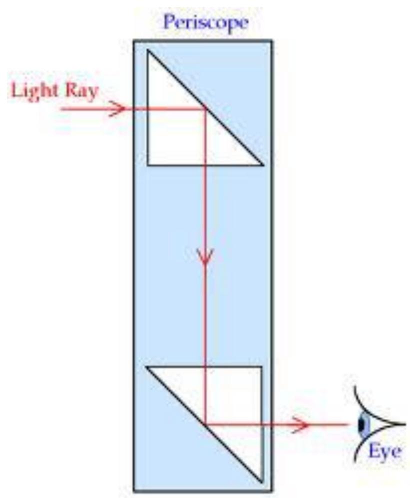
**Opaque** object: light cannot pass through

**Translucent** object: only some light can pass through

**Transparent** object: all light can pass through
Light can be redirected through **reflection** or **refraction**.

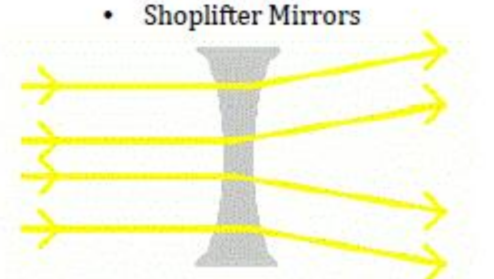
**Reflection**: the bouncing of light off an object.
Examples: mirror, periscope.

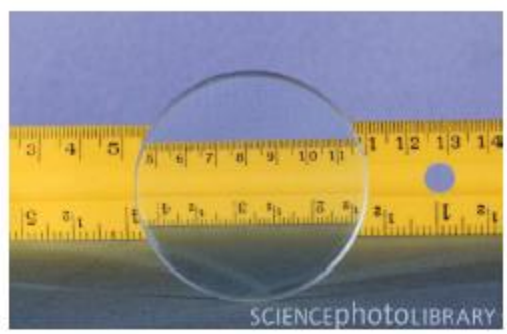



**Refraction**: The bending of light as it moves from one material to another.
**Concave lens**: A lens that is thicker at the edges than it is at the center
Uses of concave lens:

- Treat Nearsightedness
- On Door Holes
- Shoplifter Mirrors



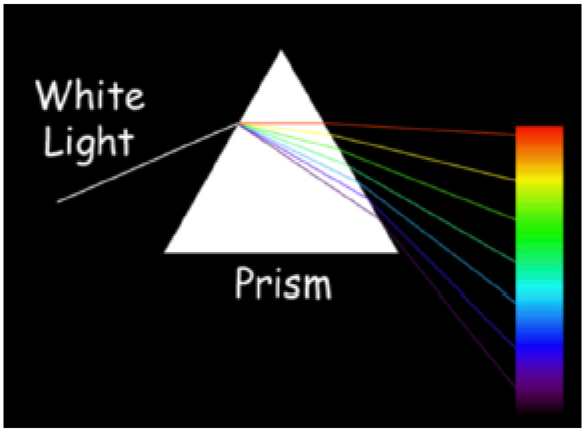


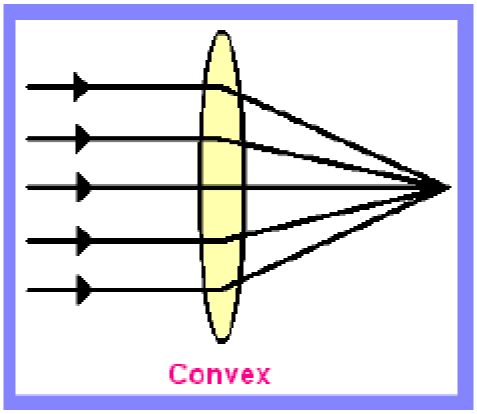
# Concave lens

**Convex lens**: A lens that is thicker at the center than it is at the edges
Uses of convex lens:

- Magnifier
- Treat farsightedness
- Used on microscope to see tiny objects
- Used on cameras
- Human eyes are double convex lens

**Prism**: (Requires color printer for this)
Usually it's a triangular prism with a triangular base and rectangular sides. It can be used to produce rainbow light.



## 5th Grade Prompt

# FIFTH-GRADE SPACE EXPLORATION ESSAY CONTEST

The New England chapter of the American Institute of Aeronautics and Astronautics and Reach for the Stars, a student club from Worcester Polytechnic Institute, are sponsoring an essay contest, based around the book *Seven Wonders of Space Technology* by Dr. Fred Bortz.

You will receive a photocopy of the book's fourth chapter, "Moon Bases and Moon Water". Read the chapter, then write an essay that answers the following prompt:

> Scientists have discovered that there is a significant amount of water on the Moon, even though the astronauts who visited the Moon between 1969 and 1972 didn't find any. This discovery could be very important for your generation. If Dr. Bortz is right, your generation could be the first to live and work on the Moon.
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> When did scientists go looking for water on the Moon, and how did they prove that it's there? What does Dr. Bortz think will happen because of this discovery? Do you agree with him? Why or why not? Can you imagine any other exciting possibilities resulting from the discovery of water on the Moon not mentioned by Dr. Bortz?

Your essay must be between 500 and 800 words. You may use other sources beyond the chapter if you wish, but you must cite them.

You should aim to write an essay that answers the questions in the prompt, is well-organized, correctly describes the factual information in the chapter, shows your understanding of it, makes a point, and backs it up. You are encouraged to go beyond the facts in the reading when exploring new possibilities. Your essay will be judged by these criteria. The contest judging is separate from your teacher's grading of your essay.

Remember to:

- Read the prompt carefully.
- Explain your answer.
- Add supporting details.
- Proofread your work.

You must turn your essay in to your teacher before the end of the school day on Monday, December 10. The essays will then be judged by Dr. Bortz and a committee of WPI students from Reach for the Stars. The authors of the three best essays in the fifth grade will each receive a copy of *Seven Wonders of Space Technology*, autographed by Dr. Bortz. These will be presented at an assembly in January, where you will get to meet Dr. Bortz through videoconferencing and see his presentation, "Our Next Planet ...".

If you have any questions about the contest, talk to your teacher or send an email to Reach for the Stars at spacecontest@wpi.edu.

## 6th Grade Prompt

# SIXTH-GRADE SPACE EXPLORATION ESSAY CONTEST

The New England chapter of the American Institute of Aeronautics and Astronautics and Reach for the Stars, a student club from Worcester Polytechnic Institute, are sponsoring an essay contest, based around the book *Seven Wonders of Space Technology* by Dr. Fred Bortz.

You will receive a photocopy of the book's fifth chapter, "Mars Rovers". Read the chapter, then write an essay that answers the following prompt:

> The rover *Curiosity* has now landed on Mars. It is the next step towards humans eventually visiting Mars. A short manned mission would take at least two years: six months to get there when Mars is closest to Earth, a year to stay on Mars until it is getting close again, and six months to return.
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> How did the landing of *Curiosity* go, and what is it doing now? What do scientists hope to learn from it? What should we know before sending humans to Mars? What do you think the next rover should do? Can you imagine other ways to explore Mars than with a rover?

Because the book was published before *Curiosity* was launched, it does not tell you about the landing or what happened next. You will have to research these topics and use other sources beyond the chapter, such as newspaper articles and websites. You must cite these sources.

Your essay must be between 500 and 1,000 words.

You should aim to write an essay that answers the questions in the prompt, is well-organized, correctly describes the factual information in the chapter, shows your understanding of it, makes good use of outside sources, makes a point, and backs it up. You are encouraged to go beyond the facts in the reading when exploring new possibilities. Your essay will be judged by these criteria. The contest judging is separate from your teacher's grading of your essay.

Remember to:

- Read the prompt carefully.
- Explain your answer.
- Add supporting details.
- Proofread your work.
- Cite your sources.

You must turn your essay in to your teacher before the end of the school day on Monday, December 10. The essays will then be judged by Dr. Bortz and a committee of WPI students from Reach for the Stars. The authors of the three best essays in the sixth grade will each receive a copy of *Seven Wonders of Space Technology*, autographed by Dr. Bortz. These will be presented at an assembly in January, where you will get to meet Dr. Bortz through videoconferencing and see his presentation, "Our Next Planet...".

If you have any questions about the contest, talk to your teacher or send an email to Reach for the Stars at spacecontest@wpi.edu.