Hotwheels and Cattails on the Moon
Enhancing Sixth Grade Science Education

Written by

Taryn Roy, Prateek Sahay, and Sean Smith

Advised by

Professor John M. Wilkes

2013–2014

This paper was submitted in partial completion of the requirements for a Bachelors of Science Degree from Worcester Polytechnic Institute.

Contents

Abstract

This project involved developing a series of sixth grade science activities with a lunar base theme at Elm Park Community School to build on a successful fifth grade series implemented the previous year. We began by assessing the students to identify major holes in their knowledge of science, which revealed uneven mastery across chapters. The activities we developed not only filled these holes but also introduced the students to Experimentation, Forces, and Botany units.

Authorship

This report is based on the work done by the 2013–2014 IQP team consisting of Taryn Roy, Prateek Sahay, and Sean Smith. Taryn Roy both spearheaded and wrote the section on the Essay Contest; Prateek Sahay conducted and wrote of the analyses of the Elm Park students' grades and MCAS data; and Sean Smith wrote the analysis of the Tower Hill Botanic Garden field trip. The remaining sections of this paper were written by all three members equally.

Acknowledgments

This is the fourth year of the Elm Park Community School, AIAA New England Chapter and WPI-cooperative science education enrichment project. We would like to thank all the teachers at Elm Park Community School who let us test ideas and materials in their classrooms. We would also like to thank Dr. Diane Ladd for helping develop the worksheets and for sharing her knowledge of nutrients and diseases for us in the run-up to the field trip while we were on break.

The fifth and sixth grade classes at Elm Park Community School have benefited from the hands-on activities WPI has been running at Elm Park over the last three years. Not only were the students at Elm Park more interested in science after our activities, but they grew to view Science as the fun class. (For example, one student asked us where he could tell his parents to buy him a gyroscope for Christmas after a demonstration in class about Forces and Motion.) These students could not have participated in this educational experiment without Principal Santa approving the project this year. We greatly appreciate that she let us continue this science curriculum enrichment program for the sixth graders. The space-themed Essay Contest has also taken place for the past two years, so we would like to thank everyone who made that happen.

We would like to thank the AAIA for funding our equipment acquisitions and the sixth grade field trip to Tower Hill Botanical Gardens. We would also like to thank the many exceptional helpers at the field trip, but in particular want to mention Ann Marie Pilch at Tower Hill for her help organizing the trip and interacting with the students and Marc Andelman for his enlightening talk and contagious passion for plants. Finally, we would like to thank our advisor, Professor Wilkes, for the hard work he put in setting up this project, for his intense passion for bettering science education, and for being the helping hand he was in times of need. This project could not have been completed without the generosity of those mentioned and many more.

Chapter 1

Introduction

1.1 Background

1.1.1 Enhancing Sixth Grade Science Education

This IQP has been recurring over the past few years. At its core its goal is to improve science education at the local Elm Park Community School located on Ashland Street in Worcester, MA. The students at this school have been performing below the Massachusetts State Standards for several years now on the Match, English Language Arts, and Science MCAS exams. State takeover of the school seemed likely before the school managed a surge in ELA scores last year; the focus this year was on Math. This IQP focused specifically on enhancing these students' science education by introducing stimulating and memorable hands-on activities and then measuring the effects, if any, of these activities.

1.1.2 Elm Park Community School

Elm Park Community School in Worcester, Massachusetts is a K-6 grade school consisting of approximately 500 students. In 2010, test averages were compared to other schools in Massachusetts, and Elm Park Community School received a rating of 43 out of 100. The poverty percentage of Elm Park Community School is 6-15% (though 90% of the students qualify for free or subsidized lunches) and the technology measure is considered to be “medium-low.” Very few of the students have Internet access at home either. While preparing the activities described in Chapter 3, all these factors had to be taken into consideration – for example, the diction used on the worksheets had to be simplified more than we had anticipated because many of the students did not read not at grade level. The students at Elm Park Elementary School lacked an enriched science curriculum prior to fifth grade. Given the sponsor, discussed in detail in Section 1.1.3, the program involved space-themed activity enrichment. The sixth grade, in particular, was the main focus of this project, so our main question throughout this IQP was how to design the science program this year for veterans of the fifth grade lunar base-themed science program in order to build on what had been done before.

There were 55 students in the 2013–2014 sixth grade. Because of Worcester Public School staffing policy, two teachers were assigned to teach the sixth grade, though there had been three the previous year. This IQP team worked extensively with one of the teachers, Mrs. Richard, whose main priority was assigned to be math rather than science. However, she was more than helpful in accommodating us as we developed and delivered activity packages to enhance the science lessons. We had a free hand in formulating from topic to assessment. One hour a day for two days (Tuesday and Wednesday) every other week were dedicated to science per class at Elm Park. This IQP group worked with both classes; thus one activity consisted of a Tuesday part and Wednesday part and was delivered to one class one week and the other class the following week. Mrs. Richard advised our group at the beginning of the IQP that because the kids could be rowdy at times, we should take the opportunity to let the kids play for a day before we got serious about data collection and analysis. As per her advice, we tried to introduce some of the 'toys' on Tuesdays to let the students get some of the playfulness out of their systems and then worked on the actual activity using these "tools" on Wednesday. This was advice we took and implemented nearly each week throughout the project. It was particularly helpful when we brought in the Hotwheels cars.

Resources were somewhat constrained for us this year because the school's main priority was on ELA and Math over Science. As a result, although the school had a computer lab, we were unable to make use of it for activities since it was reserved exclusively for English classes this year. The modern computer projectors were also given to English classes, so we had to request the use of an ELMO when we wanted to project images or videos in the classroom for our activities. Finally, science class itself was restricted to only every other week. In our case, Mrs. Richard more or less delegated science class to our group. Though at first she tried to hold us to the week designated for each subject on the WPS schedule, once it became clear that we were plugging holes in mastery from the year before and preparing for a field trip, she just delegated the activity planning, scheduling, and field trip preparation and follow-up functions to us for the 8 weeks.

The textbooks for fifth and sixth grade were analyzed at the beginning of the project and were found to be very similar. The major differences were that, for example, the two chapters in the fifth grade text on Forces and Motion were condensed to one chapter in the sixth grade text. That the authors intended to teach these concepts twice was evident, so they were expecting incomplete mastery and planning a review. Our review would be more targeted to the concepts reflected in items that that actually were not mastered in fifth grade rather than reviewing the body of material as a whole.

1.1.3 Sponsorship

The activities our team created required many different kinds of materials. Some items were left over from the previous year's fifth grade team's activities, so our group utilized some of these for the first few activities since it was useful to able to redo an activity which seemed to have failed the first time (perhaps because it did no use the correct terminology that would be on the test later). However, as more activities were developed, more materials had to be bought to support new or additional activities even when the concepts were the same. To pay for these additional materials, the sponsorship that had been set up with the American Institute of Aeronautics and Astronautics to support the fifth grade team was extended to cover our enrichment activity project with the sixth grade team as well. After all, we were working with the same students that had been in the fifth grade program when the original materials were acquired.

In return for our developing our activities around aeronautical themes, such as lunar bases, the AIAA agreed to give our group $50 for each activity we developed. We are very thankful for the generous funding from the AIAA. The AIAA gave our group over $600 for the field trip alone and then allowed us to spend $400 more on supplies for experiments and demonstrations.

1.2 Previous Work

Because the sixth grade team last year consisted entirely of biology majors, some excellent activities were proposed for a biology unit that was never delivered to last year's fifth graders. The teacher wanted help delivering the Physics and Chemistry chapters that she was supposed to be covering at that time of year.

The students tried to accommodate her and thus were ill-equipped to do anything original in fields were they were not strongly grounded. They ended up devising solely Biology activities that the teacher could use whenever the class reached the Biology unit.

By contrast, we were quite comfortable building on the physics and chemistry material introduced the year before, but were on shakier ground when it came time for biology. Regrettably, their orphan biology units concerning the carbon and nitrogen cycles were not discussed until the end of our IQP, too late to put to use in our botany program. However, combined with the work we did, the two year effort produced a solid start toward a biology curriculum with a lunar base theme.

However, enough was known about the previous fifth grade project that our team could develop activities that built upon or improved what had been done previously. For example, one of the lunar crater activities from last year involving lots of flour was not received well by the fifth grade teachers last year because of the mess it made. This year, we avoided it altogether and reviewed the phases of the moon before going on to show the students that the Earth had phases from the vantage point of the moon.

Generally, the previous year's sixth grade IQP was regarded as unsuccessful. The fifth grade team's success was mixed, but somewhere better. However, we were looking for gaps in conceptual mastery and inclined to be critical, looking for and focusing on holes and lapses. The units covered by the students as fifth graders covered Matter, Energy, Electricity, and Light; however, concepts such as friction and magnetism from the Forces chapter got short shrift and concepts from other chapters were not demonstrated effectively. Also, the section of the forces chapter on Magnetism was skipped and the whole chapter on Motion was neglected or never reached. The end result was plenty of holes in conceptual mastery for our group to fill.

In terms of the field trip, last year's sixth grade team was also unable to connect biology to the lunar base theme, which was necessary for funding from the AIAA. As a result, the field trip ended up being about matching phenotypes of leaves – a dissatisfying activity by our group's standards because it was data gathering without an underlying scientific inquiry. Our team felt that much more could be done with this opportunity while touching base with the integrative theme.

This year our group was effectively able to apply a lunar theme to all of the chapter activities and the field trip. The Tower Hill field trip very much helped extend the sixth graders' horizons of biology knowledge. The Tower Hill field trip was followed up with a post-field trip concluding activity which allowed the students to apply the knowledge they'd gained at Tower Hill. Unfortunately last year's team was unable to make the most of the trip to Tower Hill; it was more a broadening experience than a data acquisition toward answering a scientific question of making a design decision.

Looking back at previous reports, it was clear that one of the first steps to be taken was to gauge how much conceptual knowledge retention the sixth graders had regarding what was, or was supposed to be, covered in fifth grade. Chapters covered in fifth grade program were Ch. 13: Earth, Moon and Beyond; Ch. 14: Matter, Ch. 15: Energy, Ch. 16: Electricity, Ch. 17: Sound and Light, Ch. 18: Forces (Buoyancy, Friction, Gravity and Magnetism), and Chapter 19 Motion. We developed short assessments on the concepts stressed in these fifth grade text chapters.

1.3 The Sixth Grade MCAS

MCAS data and scores from the sixth graders are confidential, but scores were provided to us near the end of this project by the teachers with the understanding that we would destroy the data after analyzing it and that no names would be used. An itinerary of the actual MCAS questions is provided online as well. One of the first steps of this project was to assess the current standings of the students and to measure how much they remembered of their fifth grade material. For this purpose, we created our own set of assessments for which we borrowed extensively from old fifth grade-MCAS questions. We searched for questions the students struggled with and made sure we put those in our assessments. Poor results on such questions would indicate to us that we should go over this material again in class.

MCAS scores were also used to compare with the relative quality of the expository essays that were submitted by the students for an Essay Contest. The Essay Contest is a contest for the sixth graders that has been running for a few years. It took place at the end of WPI's B-term the preceding year and during C-term this year.

The essay contest, detailed in Chapter 5, was relevant to us because we wanted to compare the students' understanding in class with their MCAS scores for both ELA and Science and the essay contest scores. We wished to see if and how well these scores correlated and whether any particular areas revealed different pools of talent at Elm Park.

Chapter 2

Assessment Data Research

2.1 Initial Assessment

One of the first steps we deemed necessary was to gauge how much information the sixth-grade students had retained from the previous year. This information was vital to our project and would ultimately shape the path we took for most of the project. It was decided that a written examination would be MCAS-like, as well as the most efficient way of gathering these data from the students.

There was an internal debate about how exactly to implement the exams – whether each student be tested on each subject or should each student take two randomly assigned tests to estimate where the class was likely to be. While this was being decided we produced one short 10-minute assessment for each chapter from the **fifth** grade text (i.e. Earth, Moon, and Beyond; Electricity; Sound and Light; Energy; Matter; and Electricity). Since the teacher wanted to get the assessments done in one class period it was decided that each student would be given two randomly chosen 10 minute assessments.

As a practical matter, it was found that, for the sake of convenience, handing out three of the assessments first then handing out the other three as students began finishing the first assessment worked better than adhering strictly to the 10 minute guideline. To preserve randomness, different sets of three were chosen for both classes. Additionally, it was realized for the second class that all of the students should be tested on some basic knowledge from the Earth, Moon, and Beyond chapter since this IQP would have a lunar theme and since the fifth grade text only spent three pages on the moon while the Moon was ignored altogether in the sixth grade text. In order to carry on a lunar theme, our team needed to assume and build on some space and astronomical concepts. As a result, everyone in the second class who didn't take the Earth, Moon, and Beyond assessment was given an additional mini-assessment with three questions on taken directly from the Earth, Moon, and Beyond assessment.

The questions for the assessments themselves were created using concepts borrowed directly from previous fifth grade MCAS tests, oftentimes quoting directly from the original with slightly different scenarios. The team felt the assessments would be a fair estimation of the students' comprehension relative to both the state and national standards. Finally, the assessments were formatted uniformly by Prateek to limit any biases from the students while taking the assessments.

Upon analyzing the data, the following averages in percentage of items answered correctly resulted. They are listed below in no particular order.

Assessment	Average Score
Energy	42%
Forces and Motion	38%
Earth, Moon, and Beyond	47%
Sound and Light	32%
Matter	40%
Electricity	51%

The results of these assessments were drastic; as seen in the table above (and in more detail in Appendices B.1 through B.3), the students exhibited alarmingly low levels of understanding or retention in all the subjects, the least well-understood being Sound and Light with an average score over both classes of 32% and the most well-remembered being Electricity with a 51% average. Although these levels were somewhat anticipated going into the project, some of the results yielded were alarming. For example, only 37% of students correctly answered a multiple choice question regarding how shadows are formed (Question 5 from the Sound and Light assessment located at Appendix A.6). On the other hand that subject was not explicitly addressed in any of the activities the prior year since it was probably considered too much a matter of common knowledge to be worth class time. Not so; indeed a pattern emerged where the concepts stressed in the chapter activity were mastered and those that were not most students struggled with.

Scores of 80% and 20% mastery for similar concepts in the same chapter emerged when one was used in solving the given problem and the other was not. Hence, the averages around 50% mastery were a mix of concepts mastered my most and mastered by few. There were holes to fill in nearly every chapter, but some whole chapters were trouble spots, and not just the chapters that were totally neglected, like Motion.

The next course of action was thoroughly discussed – the whole team, including Professor Wilkes wanted to address the major holes in the students' knowledge, but it was finally decided that it would make much more sense to create the first activity relevant to the chapter being taught at the moment in class, which happened to be sixth-grade version of Earth, Moon, and Beyond. Though the average for that chapter was one of the better ones, there was an item that few in either class understood and it was the subject of one of the better activities the year before. This abysmal outcome on the phases of the moon deserved a closer look.

Professor Wilkes suspected that they understood the basic concept but this question asked for specific terminology that was not stressed the year before. It was decided that we should repeat the activity and then do a variation on it so that the whole activity was review instead of repetition.

Starting the activity by having the students do the same question again as a class and announcing that almost no one got the question right seemed to get their attention and everyone seemed to diligently write down names like waxing gibbons, and we then went on to see if the Earth had phases, and they were surprised to find that it did, but immediately wanted to know the names of the Earth phases. Since they have not yet been named some students got upset, saying that they should be named.

2.2 Final Assessment

Near the end of this project, the question was raised of finding enough class time to administer a final assessment in order to determine whether we had plugged any holes and to be able to quantitatively measure the impact of this IQP. A final review assessment was created recycling questions from previous assessments from chapters our group had done activities on. Essentially, the students were quizzed on the exact same questions they had been at the beginning of this IQP (with some minor shuffling around – the phase of the moon in Question 1 was flipped around and the ordering of Questions 4a, 4b, and 4c on kinetic and potential energy was rearranged). So, on the last day of visiting Elm Park in C-term, Professor Wilkes gave the final review assessments to Mrs. Richards to administer during Math class.

The results of the Final Review assessments were graded over the following weekend, and the results of each individual question were measured against the performance on the same question from the initial round of assessments taken in A-term. These results gave us an idea of how much the students were actually benefiting from our activities in the classroom. The results are tabulated below. Note that *Forces and Motion* was a subject not broached the previous year.

Question	**Chapter**	**Initial Score**	**Final Score**
1	*Earth, Moon, and Beyond*	8%	8%
2	*Electricity*	44%	67%
3	*Forces and Motion*	25%	79%
4a	*Energy*	11%	58%
4b		22%	38%
4c		33%	42%

As visible from the table, there were marked improvements in the students' performance in all areas except Earth, Moon, and Beyond which was gauged by the phases of the moon item. Upon additional critical observation, it appears that the students experienced more improvement the more recently the activity was done. With the exception of Electricity, which was performed in conjunction with a unit on experimentation, the relative increase in performance is evident. What this implies is that the students are only improving temporarily and seem to be memorizing the material instead of understanding it. For example, although the exact same question, Question 1, from the Earth, Moon, and Beyond unit was emphasized and gone over interactively with the whole class in participation multiple times, because it was done earlier on in this project, the students' performance dropped back to the same levels to which it would have been if this review project had never been done. This outcome implies that there is a deeper root cause for these students' poor grades or a problem with this kind of vocabulary-oriented assessment since there was evidence that the students got the idea of why there were phases in terms of the relationship between the Earth, Moon, and Sun.

We considered the possibility that perhaps these students are missing a crucial piece of their education or that they don't excel with memorization and rote learning. It was also considered that these students might benefit from an emphasis on the role of science in the real world rather than learning concepts that seem arbitrary and ungrounded. Perhaps they need to be given faith that a better understanding of these subjects can be obtained through hard work and that it is worth the effort to apply themselves to their studies.

Chapter 3

Classroom Activities

3.1 Phases of the Earth

This activity consisted of the students holding Styrofoam balls mounted on sticks at arm's length and observing the ball, representing the Earth, from the student's, or the Moon's, perspective. The students then were given four Oreo cookies each to carve the shapes they saw using plastic knives. The activity sheet for this activity can be found located at Appendix C.1.

The first day, the students were given a review of what they learned in the fifth grade about the moon phases. Our Earth, Moon and Beyond assessment showed us that they were all confused about the quarter moon phase. They were referring to it as a half moon because it appeared as though half of the moon was shaded. After thoroughly explaining that it had to do with the moon being a quarter of the way through the moon cycle, and demonstrating with a Styrofoam ball, they seemed to understand.

On the second day, the kids performed the activity. The students were given Styrofoam balls that represented the Earth and their heads were the moons per-

Figure 3.1: Professor Wilkes explaining a moon base to the sixth graders.

spective. Last year it was the opposite, and they had to see the moon phases from Earth. We used overhead projectors as a light source to represent the sun. The students took turns rotating the Styrofoam ball (which represented the Earth) around to see the different phases of the Earth. We told the students that they were looking at the Earth as if they were on the Moon. They were given an activity sheet to shade in how the Earth looked from different positions of the moon rotating around the Earth.

In order to make this activity fun and memorable, we handed out Oreo Cookies for the students to carve out. They were split into groups of two and handed out four cookies. They were asked to gently pull apart the cookie so that the white filling is on one side of the Oreo cookie. We questioned/quizzed the students at the end and told them to carve the cookie with plastic knives. The

Figure 3.2: Initial ramp setup was very crude and did not work well.

students were awarded more cookies if they carved the Earth phase correctly.

3.2 Energy and Moon Craters

The next topic we chose to demonstrate was energy, specifically kinetic and potential energy, since it was the next most serious trouble-point we had identified and since there had been a popular activity implemented for it the previous year. The activity developed for teaching energy was designed around crater activities implemented the previous year. It involved dropping Hotwheel cars, used to represent a lunar vehicle that delivers supplies to a science facility about 50 miles from the main base. There was so much traffic on this route that the decision was made to "pave" it by microwaving the lunar regolith to turn it into a smooth black glass.

The challenge was that just before one got to Malapert Mountain, a mountain on the surface of the Moon, there was a large oblong crater with rough territory on one end and another crater on the other that was even wider and deeper. Since going around it was not viable, a bridge was considered. Then, noting that the near side of the crater was higher that the far side near the mountain and the slope was bowl-like, one of the drivers said he thought the potential energy the car had at the top of the near rim could take the car up over the other rim.

A model to test the idea was needed and ramps with smooth, glass-like surfaces were set up to represent a lopsided crater. They were marked at 5 centimeter intervals and the students were asked to hypothesize when the cars would be able to make it to the other side of the crater-ramp.

Very little time was allotted for preparations for the first group. The experiment was performed with short segments of Hotwheels tracks or plastic-coated sheets of heavy paper were set up with cardboard boxes taped underneath for support to shape the tracks into U-shaped "craters." The activity sheet can be found at Appendix C.2.

The experiment was carried out, but not executed very well with such crude equipment. The first day consisted of explaining kinetic and potential energy to the students and repeating the fifth grade activity using the relevant energy terminology and going over the examples they had been given on the Energy Assessment item as a class. Since they'd had difficulty with this concept, we created a new activity for this year. Handing out the Hotwheels cars and ramp setups to have the students play for a few minutes brought smiles to their faces. The students were soon cheering when a car made it up and over and groaning when a car failed to make it and settled down into the bottom of the "crater."

They soon understood that the departure point had to be at least as high as the far rim to make it out the other side.

Although there were only three example questions about kinetic and potential energy, everyone in the class seemed to have a mastery of kinetic and potential energy by the end of reviewing all three questions and everyone seemed adequately able to apply these concepts to the newly-posed question of whether one needed a bridge to cross the crater en-route to Malapert mountain. On the second day, the kids were allowed to perform the experiment formally with measurements and hypotheses. However, it was very difficult for them to understand exactly what was going on since the tracks were so floppy and unmarked, as visible in Figure 3.2. Eventually the students just started playing with the Hotwheels cars and trying to launch the car as high off the other end as possible.

Then we introduced the second part of the question. How could they get back on the return trip to the base going from the low side of the crate to the high side? After they scratched their heads for a bit and started talking about bridges and cable car systems we reminded them that they had made a delivery to a base on a "mountain." The question was how high up the mountain they had to start to successful make the return trip, and how much faster would they be going when they hit the bottom? The last part on velocity got lost, despite having the equation on the board. However, looking at the equation they got the idea that one could make the calculation and that Gravity was one of the factors. Suddenly they had to think about whether this would work in one-sixth of Earth gravity. Most soon understood that the speeds would be different but the principle the same. However, there was a new issue that would return to in a later class – would there be enough friction for the vehicle traveling on a smooth glass road to turn a corner or would they end up stuck in the sandy regolith on the side of the road?

Having proven the educational value of the activity, attention turned to creating a suitable apparatus for this activity that could be part of an activity kit left for future enrichment team to use. Prateek was skilled at laser cutting plastic and had access to WPI's equipment for doing this. There was a maximum size that the system could handle and only one place in the city that distributed the proper material, since we could not use the WPI supply. It would cost a bit more than $20.00 for what we needed but the AIAA budget was $50.00 on average for each activity and the Hotwheel cars had not been very expensive.

Thus, during the two week-hiatus due to Christmas Break, we created three new ramps and "craters" in SolidWorks and had them laser-cut from three clear acrylic sheets purchased from Ultimate Plastics in Worcester. The tracks were sized for the Hotwheels cars and worked very well except for the occasional bump of cooled hot glue on the track. Marks were cut into the track at every 5 centimeters of height to aid with the measurements that added rigor to the data collection part of the activity.

It was found that by the end of this activity the students seemed to understand the conversion between kinetic and potential energy very well and were able to apply it to practical problem solving and theoretical situations to some degree. In any case they had an idea of how to recognize this kind of question on a test and had a vivid memory to connect with the appropriate terminology. One possible improvement for coming years might be to expand on this to show how kinetic and potential energy can be converted to other forms of energy, such as electrical or mechanical, and vice versa.

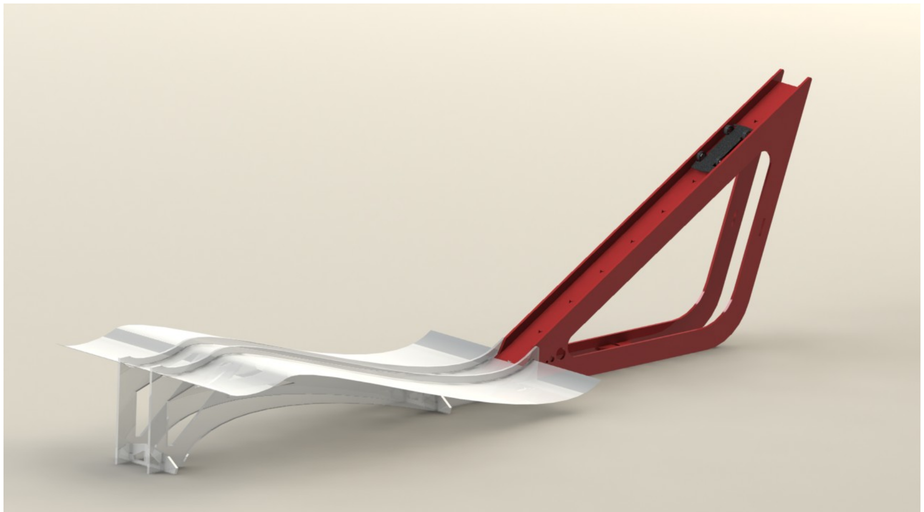


Figure 3.3: SolidWorks model of 30° incline concepts marked at every 5 cm.

Figure 3.4: Completed laser-cut acrylic ramps and craters with Hotwheels cars.

3.3 Forces and Motion

The Forces and Motion activities required more setup than the other activities had, but covering these were essential since the prior year they never built the friction apparatus they wanted to use in an activity and had skipped the Motion chapter. It is surprising that the students did as well on this part of the assessment as they did. Three separate stations and four different demonstrations/thought experiments were generated for these topics. In addition, a Hot Wheels track with three loops and a battery powered car launcher was purchased during the break and constructed during the week. It was about $30 on sale for the usual $50.00, but thankfully we were not operating without a budget, as so many elementary science teachers are. The activity sheet can be found at Appendix A.4.

The first day of activities consisted solely of demonstrations and videos. Unfortunately, because this activity had so many stations and therefore many parts to prepare, the Hot Wheels track was not put together in time for the first class. As a result, the first class was shown a video of a real-life car going around a loop-de-loop. The Hot Wheels track was finished for the second day and shown to the kids at the beginning of the class.

Realizing that showing the Hot Wheels car doing a loop after showing the video of it done in real life with many explanations and calculations already provided was less exciting. We decided to show the second class of sixth graders the Hot Wheels set with three loop-de-loops first, and then showed the video of the life-size loops to demonstrate centripetal acceleration. This proved to be better and received a much greater reaction than with the previous ordering of events. Both classes were then told relatable stories about inertial forces when traveling in a car and during a rocket takeoff, as well as given a discussion on reduced friction forces which would affect a rover's ability to turn on the moon.

With some coaching they soon got the idea that by slowing down for turns they could stay on the lunar road in 1/sixth gravity. We did not get into banking the roads, but we could have.

Finally, Prateek demonstrated a gyroscope to the students by spinning one quickly using a string and then showing that it could be balanced on the tip of his finger and that it would revolve around one point when turned on its side. This seemed especially to have a "wow-factor" on the students because immediately after class ended multiple students came up to us asking where they could buy one for themselves. The gyroscope demonstrated ideas beyond the scope of the sixth grade curriculum – specifically, torques – but the students seemed to enjoy seeing how forces could be manipulated in the real world to perform seemingly impossible tasks.

The second day for both groups consisted of three activity stations set up around the room, one each dealing with inertia, friction, and centripetal acceleration. The inertia station consisted of a simple activity where a coin was placed on top of an index card placed on top of a styrofoam cup and the kids had to quickly flick the index card out, dropping the coin into the cup. The activity was meant to demonstrate the inertial resistance to motion of the coin. The activity worked well and the kids had fun and understood inertia well afterward since in this case they had not expected what happened.

The friction activity consisted of three thirty-degree incline ramps with different materials lain over each – sandpaper, aluminum foil, and wax paper – and three wooden blocks (the sandpaper actually offered so much friction that the wooden blocks couldn't slide down the ramps so the sandpaper was turned over and the bottom face was used instead). The students were shown the ramps and told to feel them and to predict which block would reach the table first if all three blocks were released down three ramps at the same time. In effect they were asked to hypothesize about the friction forces of each ramp. Finally, the experiment was performed. The aluminum foil ramp was the most slippery and had the least friction, so the block from that ramp reached the table first, then the block from the wax paper ramp, and finally the block from the sandpaper ramp. The students were then asked to comment on their previous hypotheses.

The purpose of this station was to experiment with friction and create relationship between the abstract concept of frictional forces and the feeling of roughness of a surface and to demonstrate its real-world effects. However, this was not an exciting activity and the students were subdued at this station.

Finally, the centripetal acceleration activity concerned the simple concepts behind centripetal forces and tangential motion. The students were given small, hollow, plastic balls with strings attached and asked to hypothesize when they needed to release the balls when swinging them over their heads to have the balls hit a cardboard box target against the wall of the classroom about 10 feet away. Most of the students hypothesized that they would have to let go of the string just when the ball was closest to the box. Upon performing the demonstration, most of the students realized they had to let it go sooner than that. Indeed the balls were flying at right angles to what they expected. Some students managed to actually have the ball fly in the opposite direction. The teacher was hit by one of them standing across the room. A few students standing to the side of the box were hit and so was Professor Wilkes when he thought he was out of the line of fire. Few students hit the box the first time and that was sometimes by accident, so we asked them at what point in the arc of the circle they were trying to let go. That made the point better.

Finally, the students were told about tangential motion and how to release the ball correctly. They then wrote down their observations and conclusions before moving to the next station. This was the activity that generated the most enthusiasm and was probably the most memorable. Some boys tried again and again until they got the idea and could hit the box consistently by releasing when the ball was at their side.

3.4 Electricity and Experimentation

In February 2014, we performed an activity on experiment design and Electricity at Elm Park. Because our energy kit did not have enough materials, Mrs. Richard gathered the students around a table to see the activity. Enough materials for three setups would have allowed us to show them the demonstrations in groups. The students were asked to make hypotheses about how the number of batteries would affect the speed of the motor. The motor was set up to turn a propeller so the speed of the motor could be easily visualized and heard, but in a noisy group setting something more easily visible was preferred and so we used several ping-pong-sized balls of various weights and blew them around instead. We then demonstrated how the speed of the motor changed depending on the number of batteries. We used one, two, and three batteries, and showed the students what would happen if a battery was replaced with a dead battery. They were asked whether this would make any difference: would it break the circuit and stop the propeller or reduce the power? Next, we reversed one of the batteries and asked the same questions. We did not have a way to measure the speed of the motor precisely, so we created a slight incline and used the propeller to blow ping-pong balls, fake golf balls, and small whiffle balls up the incline. It took one battery (1.5 volts) to blow the ping-pong balls, two batteries (3 volts) to blow the fake golf balls, and three batteries (4.5 volts) to blow the small whiffle balls. The activity sheet created can be found at Appendix C.4. Thus the students could tell if the three batteries were delivering at the one- or two-battery level depending on placement.

The second week, we carried out the activity by going through the activity sheet with the class as they saw the demonstration group by group. The class was split into three groups. Before the first group, we made sure each student had his or her hypotheses written. This time around we were able to complete the activity sheet because working through it with the students on the overhead projector kept everyone on the same page. Because of the time saved doing the activity in a more effective way, we were able to demonstrate how voltage is not related to battery size or even the number of batteries. We showed the students a large 6V battery and two small 9V batteries to help them further think of the activity in terms of voltage.

3.5 Science Fair Preparation

To prepare the students for the science fair, Professor Wilkes went to Elm Park to demonstrate how to design an experiment. However, it was found the students were not in a good position to propose experiments for the science fair because they could were unable to distinguish the demonstrations and activities we brought to the classroom from actual experiments. Using the experiment worksheet, Professor Wilkes clarified to the students what an experiment is. He then walked them through a sample plant experiment that could be done which involved observing how different light patterns would affect plant growth. The patterns were not arbitrary; they were designed to reflect conditions at different places on the moon compared with the day and night light cycle on Earth. The question to be answered was which pattern would grow the healthiest plants. Relating to moon bases, the question was whether one had to mimic Earth conditions to have Earth plants thrive.

The three situations were to represent plants using natural lighting patterns at the equator of the moon which had a 28 Earth-day long day, i.e. 14 Earth-days of light then 14 Earth-days of darkness. This was the same duration as night and day on Earth but in a different pattern and the students were pretty sure it would matter and not be good for the plants. Thus, Gro-lights may be required for agriculture on the moon.

By contrast, at the lunar poles there is no dark period at all. The students were asked, whether night have to be created artificially by blocking the light, or would the plants thrive in the continuous day of this region? Some students thought they would have more time for photosynthesis and grow faster and bigger. Others thought the plant might get too hot or perhaps the heat would wear out the plants, so they would not do as well as on Earth.

When the students had offered their theories, Professor Wilkes offered another one from professional agronomist and botanist Marc Andelman; he imagined that the plants would grow just fine with no night, but then would never flower and seed since the length of day is a signal to plants about when Winter is coming on Earth.

Professor Wilkes told the students he had no idea whether this was true, but that they could find out. Plants producing more seeds for the next generation was vital to a sustainable lunar greenhouse. The professor asked the students how much it would impact the food supply or the cost of the base if seeds had to be imported each year from Earth.

To test the effect of the three different lighting conditions, the class was given three hydroponic plant incubators with Gro-lights that the IQP team supplied using their sponsored money from AIAA. They cost $62.00 each not counting seeds or chemical kits that then pushed the price up to $80.00 each.

The next day the students would learn to use the apparatus and figure out what data they needed to gather and what procedures to use. A major complication was that the lights have timers and cannot be set for 17 hours of light and

7 hours of darkness. It would be necessary to manually override the preset light pattern. It was also soon clear to them that to make the conditions identical, except for to light all three incubators, would have to be completely covered so that the only light would come from a Gro-light of the same power set at the same distance from the seeds. They decided that a cardboard box at least 22 inches deep (so they could move the Gro-light up as the plants grew) would be needed. To avoid a fire hazard and increase the lighting, they would need to line the identical boxes with aluminum foil. Since this NASA-approved equipment made plants grow ten times faster than normal, the plants could get through a growing season in a month and could be finished growing approximately ten days before the Science Fair.

Since there were concerns that this experiment was too "coached" to be a science fair entry, the students were given a list of ideas for plant experiments and were to think of the factors that might affect plant growth. This was similar to some online listings of project ideas teachers at other schools were using.

When the science fair organizers were contacted, they approved all the ideas from Elm Park – including the plant light class experiment if it was turned over to a three person-student for execution. Mrs. Richard was glad to see some students step up to run the experiment for the class. On March 25th, the students were ready to turn on the Gro-lights but had yet to write out the class hypotheses.

The class voted on which of the ideas was most interesting and decided that the most interesting questions were whether water could get too "clean" for plants to thrive, how much extra carbon dioxide was needed to get C3 plants to thrive better than C4 plants, and whether nitrogen-fixing plants make the plants nearest to them grow better than those further away. A close runner-up was whether plants need animals to thrive. The students were curious about insects that pollinate and worms that facilitate the composting of organics in particular.

With regard to over-coaching the students, we concluded that we would provide the incubators to do the class-designed experiment whether or not a three-person team ran it and decided to enter the science fair giving proper credit to the source of their hypotheses. This was a class exercise and it was fine if it was nothing more than that.

Chapter 4

Field Trip

4.1 Background

The students of the sixth grade at Elm Park School visited Tower Hill on January 24, 2014 by bus. Fifty-two students (both sixth grade classes) attended this event, along with three chaperones and the sixth grade curriculum science team of Professor Wilkes, Taryn Roy, Sean Smith, and Prateek Sahay. Because of scheduling conflicts, Taryn attended the field trip for the first half until the lunch break, and then went back to WPI for classes. Meanwhile, Professor Wilkes drove Sean and Prateek to Tower Hill and arrived just after lunch break ended.

4.2 Events

As soon as we arrived at Tower Hill Botanic Garden, the kids were led to the auditorium where Marc Andelman gave his presentation about plants and their significance if and when we are to travel to the moon in the near future.

Marc Andelman is a part time lunar agronomist. An agronomist is a scientist that studies the science and technology of producing and using plants for food, fuel, fiber, and land reclamation. His studies include doing this on the moon and finding ways to produce food and live on the moon in the future. He started by telling the students that they are 60% genetically the same as a banana. The students found this incredible. They did not know this was possible since they are so phenotypically different.

He then explained to the kids that plants are capable of making lots of food and other common products. He gave examples such as: medicine, chocolate, rubber, perfume, vanilla, cinnamon, silk, and chewing gum.

To introduce the lunar theme to the students, Marc Andelman showed a photo of Shackleton Crater from his PowerPoint onto the projector. He explained how it was located on the South Pole of the Moon. He explained how the peaks of the craters were continuously in sunlight, while the deepest part of the crater was cold and dark. There were panels above the greenhouse on Shackleton Crater that are facing the sun at all times in order to produce light for the plants.

Andelman gave an example of a plant that he claimed would be very useful, nearly essential, on the Moon. Cattails are wetland plants that grow in swamps and ponds that grow to be from 3-10 feet tall. They are six times more productive than the famous crop of corn, but nobody realizes that cattails are edible. Their roots are 100% starch and edible. The fact that they can be used as food is just an additional resource. The main reason why these cattails would be so essential on the Moon is because they are a great way to purify and cycle water. They are valuable resources on both the Earth and the Moon, but on the moon all parts of the plant would be useful and the seeds in the brown top are a good source of protein.

Photosynthesis on the moon and Earth were then compared by Andelman. He explained how carbon dioxide buildup from people breathing would poison the air for people in a lunar base. It is important to have plants on the Moon so the plants can use the carbon dioxide and produce food (sugar/starch) and oxygen for humans.

Mr. Andelman then went into the history of plants. 600 million years ago, the only plants that existed were algae. This time period was before the dinosaurs existed. He explained how the Devonian period consisted of trees and swamps, but nothing with seeds existed yet. The third time period he introduced was the seeded plants. The seeded plants still did not have flowers yet during this time. Finally, the flower plants came along during the time of the dinosaur period. Marc Andelman told the students that there are over 10,000 kinds of flowers in the world. He asked them how we can tell what type of flower we are looking at, and the students replied with the color of them. He responded by informing them that many flowers have the same color and that the real way to distinguish flowers from others is their anatomy. Plant experts tear apart flowers to determine the anatomy of what they have.

Marc Andelman described the two different types of flowering plants: monocots and dicots. Monocots only have one seed leaf, while dicots have two seed leaves. Monocots have parallel veins in their leaf, while dicots have "net-like" veins in their leaves. Monocot petals also have petals in multiples of three. Mr. Andelman told the students to keep this in mind while looking for plants in the greenhouses.

Grasses like wheat that we use developed existed after the time of the dinosaurs. This is because of the levels of CO_2 in the air have changed. There was ten times as much CO_2 in the air during the time period of the dinosaurs than there is now. Under those conditions C3 photosynthesis-plants dominated the Earth. Over time, plants produced so much oxygen that they started to poison themselves and the Atmosphere is now 21% oxygen and the the CO_levels have dropped from 3000 ppm to about 300 ppm today. Also, the way C4 plants which could minimize the toxic effects of Oxygen for plants evolved and now make up 69% of the vegetable mass on Earth.

But, we are burning coal and oil and returning carbon dioxide to the atmosphere. Before we started doing that the carbon dioxide level was under 200 ppm. As we return carbon dioxide to the air it is not good for animals including us and the C4 plants, but the C3 plants are getting advantages from it and may start to recover their former dominance. That is why we think there is now too much CO_2 in our atmosphere. In the past there was more, but not while we existed and it is responsible for global warming. The Earth was hotter and wetter when the dinosaurs roamed the Earth.

To make sure the students understood this, Marc Andelman told the kids that we need plenty of plants if we were to live on the Moon because they consume CO_2. He told them that a surplus of CO_2 would cause sickness among the humans that are the base crew. So people need plants to balance the biosphere, and in a closed setting like a moon base the plants need animals too. It is not clear that they need animals on Earth, but over time the two have come into balance with each other.

Mr. Andelman switched topics to how plants have unique climates in which they prefer to live, and survive better. He used taro as an example and told the students that it is a tropical plant. When people tried to bring taro to Russia, it died. He then brought up the term, "grafting" which means breeding closely related plants together to form a hybrid.

Plants "breathe in" O2 and CO_2, according to Mr. Andelman when describing how plants function with the atmosphere. Plants used to "suffocate" with too much oxygen and too little CO_2, but then some adapted to the changed atmosphere and C4 plants emerged. He described this as direct evidence supporting the theory of evolution, the gradual process in which something changed into a different form. C3 plants grow fast with higher levels of CO_2, while C4 plants grow better than C3 plants in low levels of CO_2. Changing the atmosphere will change which plants thrive in their environment. For example, weeds are a C4 plant, while grass is a C3 plant. If there is a decrease in the CO_2 level, the weeds will overtake the growth of the grass and could possibly take over a whole grass field.

Microscopes are needed to determine if a plant is a C4 plant. If the cells are in rings, it is usually C4. These rings capture CO_2 efficiently. One student then asked, "What if there's too much CO_2 in the air, what will the plants do then?" Marc Andelman's response led to the history of Earth's CO_2 levels. He explained that 100 years ago, the sun was cooler, which caused fusion. He then explained how the sun's temperature is increasing with time. This led to a discussion of the sun blowing up, and Marc Andelman relieved the students by telling them this would occur five billion years from now.

When the students heard that the sun will blow up and humans will not exist, this took the topic off of plants. They were asking how Marc Andelman knew the sun would blow up, and he responded with a complex answer that the students could not understand. Instead of the students leaving the speech wondering about plants, they were distracted by a chance comment in response to a question that raised questions about the future of the human race and life on Earth. That was unfortunate. It would now be our task to bring them back to the topic in greenhouse design activities that would build on the Tower Hill experience.

Before the students were dismissed a student asked Mr. Andelman, "How much would it cost to send plants to the moon?" He answered that they would not send whole plants to the moon, but only seeds. Water is too heavy to carry to the moon, and this is why cattails and other plants that process water are

Figure 4.1: Students exploring the Orangerie at Tower Hill Botanical Gardens.

essential on the moon. This will circumvent the need to gather water from the bottom of Lunar craters at the poles or transport water to the moon.

Mr. Andelman ended his speech by saying there is a drought in California, and as a result, vegetables and fruits will become expensive. Now that the rain is limited, they need to compensate for the loss of production by increasing the prices. Marc Andelman told the students to plant their own fruits and vegetables this spring to save money.

Mr. Andelman's speech ended strangely but for most of the time was very informative and he excited the students as he walked with them through the greenhouses at Tower Hill answering questions and talking about exotic plants, especially one that eats insects. However, he also could point out plants with practical uses from the production of paper to rubber.

His speech was recorded to use for future field trips to Tower Hill in case he is unable to attend for future years. The speech was recorded using equipment provided by the ATC Office at WPI.

4.3 Tour and Scavenger Hunt

After Marc Andelman's speech, the students were separated into three different groups. One group went with Ann Marie Pilch to pot plants that they could then take home, one group walked around with Andelman working on the scavenger hunt that our IQP team provided, and the last group listened to a talk on keeping the plants alive indoors in the greenhouse. These three groups were rotated every 45 minutes.

Marc Andelman's tour with the students interested the students. He gave examples of C3 plants and C4 plants. He showed them papyrus and told them that this was used when the first piece of paper was made, and also noted other plants that would be essential for traveling to the moon.

The scavenger hunt, as seen in Figure 4.1, was constructed to show students some plants that would be useful on the moon, but in a fun way. We marked plants with orange and yellow flags in each of the two Greenhouses, the Limonaia and the Orangerie. The plants that were marked are located in the chart below. The plants were marked because there were around 100 plants in each greenhouse, and we wanted to point the kids in the right direction. The marked plants were the ones that were mentioned on our worksheet/scavenger hunt (Appendices D.4 through D.5). There were 10 questions on the activity sheet, but the students only had 30 minutes to complete it. We wanted to narrow the search time for finding the plants, and actually have them find the plants quickly and decided which plant correctly matches with the question. Most of the questions were multiple choice. We made the questions related to resources on the

Figure 4.2: Marc Andelman lecturing on a bird-eating plant at Tower Hill.

moon. We also wanted to have the students pick one beautiful plant from the greenhouse that would remind them of Earth when they get homesick.

The students enjoyed the scavenger hunt (Figure 4.1) and were very impressed with the names of all the plants. They were asked to find which plants they considered beautiful and which plants would be useful as resources if they were to have greenhouses on the moon. They were then asked to see if these lists had any overlaps. Not only did we want the kids to find food and staples, but the "beauty" was an essential part too. They were all asked to pick a plant that reminded them of home and why. This was to make a greenhouse on the moon that left a home feeling.

4.4 Lunch

Elm Park School provided lunch for the students so it did not cut into the AIAA budget. Lunch break was from 11:30 am – 12:15 pm.

4.5 Planting

Ann Marie Pilch helped with the organizing and planning of the trip. She was in charge of the planting station. The kids were to choose from about seven different types of plants and a small part of the stem was cut with assistance from Taryn, one of the teachers, and Ann Marie Pilch. They were then asked to shovel in dirt about two inches away from the rim of their pots. The plants were then planted and labeled. The plants were boxed and brought back to the school, and the students were allowed to take them home.

4.6 Field Trip Follow-Up Activity

During the preparation for the Tower Hill field trip, Dr. Ladd spoke about nutrition and diseases associated with various vitamin and protein deficiencies. She prepared some handouts at that time, but did not have a chance to distribute them. We used those materials in the aftermath of the field trip. The first page consisted of a table of useful staple plants. Few of them were on display at Tower Hill, but the students now knew how to classify plants so they could tell which one needed which conditions to thrive. The table provided information on their CO_2 type, preferred temperature range, calories produced, protein, vitamin richness, and where they are native to the region.

Using the information on this table, the students were then asked to list two of their favorite plants, two plants with the highest calories, two plants high in

Figure 4.3: Plant potting activity at Tower Hill Botanical Gardens.

protein, and two plants that are vitamin rich. After describing what they thought was the most attractive plant in the Tower Hill Gardens, they were then asked to consider what plants need to grow well and then group them into two greenhouses, one of which would have twice as much carbon dioxide in the air as the other. They could also make the temperatures different. They were also to decide whether the bigger or smaller (one was twice the size of the other, just like the two greenhouses they saw at Tower Hill) one would have an atmosphere in which humans could comfortably breathe. It was pointed out that most of the staple plants were C3 and they benefit from more carbon dioxide than humans can handle without an oxygen mask. The rest of the packet included information about deficiencies that occur from lack of vitamins, plant types and plant characteristics.

Due to snow storms and vacations, only one class had both days to work on the follow up packet and only one group was able to finish. The group that finished was asked to decide if they believed temperature or carbon dioxide was more important for growing plants, and based on their decision they decided how to group the plants in the two greenhouses according to their most important criteria.

4.7 Concluding Remarks and Recommendations

The field trip from the previous year involved going through the greenhouses matching leaf shapes and there was no preparation for the trip and no follow up. From our perspective, this was a fair amount of money to spend ($7.00/ student) last year on what was more of a broadening experience without a lot of science introduced and no problem to solve. The students thought it was beautiful and interesting, but lacked a theme. Ours was not a perfect success, but we were able to tie the Tower Hill field trip to a lunar theme very well.

To improve the field trip, it should be planned earlier next year, and the activity sheets should be created before Winter Break. The talk delivered to the students should also be strictly related to plants so it does not get off topic. We simplified the data sheets as we tried the activity several times. Our advice is to start with the simple ones we had at the end.

Chapter 5

Essay Contest

5.1 Introduction

The Essay Contest has been held twice, the pilot program last year at only Elm Park is the one relevant forerunner to the contest this year. The contest last year was run by an overstretched fifth grade curriculum team. This year there was a whole team dedicated to running it on the larger scale but we wanted to process the sixth grade submissions personally to enhance a data set we were creating. The prompt was negotiated with the English Language Arts and Science curriculum coordinators and then given to the Elm Park students on February 7, 2014. This year the essay was to be expository writing whereas last year the rubric had emphasized imagination and rewarded creativity. The students were given two weeks to write their essays, which were due on February 25, 2014. (Elm Park was actually given more time than the other participating schools that were told one week by the central administration.) The fifth grade prompt was related to the search for water on the moon, so it tied to the lunar base theme that we had been working with this year. However, the students in sixth grade that we were working with wrote about Mars rovers. Still, it was a space and science theme and our students had been exposed to such material for 2 years and were writing their second essay of this type.

Our sixth grade science curriculum enrichment team was looking for ways to identify science talent, and wanted to see if there was a correlation between the winners of the Essay Contest and the top students that excelled in the science activity programs in the classroom.

Our data actually referred to mastery of the fifth grade concepts, and the tie to our program was indirect, but we still got to compare in class quiz scores to essay performance and MCAS scores. The essay prompt is reproduced below for the convenience of the reader from the official prompt (included in Appendix E.1).

> *A little over a year ago, the rover Curiosity landed on Mars, marking the beginning of a new adventure and another chance to learn more about the "Red Planet". Two other rovers, Spirit and Opportunity, landed in 2004. Spirit is no longer operational, but Opportunity still provides us with valuable data. Describe the differences among the rovers Spirit, Opportunity, and Curiosity, including their tools, their power sources, and their goals. What challenges did NASA have to overcome when preparing to land on Mars?*

The students were able to use the chapter on Mars Rovers from Dr. Bortz's book, "Seven Wonders of Space Technology," and the NASA website. The book was written before Curiosity landed so the NASA website filled in that gap. The essay had to include 500-1000 words. The rubric graded across four different categories: scientific accuracy, spelling and grammar, organization, and comprehension (Appendix E.2). There was more weight on the two categories scientific accuracy and comprehension. Students were able to work at home and in the classroom. We were fortunate that the teachers allowed the students to work on their essays during class time, but not all the sixth graders participated.

Taryn was assigned to assess each of the sixth grade essays that were handed in. Unexpectedly, only 23 sixth grade essays were submitted into the contest from a pool of 55 students at that grade level – fewer than half. This was disappointing as we had hoped all the sixth graders to participate in this essay contest and thus lost a lot of data points when they did not.

The main purpose of performing this correlation with the students was to see whether the same students excelled across all categories or not. There would be practical consequences since an after-school science program was proposed by Taymon Beal who was also trying to create a WPI student science education service club called "Reach for the Stars" specifically geared toward nurturing the best students at Elm Park.

The purpose of the organization would be to nurture those students who showed promise in science and to encourage them to consider a career in science. We made it our job to identify the potential star students for this project. The principal thought MCAS scores should be used, but the teachers wanted to make subjective judgments based on classroom grades and behavior, while the WPI students thought a creative expository writing assignment using nonfiction sources would be more revealing.

Our job was to see if it matters what you used and express an opinion about what was most promising. Our own concept mastery assessments could also be added to the mix of possible talent search indicators. However, most science talent search programs depend on ratings of science fair entries. That possibility was lost to us when the sixth grade science teacher decided that her students would not participate in the city wide science fair. However, Taymon countered by offering to recruit WPI students to come after school and coach sixth graders who wanted to enter the regional fair two months later.

Taymon, who was on the fifth grade project team last year, met with an Elm Park school administrator and was encouraged to establish an after school program for advanced students who were no longer challenged in class. One possibility was to have these students design and test an experiment for the Science Fair. Elm Park can send up to 10 teams of not more than 3 students to his fair. We were hoping that seven sixth graders might be interested in this opportunity.

Based on assessments of the students' MCAS scores, Essay Contest scores, and assessment scores, Taryn has provided groups of students that excel in the different areas. This should yield an equal number of students with high level writing skills and high science skills to form teams. These student teams will have coaches that will brief them and assist them with the experiment they want to do.

5.2 Results

For confidentiality reasons, each student was assigned a number, and in this paper, only the student numbers will be used except for the Essay Contest winners. The Essay Contest winners are shown below; two students tied for second place.

First place	Elvis Morocho
Second place	Hazel Rivera
Second place	Melyssa Oliveria
Third place	Gabriel Hernandez

These scores are based on the rubric that was developed by the IQP Essay Contest team which negotiated with the Worcester Public Schools curriculum coordinators. The other nineteen Elm Park sixth graders to write essays are rank ordered in the complete table of results, which appears in Appendix E.3.

The assessment data was very interesting. Two assessments were handed out: one before we started our classroom activities and one after our classroom activities. The table shows the student number and their corresponding grades for each assessment. In one column, there is the percentage that shows the difference from the first assessment at the beginning of the year with the assessment at the end of the year. This data shows which students have the ability to retain science concept information from the year before and which ones benefited the most from a review this year. We consider this almost like getting a "most improved" award. The most improved students from the sixth grade class consisted of the following students.

Student	Improvement
43	65%
53	43%
25	39%
42	38%
19	36%
54	35%

The averages of both assessments were also taken and the following students had the highest overall scores.

Student	Average
32	79%
48	72%
35	68%
20	67%
19	65%

Student 19 appears on both lists, though a big jump into the top ranks was not expected.

MCAS scores for the Science and English sections were given to our team to assess. They were shredded post-analysis to preserve confidentiality. The students with the highest Science MCAS percentages were the following.

Student	Math MCAS Score
48	65%
32	48%
35	45%
39	45%

We wanted to determine the students with the highest English MCAS scores to compare them with the scores from the Essay Contest. The students with the highest English MCAS percentages were the following.

Student	English MCAS Score
48	65%
25	63%
29	60%
39	60%
19	58%
32	58%

Looking back at the Essay Contest, the students who excelled in the English portion of the MCAS scores had the following Essay Contest scores.

Student	English MCAS Score	Essay Contest Score
48	65%	74%
25	63%	68%
29	60%	*No essay submitted*
39	60%	95%
19	58%	96%
32	58%	*No essay submitted*

There seems to be a relationship between the students who scored highly on their English MCAS scores and their Essay Contest scores.

5.3 Moving Forward

With the following results, Taryn proposed some groups of students who showed promise and should be considered for strong science fair teams. Taymon claimed that he should be using an indicator of motivation, passion or interest, but Professor Wilkes contended that to encourage students to try you must show that you have faith in them and tried to put them with other strong students who have something to contribute. So, it was determined that it was equally legitimate to recruit them and to wait and determine which students, if any, were self-motivated. The following proposed groups are composed evenly of students with high science scores, high English MCAS scores or a high score on the Essay Contest, and students who performed well on the concept mastery assessments averaged together or who improved greatly from the beginning to the end in response our activities in class.

Group 1:

- Dan Tran
- Hazel Rivera
- Yeimy Vinatoro

Group 2:

- Brendan Mozer
- Elvis Morocho
- Miguel Ortiz

Group 3:

- Ohemaa Pipm
- Samantha Torres
- Yariann Hernandez

Group 4:

- Gabriel Hernandez
- Melyssa Oliveira
- Lennox Santiago

Overall, there were many students that overlapped in these areas. Student 19 excelled in practically every section on the charts: English MCAS scores, Essay Contest winner, assessment improvements and assessment overall average. Student 48 excelled in the assessment average and both the science and English MCAS scores. Student 35 did well on the science MCAS and the assessment average. Student 32 did well in the science and English MCAS scores, in addition to the assessment averages. Student 25 greatly improved in the assessments and excelled in the English MCAS scores. The students that our team considered to be above average compared to the rest of the sixth grade class were students 19, 25, 32, 35, and 48. These students that we considered promising for a long term encouragement and talent nurturing program like "Reach for the Stars" do not all look the same on all assessments but they did show up as promising on at least two indicators, a form of cross validation.

Thus, the answer to our original question was that there is little to no correlation, but by combining the indicators to get an overall picture, potential star pupils can be identified and strong student teams can be created. All of the identified students should be encouraged to enter the after school program, but any other students that strongly want to be part of it should be allowed to participate as well. Interest, ambition, motivation and passion all come together to define intellectual ability.

Chapter 6

Recommendations and Conclusion

6.1 Moving Forward

Our general conclusion was that we succeeded in three main and that set major precedents that could make a difference to the students of Elm Park.

First, we grounded our plan in explicit knowledge of the students' experiences in fifth grade. We understood what had been covered well and what had neglected, and took the time to see how much of what was covered was retained by the students. This led us to conclude that mastery and retention of concepts not used in an application or problem solving effort were unlikely to be retained, and perhaps were never truly mastered to begin with. The chapter-by-chapter assessments are available to future teams without the need to spend a month creating them in Appendix A.

Secondly, we pioneered the multiple-measures-of-student-promise approach by looking at which students were excelling in several different categories rather than accepting that the state achievement test was the most important outcome measure.

Finally, we were finally able to produce a biology unit tied to the lunar base theme and were able to successfully integrate the field trip into the course material as well. Along the way, we used the field trip to lead into a lesson on experimental design and acquired the equipment to perform something memorable with the students. The resource requirements were substantial but if Tower Hill is to be a regular part of the 6th grade experience, it will be well worth the investment.

Overall, we succeeded in enriching the sixth grade class with hands-on activities, involved the students in an essay contest, and organized a field trip while plugging holes left over from the previous year and making sure that science remained the fun class. There is definitely more to do, but we think the approach we used shows great promise and that we used the AIAA resources effectively. We want to thank the sponsors thoroughly once again for enabling us by eliminating the concern for a lack of funds. Without them we may have been prevented from doing the kind of activity-rich program we envisioned and ultimately realized.

6.2 Kit Development for the Future

6.2.1 Phases of the Earth

The costs involved with all of the following activities are listed in Appendix C.6. If a future team decides to repeat the Phases of the Earth activity, we have some recommendations for the kits. To make the activity less confusing, the future team should attempt to purchase blue-colored balls to represent the Earth, instead of the white Styrofoam balls that we used. Using the white Styrofoam balls confused some of the students because they thought it was supposed to represent the moon. The students had done almost the same activity as fifth graders for phases of the moon. Any blue cookies could also be used instead of the white cream of the Oreo to further illustrate the shading of the Earth from the moon's perspective.

6.2.2 Energy and Moon Craters

For the first day, we still recommend the Hotwheels tracks be used to let the kids play around with them and bend them in different ways to see what can affect potential and kinetic energy, and the acrylic ramps should be used on the second day. To improve this activity, the ramps can be made to look more like the inside of a moon crater, and the end extended or lifted higher to prevent the cars from falling off of the ramps. Perhaps papier-mâché could be used, although transporting it to the school might become very hard.

6.2.3 Forces and Motion

Each station had appropriate materials, and if these activities were to be repeated next year, these materials can be used for the next Forces and Motion kit.

6.2.4 Post-Field Trip

The information given during the Tower Hill follow up activity was useful, but the table was too complicated for most of the students. The follow up packet should be taken down to the sixth grade level. It is currently more suitable for 8th graders.

6.2.5 Electricity/Experimental Design

The kit for next year should have at least two more propellers and something else that indicates the strength or current of the motors, so the kids can be split into groups instead of either showing the whole class, or giving them just a brief look by showing them to one group and then another.

The table in Appendix C.6 lists the costs of all of the materials used by this project group organized by activity.

6.3 General Recommendations

We have several recommendations for improving this project for future teams.

The sixth graders thought that the activities and demos that we were doing during classes were actually experiments. When preparing the students for the after school Science Fair Program to be operated by the Reach for the Stars, we asked the students to think about what experiments could be done.

Many students described the activities that we did in class, and did not understand the difference between an experiment and a demonstration or illustration. Their text is not very helpful in this regard either, stressing data collection over answering a question stated as a hypothesis. The hypotheses were not critical to their conception of an experiment. In retrospect, our team should have made it a point to make this distinction. We could have also given more examples of actual experiments throughout the two terms that we were visiting Elm Park.

We had to repeat activities because the classes alternated each week. It would have more efficient if we were able to do an activity a week, since this would have allowed for more activities. Unfortunately, we could not control this because of the lack of classroom time dedicated to Science.

The field trip preparation was executed relatively poorly because it was difficult for us to come up with an activity sheet and plan the field trip during winter break when we could not meet. Therefore it was rushed when we returned. The activity sheet was put together only two days before the field trip. The field trip was moved two days back because of a snow day. This gave us more time to prepare and make last minute changes to our activity, but it also put us a little behind schedule for the rest of the year's activities.

Because the postponed field trip was on a Friday, planning for the post-field trip activity was delayed. Mrs. Richard expected a plan for the following week's post-field trip activity on the Friday before our visit to the school but we were not prepared that week. The following week when the second class was due to do the post-field trip activity, classes were canceled both Tuesday and Wednesday because of snow. As a result, because the classes alternated, we were thrown off schedule. The class the following week had already done the post-field trip activity so the second activity for post field trip had to be done before the other class started the activity. Our suggestion to future teams is to have the school arrange for both classes to have science class in the same week so the chances of snow days affecting the schedule will be reduced.

Professor Wilkes learned later in a meeting that there was a computer lab in the school. However, when he asked how to schedule it he was told that was impossible since it was "owned" by the English language program to do a special program to push literacy. Every class in the school has to have access to the room at least once a week. It is never free during the day for science activities, though it may be able to be used after school.

When we heard of this lab we were initially excited – we imagined we might have used it to coach the students to research information for the Essay Contest. We also could have had the sixth graders research specific plants, vitamins, and resources as preparation for both the field trip and the post-field trip activity.

Because we were unaware of the computer lab we made paper charts with all the information the students needed for the activities. However, the charts were too complicated for the sixth graders. Part of the problem may have been that we compressed information into a table, unaware the most of the students did not know how to read a table. Time needs to be allocated to table interpretation so the students can effectively complete the proposed activity. The Internet would have been very helpful for some of our activities, especially the pre- and post-field trip activities. However, the science program has to do without a dedicated ELMO and access to the computer lab. These resources are available primarily for the English program,

In B-term, Sean and Prateek's schedules allowed for them to attend the school on Tuesdays and Wednesdays from 1:40–2:20 pm. Taryn could attend on Wednesdays, but was unable to go on Tuesdays. Having the four of us (Professor Wilkes, Taryn, Sean, and Prateek) and Mrs. Richard supervising the class allowed us to break the class into three to four large groups for each activity and have one or two roamers in case extra help was needed.

In C-term, attendance was a huge issue while visiting the school for activities. The majority of the term, only Professor Wilkes and Sean could attend the school, leaving only three adults in the classroom. Mrs. Richard usually was not briefed prior to our visit, so she was unable to lead a group. This made it more difficult to keep all of the students focused. Prateek and Taryn's schedules did not allow for them to go to the school on Tuesdays and Wednesdays due to classes. Sometimes neither Sean, Prateek, nor Taryn could attend due to meetings and classes when their assistance was needed. In these cases, a student from last year's team, Taymon, volunteered to accompany Professor Wilkes to Elm Park.

Professor Wilkes also had Dr. Ladd (a medical doctor who has worked in public heath) come to help during a break when our group was unable to run an activity. In the future, we recommend to IQP students to make sure that class schedules do not overlap with the times for science class at Elm Park School. Planning the classes around this hour of going to Elm Park is crucial for the success of an activity-rich program and boosts the students' understanding of the material. If all of us could have been present all three terms, more could have been accomplished. Maintaining control was particularly problematic the day taht a substitute was teaching. He had trouble organizing the class into small group activities, and even when Mrs. Richard was present it took 5–10 minutes to organize the class.

Magnetism is a subject that should definitely be taught next year, because looking at the students' MCAS performance, the score on questions related to magnetism was especially low statewide. Magnetism should have been one of the first activities covered in this project, but it was not scheduled to be done at this time of year and did not get flagged in our assessment either so the lapse was not realized until far too late.

There were a few more things beyond our control that could be improved for next year's class. Elm Park could consider a few things for future years while working with us. First, it is a fact proven by many schools that students learn better when there is a specific teacher just for science. This would be a huge benefit to the science education for the students of Elm Park. If there are over 60 students in next year's class it is expected that a third teacher will be hired, so we strongly encourage Elm Park to consider getting and holding a science teacher. It was a setback to us that the Science teacher doing sixth grade last year who wanted to work with us was no longer there due to this class sizing rule. If this is impossible, it would be nice if our group had had more time with the students. Science class needs to be longer when there are activities to be set up. We rarely finished a prepared lesson plan.

The main problem identified with the students was that they were memorizing science concepts as if preparing for a test. This was a general problem but it especially hampered us given out goal of having the students apply what they had learned to solve a problem associated with a lunar base. It might help if one had time to walk them through many more demonstrations of each concept. Spending more time on each would have helped even if there were no more activities and demonstrations.

Finally, a meeting was scheduled in January 2014 with several of the teachers and the school principal in attendance, but was canceled on the day of due to a surprise bomb scare at Elm Park Community School and never rescheduled. Our group intended to go over the assessment results and conclusions that we detail in this paper instead. This meeting should ideally have been rescheduled but to date no one but us has seen those results and commented on how best to address the lapses we did not have time to address.

It is also evident that the fifth and sixth grade teachers rarely discuss what has been done before and how to build on it. Our efforts to do so were considered quite radical, and so was our assessment of what was supposed to have been covered the prior year. It seems that student teams normally just assume that what was covered does not need to be repeated. Redoing things already mastered is not targeted since the texts in use go over them again indiscriminately. Attention to a staff and student information support system might be time well spent.

6.4 Remarks

The students' and Mrs. Richard's reactions to our activities, with only a few notable exceptions, indicated to us that our activities were especially memorable, engaging, and inspiring. We believed the most important things to keep in mind when designing the activities was to make them memorable, fun and engaging, and that the activities should build upon one another. The students very much enjoyed the activities involving Hotwheels about centripetal acceleration, for example, because they enjoyed watching the triple loop-de-loop track with multiple cars going at once. However, although the Hotwheels cars were especially popular, they were also difficult to connect with the lunar theme. We found the connection between cattails and the lunar theme unexpected. During the field trip, many students were shocked to learn that cattail roots were edible and could be used to purify water. This group went out of its way to make sure that the activities that excited the students were repeated because we believe these are the concepts the students will remember better and will be able to apply more easily in the future. We would very gladly advise future IQP groups doing science enrichment to adopt a similar approach.

Appendix A

Assessments

A.1 Earth, Moon, and Beyond

Earth, Moon, and Beyond

Name: ______________________________ Date: ________________

Follow the directions below. Circle the most appropriate answer for the multiple-choice questions.

1. Fill in the blanks below using the words from the word bank below

Sun	Equator	Rotate
Orbit	Axis	

   a. _______________ The star at the center of our solar system.
   b. _______________ To spin around an axis.
   c. _______________ To travel in a closed path.
   d. _______________ An imaginary line that passes through the Earth's center and its North and South poles.

2. How many stars and planets does the Solar System have?
   a. Seven planets and seven stars.
   b. Eight planets and one star.
   c. Nine planets and three stars.
   d. Ten planets and fifty million stars.

3. Which of the following planets is the largest?

   a. Saturn b. Neptune c. Jupiter d. Earth

4. Which of the following planets is closest to the Sun?

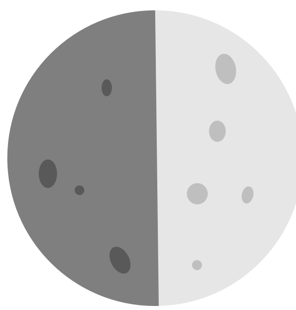
   a. Saturn b. Mercury c. Uranus d. Earth

5. What is of the following is a way scientists classify stars?
   a. Size
   b. Color
   c. Temperature
   d. All of the above

6. Which season has the most hours of daylight?

   a. Spring b. Summer c. Winter d. Fall

7. How often does Earth's moon appear to change?
    a. Weekly
    b. Monthly
    c. Daily
    d. Yearly
8. Approximately how often do the phases of the moon repeat?
    a. Every 48 days.
    b. Every 12 days.
    c. Every 29 days.
    d. Every 15 days.
9. What is a solar eclipse?
    a. When the moon seems to completely cover the Sun from the Earth's perspective.
    b. When the moon passes through Earth's shadow
    c. All of the above.
    d. None of the above.
10. Which phase of the moon is represented below?



    a. Half moon
    b. Quarter moon
    c. Waning crescent
    d. Full moon

A.2 Electricity

Electricity

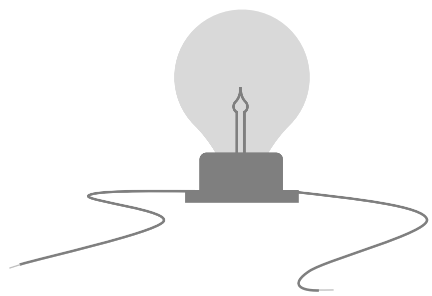
Name: ______________________________ Date: ________________

Follow the directions below. Circle the most appropriate answer for the multiple-choice questions.

1. Electricity is the movement of:

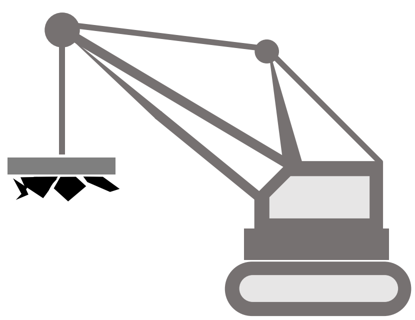
   a. Protons b. Electrons c. Neutrons d. Neurons

2. The picture below shows an incomplete circuit. Which of the following objects can be connected to the ends of the two wires to light the bulb?



   a. A switch b. Another bulb c. A battery d. A motor

3. The pieces of scrap metal are attracted to the metal disk on the crane below. The metal disk is most likely functioning as which of the following?



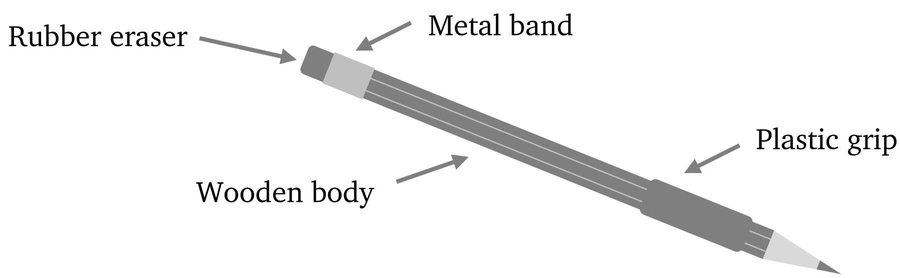
   a. A battery b. A motor c. An electromagnet d. An insulator

4. Which of the following explains why an electrician wears rubber gloves when working with high-voltage wires?

   a. The rubber is an electrical insulator.
   b. The rubber will not melt.
   c. The rubber has a negative charge.
   d. The rubber conducts heat.

5. Tom walked across a carpet and felt a shock when he touched a doorknob. What caused the shock?
    a. The knob was an electromagnet.
    b. The carpet was a conductor.
    c. Tom developed a magnetic moment.
    d. Tom developed a static charge.

6. Which part of the pencil below is the **best** conductor of electricity?



a. Metal band b. Plastic grip c. Rubber eraser d. Wooden body

7. A recycling center needs to separate lots of aluminum cans from steel cans. What is the best way the recycling center can sort the cans quickly?

____

____

A.3 Energy

Energy

Name: ______________________________ Date: ________________

Follow the directions below. Circle the most appropriate answer for the multiple-choice questions.

1. Which of the following is a **nonrenewable** resource?

   a. Wind b. Water c. Gasoline d. Solar power

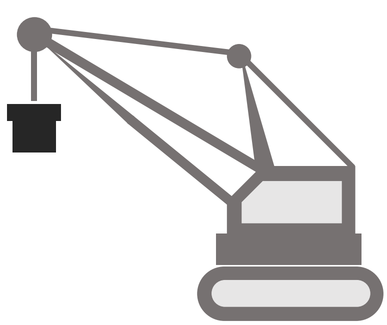
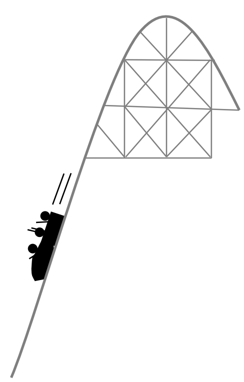
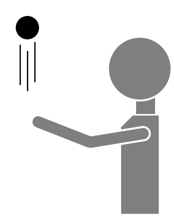
2. Circle a word from each pair of words to make the sentence true.

   The law of conservation of energy states that energy can neither be **(transformed/created)** nor **(destroyed/maintained)**.

3. Identify each of the following materials as thermal conductors or thermal insulators.

   a. The lining on your refrigerator is meant to keep heat outside of the cool compartment. This lining is a(n) ______________.
   b. Graphene is a recently discovered material made of carbon that is extremely good at allowing heat to transfer through it. Graphene is an excellent ______________.
   c. Thicker jackets are much better at keeping you warm because they trap more air inside, and air is very good at trapping heat. Air is a very good ______________.

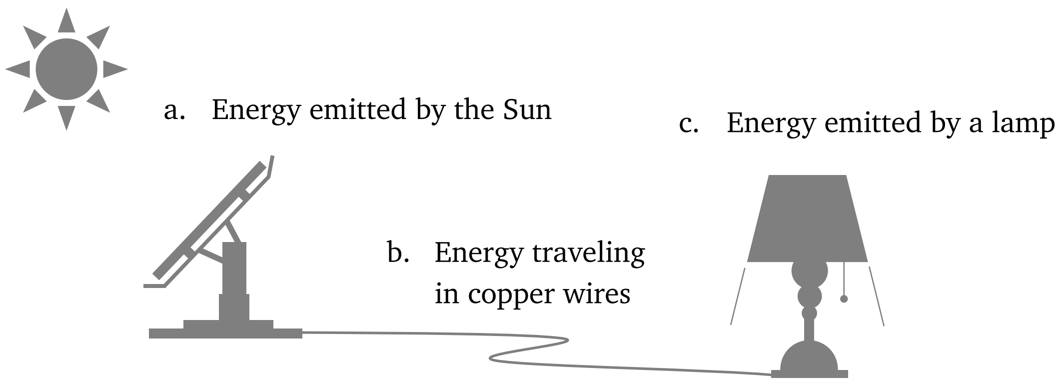
4. Label each of the black objects in the pictures below as either representing **potential energy** or **kinetic energy**.

a. ________________ b. ________________ c. ________________

5. In the following diagram, label each form of energy using words from the word box below that most accurately represent each object.

Mechanical energy	Solar energy	Sound energy
Electrical energy	Light energy	



a. ____________ b. ____________ c. ____________

6. Match the following forms of heat transfer to their definitions on the right.

a. ____ Conduction
b. ____ Convection
c. ____ Reflection
d. ____ Radiation

1. The transfer of heat through the movement of a gas or a liquid.
2. The bouncing of heat or light off an object.
3. The transfer of heat from one solid object directly to another.
4. The transfer of energy by means of waves that move through matter and space.

A.4 Forces and Motion

Forces and Motion

Name: ______________________________ Date: _____________

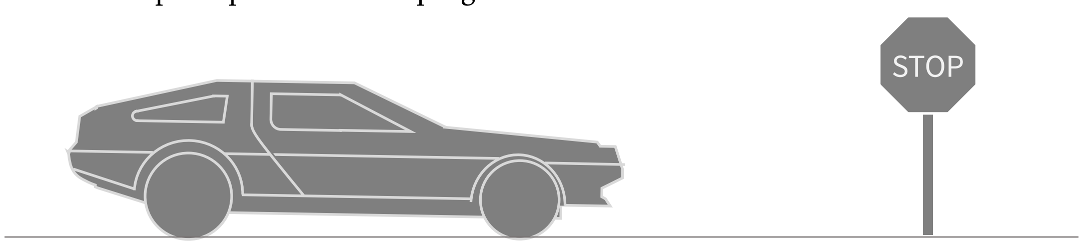
Follow the directions below. Circle the most appropriate answer for the multiple-choice questions.

1. Match the following words to their definitions.

A. ____ Inertia	1. The speed and direction of a moving object.
B. ____ Velocity	2. The distance an object travels in a certain amount of time.
C. ____ Speed	3. The rate of change of a velocity.
D. ____ Acceleration	4. The tendency of an object to maintain its state of motion.

2. Which two factors influence momentum?
   a. Mass and velocity.
   b. Force and mass.
   c. Mass and acceleration.
   d. Velocity and gravity.

3. What force helps stop a car at a stop sign?



   a. Friction b. Gravity c. Inertia d. Magnetism

4. In Newton's second law, an object's acceleration depends on its ________ and the ________ being applied on it.
   a. Weight, inertia
   b. Mass, force
   c. Gravitational force, momentum
   d. Position, force

5. What is the speed of a sailboat that travels 100 meters in 10 seconds?
    a. 0.1 meters/second
    b. 1 meter/second
    c. 10 meters/second
    d. 100 meters/second
6. This is the measure of how far something or someone has actually traveled:
    a. Mass
    b. Force
    c. Inertia
    d. Distance
7. The first law of motion states that an object in motion will stay in motion. If that's the case, why do you have to keep pedaling your bike to keep moving forwards?

    ____

    ____

8. Which of the following is the best way of separating iron filings from sand if the two are found in a mixture together?
    a. Stir the mixture in hot water and dissolve the sand.
    b. Strain the mixture through a paper filter to collect the sand.
    c. Drag a magnet through the mixture to attract the iron filings.
    d. Shake the mixture to cause the iron filings to settle to the bottom.

A.5 Matter

Matter

Name: ______________________________ Date: ________________

Follow the directions below. Circle the most appropriate answer for the multiple-choice questions.

1. Which of the following is an element?

   a. Water b. Carbon c. Air d. Proton

2. Which of the following is **not** a state of matter?

   a. Liquid b. Solid c. Water d. Plasma

3. What is the freezing point of water in Fahrenheit?

   a. 32° F b. 130° F c. 212° F d. 50° F

4. Fill in either “physical” or “chemical” for each of the following reactions.

   a. __________ A bike is left outside overnight and begins to rust because it rained.
   b. __________ Chocolate melts on a hot summer day.
   c. __________ A balloon is popped with a sharp pin.
   d. __________ Fireworks are shot into the sky on the Fourth of July.

5. Fill in the blanks with words from the word bank below.

Combustibility	Nucleus	Molecule
Solution	Element	Atom

   a. How easily and quickly a substance burns is its ____________.
   b. The dense center of an atom is the ____________.
   c. Matter made up of only one kind of atom is a(n) ____________.
   d. Two or more atoms joined together make up a(n) ____________.
   e. The smallest particle that still behaves like the matter it came from is a(n) ______.
   f. A mixture in which all the parts are mixed evenly is a(n) ____________.

6. The pie chart below in Figure 1 represents the gases in the Earth's atmosphere broken into three categories: Gas 1, Gas 2, and Gas 3. Which of the categories **best** represents:

   a. Nitrogen gas? ________________

   b. Oxygen gas? ________________

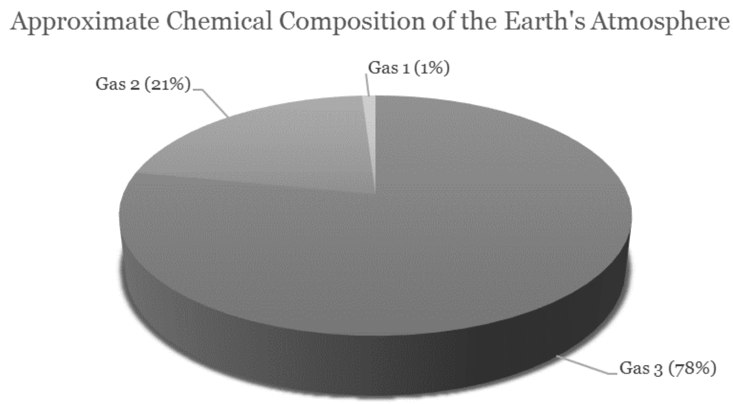


Figure 1: Approximate composition of the air.

One of the major problems on the moon is separating iron from the titanium and aluminum in the moon dust. One way to do this involves using the temperature at which the materials will change state. Keep this in mind while answering the following three questions.

7. Between the three metals mentioned above (Iron, Aluminum, and Titanium), if the temperature of each is slowly increased from 20° C, which will become a liquid first?

   ____

8. As temperature increases, what do you need to know about these metals to tell which will change from a solid to a liquid first?

   a. Mass
   b. Density
   c. Melting point
   d. Volume
   e. All of the above

9. How would someone re-shape iron into a shape like a cutting tool?

   ____

A.6 Sound and Light

Sound and Light

Name: ______________________________ Date: ________________

Follow the directions below. Circle the most appropriate answer for the multiple-choice questions.

1. Fill in the blanks below using the words from the word bank below.

Volume	Pitch	Concave lens
Refraction	Opaque	
Transparent	Translucent	Convex lens

   a. A sound with a high frequency also has a high __________.
   b. A material that does not allow any light to pass through is __________.
   c. The loudness of a sound is also known as its __________.
   d. Water and plastic wrap are materials that are __________.
   e. A lens that is thicker at its edges than at its center is __________.
   f. The bending of light as it moves from one material to another is __________.

2. What must happen for a sound wave to form?
   a. An electric current must flow.
   b. A certain frequency must be reached.
   c. Matter must vibrate.
   d. Volume must be absorbed.

3. Which of the following surfaces would bounce back almost all the light waves hitting it?
   a. A white wall.
   b. A piece of tinfoil.
   c. A mirror.
   d. A stained glass window.

4. Visible light is a small part of which spectrum?
   a. Electromagnetic
   b. Frequency
   c. Radio
   d. Vibration

5. Which of the following **best** describes why we have shadows on sunny days?
    a. Our body changes the color of sunlight hitting the ground.
    b. Our body reflects sunlight into the ground.
    c. Our body bends light waves from the Sun.
    d. Our body blocks light from the Sun.
6. A student places a sheet of black construction paper on her desk. What happens to **most** of the light that strikes the black construction paper?
    a. The light is bent by the paper.
    b. The light reflects off the paper.
    c. The light is absorbed by the paper.
    d. The light passes through the paper.

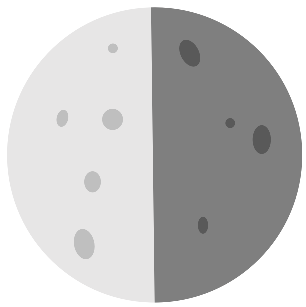
A.7 Final Review

Final Review

Name: ______________________________ Date: ____________________

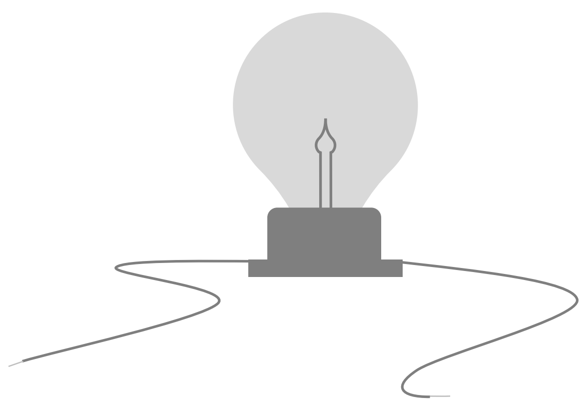
Follow the directions below. Circle the most appropriate answer for the multiple-choice questions.

1. Which phase of the moon is represented below?



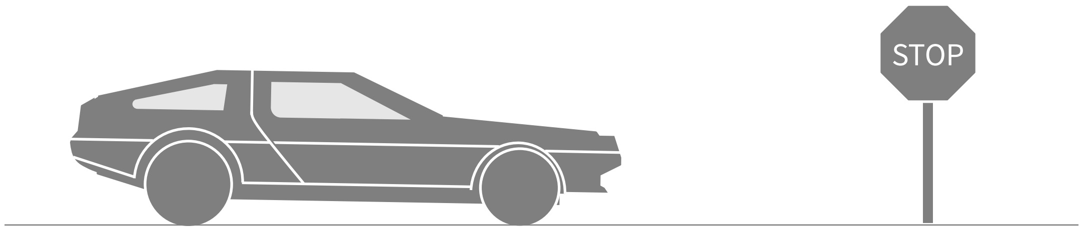
   a. Half moon
   b. Quarter moon
   c. Waning crescent
   d. Full moon

2. The picture below shows an incomplete circuit. Which of the following objects can be connected to the ends of the two wires to light the bulb?



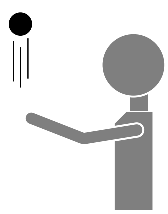
a. A switch b. Another bulb c. A battery d. A motor

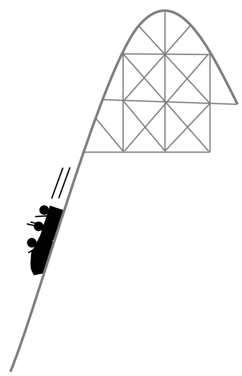
3. What force helps stop a car at a stop sign?

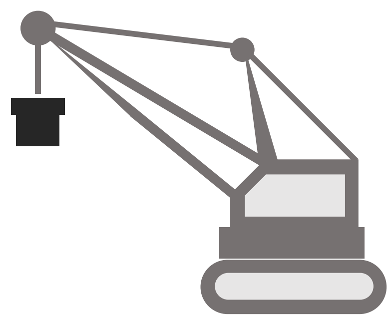


a. Friction b. Gravity c. Inertia d. Magnetism

4. Label each of the black objects in the pictures below as either representing **potential energy** or **kinetic energy**.







a. ____________________ b. ____________________ c. ____________________

Appendix B

Assessment Results

B.1 Assessment Results by Question for Class 1

Assessment Results: Class 1

Test	Question	Performance By Question	Average Test Score
Energy	1	63%	41%
	2a	13%	
	2b	25%	
	3a	25%	
	3b	25%	
	3c	50%	
	4a	38%	
	4b	63%	
	4c	38%	
	5a	75%	
	5b	63%	
	5c	63%	
	6a	25%	
	6b	25%	
	6c	50%	
	6d	25%	
Forces and Motion	1a	75%	50%
	1b	50%	
	1c	50%	
	1d	75%	
	2	0%	
	3	100%	
	4	25%	
	5	75%	
	6	50%	
	7	25%	
	8	25%	
Earth Moon and Beyond	1a	86%	51%
	1b	86%	
	1c	57%	
	1d	71%	
	2	29%	
	3	43%	
	4	29%	
	5	71%	
	6	71%	
	7	43%	
	8	14%	
	9	57%	
	10	0%	

Sound and Light	1a	20%	24%
	1b	40%	
	1c	20%	
	1d	0%	
	1e	20%	
	1f	0%	
	2	0%	
	3	80%	
	4	20%	
	5	40%	
	6	20%	
Matter	1	17%	37%
	2	0%	
	3	83%	
	4a	33%	
	4b	50%	
	4c	83%	
	4d	67%	
	5a	17%	
	5b	50%	
	5c	0%	
	5d	0%	
	5e	83%	
	5f	33%	
	6a	17%	
	6b	33%	
	7	50%	
	8	33%	
	9	17%	
Electricity	1	100%	51%
	2	71%	
	3	57%	
	4	29%	
	5	29%	
	6	57%	
	7	14%	
Final Review	1	16%	46%
	2	89%	
	3	47%	
	4a	32%	
	4b	63%	
	4c	32%	

Assessment Results: Class 1

B.2 Assessment Results by Question for Class 2

Assessment Results: Class 2

Test	Question	Performance By Question	Average Test Score
Energy	1	56%	43%
	2a	22%	
	2b	11%	
	3a	44%	
	3b	33%	
	3c	44%	
	4a	33%	
	4b	22%	
	4c	11%	
	5a	75%	
	5b	75%	
	5c	50%	
	6a	63%	
	6b	50%	
	6c	63%	
	6d	50%	
Forces and Motion	1a	38%	25%
	1b	0%	
	1c	25%	
	1d	38%	
	2	25%	
	3	25%	
	4	13%	
	5	38%	
	6	50%	
	7	0%	
	8	25%	
Earth Moon and Beyond	1a	63%	43%
	1b	63%	
	1c	13%	
	1d	50%	
	2	25%	
	3	13%	
	4	38%	
	5	75%	
	6	75%	
	7	38%	
	8	23%	
	9	75%	
	10	8%	

Sound and Light	1a	44%	39%
	1b	0%	
	1c	56%	
	1d	44%	
	1e	44%	
	1f	22%	
	2	22%	
	3	44%	
	4	67%	
	5	33%	
	6	56%	
Matter	1	0%	43%
	2	0%	
	3	50%	
	4a	88%	
	4b	75%	
	4c	88%	
	4d	38%	
	5a	25%	
	5b	38%	
	5c	38%	
	5d	38%	
	5e	88%	
	5f	38%	
	6a	50%	
	6b	50%	
	7	50%	
	8	13%	
	9	13%	
Electricity	1	67%	51%
	2	44%	
	3	78%	
	4	11%	
	5	67%	
	6	78%	
	7	11%	
Final Review	1	8%	49%
	2	67%	
	3	79%	
	4a	58%	
	4b	38%	
	4c	42%	

Assessment Results: Class 2

B.3 Cumulative Assessment Results by Class

Cumulative Assessment Results By Class

Test	Question	Performance By Question	Class 1 Averages	Class 2 Averages	Average Test Score
Energy	1	59%	41%	43%	42%
	2a	17%			
	2b	18%			
	3a	35%			
	3b	29%			
	3c	47%			
	4a	35%			
	4b	42%			
	4c	24%			
	5a	75%			
	5b	69%			
	5c	56%			
	6a	44%			
	6b	38%			
	6c	56%			
	6d	38%			
orces and Motic	1a	56%	50%	25%	38%
	1b	25%			
	1c	38%			
	1d	56%			
	2	13%			
	3	63%			
	4	19%			
	5	56%			
	6	50%			
	7	13%			
	8	25%			
n Moon and Bey	1a	74%	51%	43%	47%
	1b	74%			
	1c	35%			
	1d	61%			
	2	27%			
	3	28%			
	4	33%			
	5	73%			
	6	73%			
	7	41%			
	8	19%			
	9	66%			
	10	4%			

Sound and Light	1a	32%	24%	39%	32%
	1b	20%			
	1c	38%			
	1d	22%			
	1e	32%			
	1f	11%			
	2	11%			
	3	62%			
	4	43%			
	5	37%			
	6	38%			
Matter	1	8%	37%	43%	40%
	2	0%			
	3	67%			
	4a	60%			
	4b	63%			
	4c	85%			
	4d	52%			
	5a	21%			
	5b	44%			
	5c	19%			
	5d	19%			
	5e	85%			
	5f	35%			
	6a	33%			
	6b	42%			
	7	50%			
	8	23%			
	9	15%			
Electricity	1	83%	51%	51%	51%
	2	58%			
	3	67%			
	4	20%			
	5	48%			
	6	67%			
	7	13%			
Final Review	1	12%	46%	49%	48%
	2	78%			
	3	63%			
	4a	45%			
	4b	50%			
	4c	37%			

B.4 Cumulative Assessment Results by Student

Cumulative Assessment Results By Student

Student	Initial Assess	Final Assess	MCAS Average	Ntbk Score	Class Data Avg	Assess Avg	Overall Averages
1	No data	33%	18%	0%	12%	33%	17%
2	38%	No data	No data	No data	No data	38%	38%
3	31%	33%	16%	0%	11%	32%	19%
4	63%	No data	45%	100%	63%	63%	63%
5	51%	67%	29%	100%	53%	59%	55%
6	25%	33%	14%	100%	43%	29%	37%
7	44%	67%	21%	100%	48%	55%	51%
8	30%	0%	20%	100%	47%	15%	34%
9	26%	50%	40%	100%	60%	38%	51%
10	39%	33%	10%	0%	7%	36%	18%
11	60%	67%	40%	100%	60%	63%	61%
12	49%	No data	23%	0%	15%	49%	24%
13	44%	50%	28%	100%	52%	47%	50%
14	25%	No data	29%	100%	53%	25%	46%
15	40%	33%	19%	100%	46%	37%	42%
16	No data	No data	No data	No data	No data	No data	No data
17	40%	67%	24%	100%	49%	54%	51%
18	58%	33%	20%	0%	13%	45%	26%
19	47%	83%	41%	100%	61%	65%	63%
20	No data	67%	23%	100%	61%	67%	63%
21	No data	17%	No data	100%	100%	17%	58%
22	38%	17%	21%	70%	38%	27%	33%
23	48%	50%	26%	100%	51%	49%	50%
24	No data	No data	31%	0%	21%	No data	21%
25	40%	83%	50%	100%	67%	62%	65%
26	58%	No data	No data	No data	No data	58%	58%
27	No data	No data	No data	No data	No data	No data	No data
28	33%	0%	15%	0%	10%	16%	13%
29	64%	50%	46%	100%	64%	57%	61%
30	18%	0%	20%	100%	47%	9%	32%
31	37%	0%	40%	60%	50%	19%	34%
32	74%	0%	53%	100%	68%	37%	56%
33	12%	0%	18%	0%	12%	6%	9%
34	20%	0%	38%	100%	58%	10%	39%
35	52%	0%	50%	100%	67%	26%	50%
36	29%	50%	14%	0%	9%	40%	21%
37	31%	No data	38%	100%	58%	31%	52%
38	38%	50%	19%	70%	36%	44%	39%
39	31%	50%	53%	100%	68%	41%	57%
40	28%	0%	20%	75%	38%	14%	29%
41	33%	No data	43%	70%	52%	33%	47%
42	45%	0%	40%	80%	53%	23%	41%
43	18%	0%	31%	70%	44%	9%	30%

Cumulative Assessment Results by Student

44	39%	0%	41%	100%	61%	20%	44%
45	33%	0%	19%	0%	13%	17%	14%
46	21%	0%	No data	No data	No data	11%	11%
47	52%	50%	34%	0%	23%	51%	34%
48	62%	0%	65%	100%	77%	31%	58%
49	37%	0%	24%	60%	36%	19%	29%
50	31%	No data	No data	No data	No data	31%	31%
51	31%	0%	23%	60%	35%	16%	27%
52	43%	0%	35%	100%	57%	22%	43%
53	7%	50%	15%	100%	43%	29%	37%
54	32%	67%	34%	100%	56%	50%	53%

Appendix C

Activities

C.1 Phases of the Earth

Phases of the Moon Activity

Name: ______________________________ Date: ________________

Input

Investigation: Phases of the Earth
Materials: Oreos, Styrofoam ball, light source, plastic knife
Procedure:

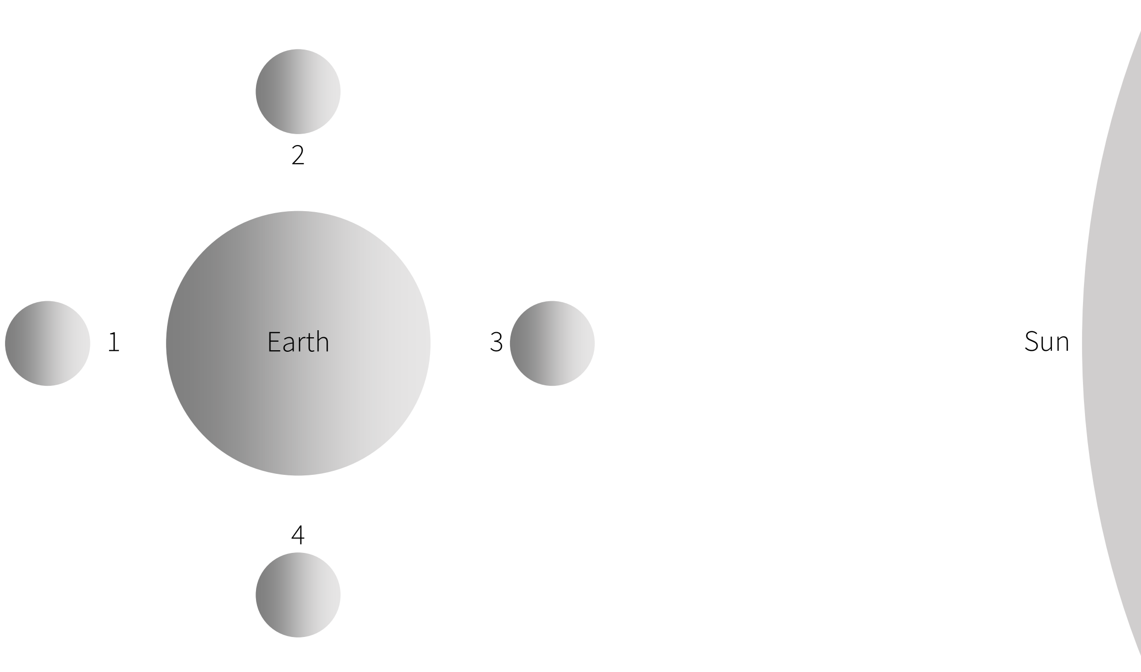
- Write down a hypothesis about the phases of the Earth below
- Insert a pencil into your Styrofoam ball
- Hold up the Styrofoam ball by the pencil and lift it up to your eye's height
- Face towards the light source holding the ball and stick at arm's length in front of you
- Record what you see in the picture of the Earth below labeled 1
- Turn ninety degrees to the right and record the phase you see in picture 2
- Repeat for all four phases of the Earth
- Receive your Oreos and split them in half
- Carve the Oreo cream to match the Earth phases using your knife
- Eat the Oreos

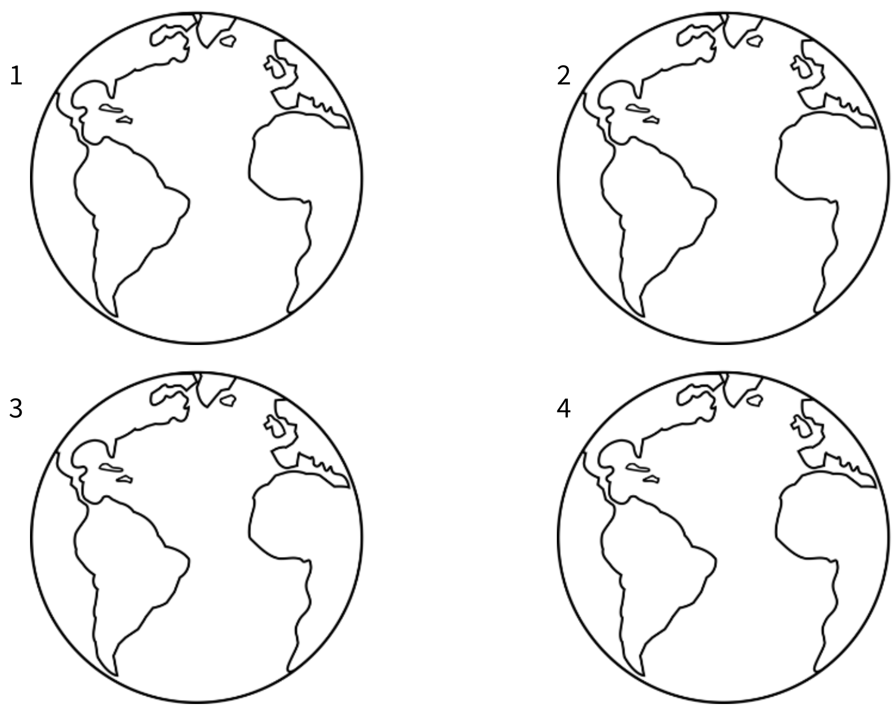
Hypothesis—I claim that ____

____.

Output

Investigation: Phases of the Earth
Earth phases drawing





Conclusion: I conclude that my hypothesis was (proven/disproven). The evidence for my conclusions based on the fact(s) that ____

____.

C.2 Energy and Moon Craters

Energy and Moon Craters Activity

Name: ___________________________________ Date: ____________________

Input

Investigation: Energy and Moon Craters
Materials: *Hotwheels* cars, ramps, ruler
Procedure:

- Write down a hypothesis about how potential energy will let you get through the crater without stopping. (Remember, the crater is too big to just go around it and too big to jump over it, so you must go through it.)
- Obtain a hot wheels car.
- Place the vehicle at different heights on Malapert Mountain (the ramp). Record how far it goes and if it makes it out of the crater and back to the base.

Hypothesis—I claim that ____

____.

Output

Investigation: Energy and Moon Craters

1. At which height on the ramp will the vehicle on the moon make it through the crater? Why?

   ____

   ____.

2. When the car is at the top of the ramp it has ____________________ energy and when the car gets to the bottom of the ramp, it has ____________________ energy.

3. Do you expect the weight of the *Hotwheels* car makes a difference? Why?

   ____.

Complete the chart below while doing the activity:

Starting height on Malapert Mountain (cm)	Distance from the bottom of Malapert Mountain (cm)	Did it make it through the crater? (Yes/No)
5 cm		
10 cm		
15 cm		
20 cm		
25 cm		
30 cm		
35 cm		
40 cm		
45 cm		

Conclusion: From this activity, I conclude that my hypothesis was (proven/disproven). The evidence for my conclusions based on the fact(s) that ______________________________________

____

____.

C.3 Forces and Motion

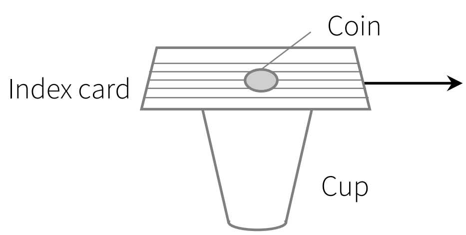
Forces and Motion

Name: ______________________________ Date: __________________

Station A – Inertia

Investigation: Inertia, friction, and centripetal acceleration
Materials: Styrofoam cup, index card, coin, sandpaper ramp, tinfoil ramp, wax paper ramp, ball
Procedure:

- Place the cup on the table with the open side facing up.
- Place the index card on top of the cup.
- Place the coin on top of the index card.
- Pull on the index card very slowly. Record what happens to the coin.
- Pull on the index card very quickly. Record what happens to the coin.



Hypothesis—I claim that when I pull on the index card, slowly the coin will ________________

______________. When I pull on the index card quickly, the coin will ______________________

____.

Why did the coin fall into the cup some times and not others?

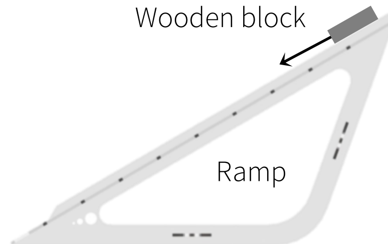
____

____

Conclusion: I conclude that my hypothesis was (proven/disproven). The evidence for my conclusion is based on the fact(s) that ____

____.

Station B – Friction



Procedure:

- Place the three ramps next to each other
- Place all three wooden blocks at the top of the ramps
- Release all three wooden blocks at once
- Record which block reached the table first and last

Hypothesis—I claim that the block on the ____________________ will reach the bottom of the ramp first because it has the ___________________ friction. And the ____________________ will reach the bottom of the ramp last because it has the ___________________ friction.

Material	Ranking
Sandpaper	
Tinfoil	
Wax paper	

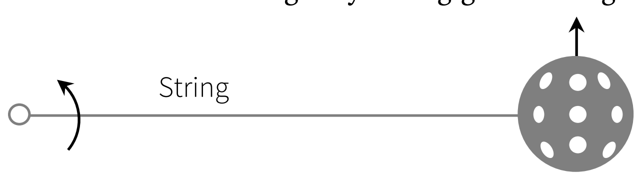
Conclusion: I conclude that my hypothesis was (proven/disproven). The evidence for my conclusion is based on the fact(s) that ____

____.

Station C – Centripetal Acceleration

Procedure:

- Hold the ball by the string and swing it in a circle
- Try to get the ball to land in the box target by letting go at the right time.



Hypothesis—I claim that when I let go of the string, the ball will _________________________

____.

Which way does the ball go when you let go of the string? ________________________________.

Conclusion: I conclude that my hypothesis was (proven/disproven). The evidence for my conclusion is based on the fact(s) that ____

____.

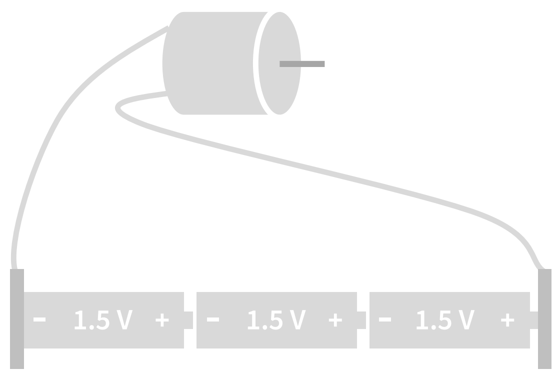
C.4 Electricity and Experimentation

Designing an Experiment

Name: ______________________ Date: ______________

Designing an Experiment about Electricity

Fill in the following questions as we go over them together.



1. Make a hypothesis about how the number of batteries will affect the speed of the motor when the batteries are attached.

 ____

 ____

2. Each battery is 1.5 Volts. What happens when only one battery is attached to the motor?

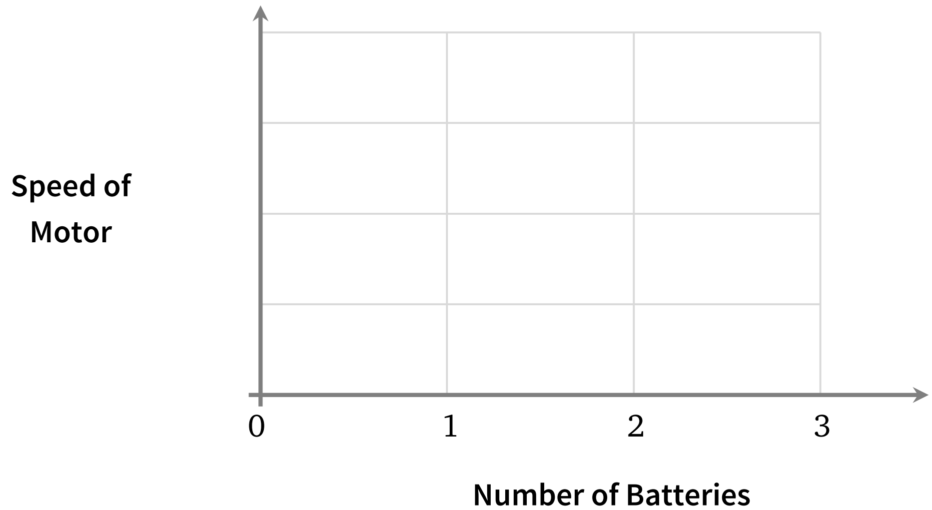
 ____

3. What happens when two batteries are attached to the motor?

 ____

4. What happens when three batteries are attached to the motor? Graph all the results below. Since the **Number of Batteries** is the cause, it is called the *independent variable* and is put on the x-axis. Since **Speed of Motor** is the effect, it is called the *dependent variable*, and is put on the y-axis.

 ____



5. What happens when one of the three batteries is turned the wrong way? What about when a dead battery is put in? What does this mean about our graph?

____

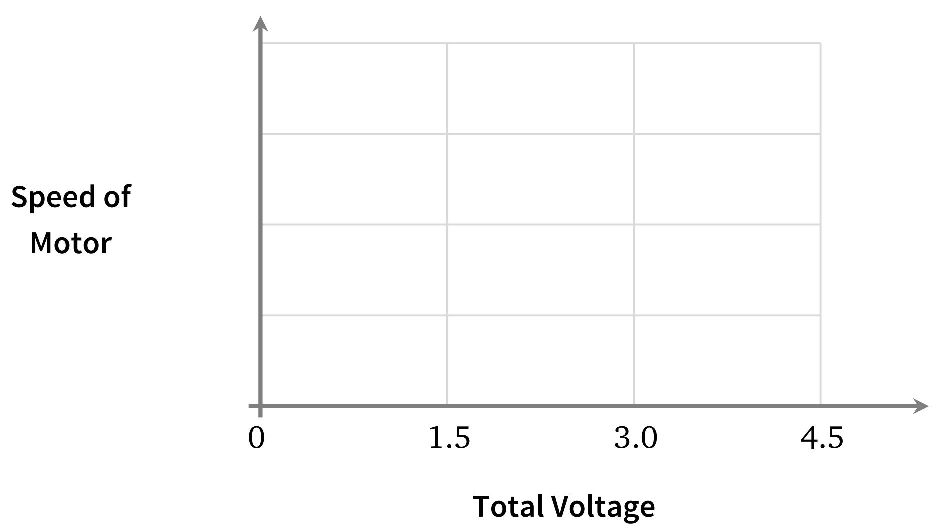
____

6. It seems that we need to change our hypothesis. Write a hypothesis below about how the *total voltage* of the batteries affects the speed of the motor.

____

____

7. Redo the graph below, this time using *voltage* instead of *number of batteries*.



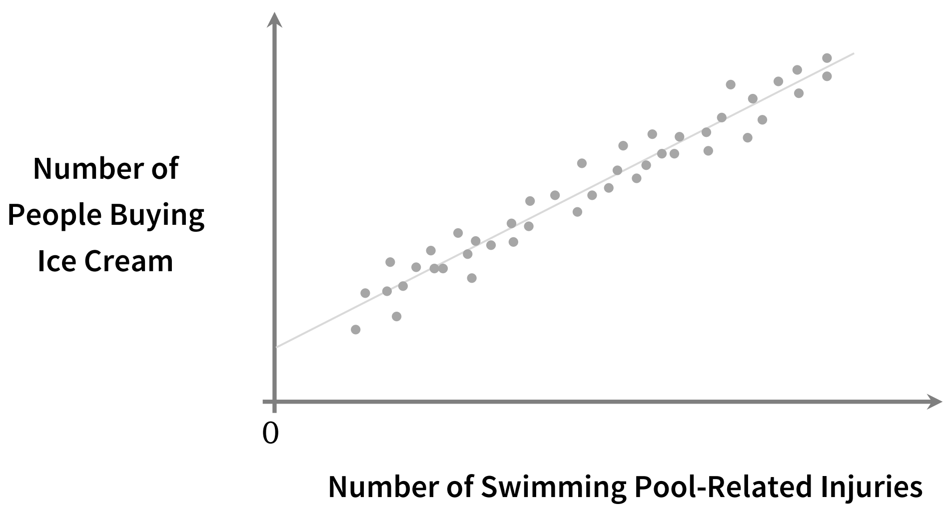
8. Make a conclusion about what property of the batteries affects the motor speed.

____

____

More about Experimentation

Sometimes, experiments can be done and a relationship between two variables can be developed. However, just because there's a relationship between them, it doesn't mean one causes the other. For example, look at the graph below.



From the data above, we can make the conclusion that as the number of people who get injured at pools increases, so do the number of people who are eating ice cream. However, we know that injuries at swimming pools are not *causing* people to buy more ice cream. Instead, here we have a *lurking variable* which is the cause for both variables, which is the season. In the summer, the number of injuries at swimming pools go up and the number of people buying ice cream go up. In the winter, both of these decrease together. Thus, *correlation does not imply causation.*

Designing an Experiment about Plants on the Moon

We want to find out the effect of different solar cycles for growing plants on the moon. On the moon, there are fourteen Earth-days of daylight and fourteen Earth-days of darkness at the equator. On one of the poles of the Moon, there is continuous daylight. We want to see how these different conditions affect the growth of plants

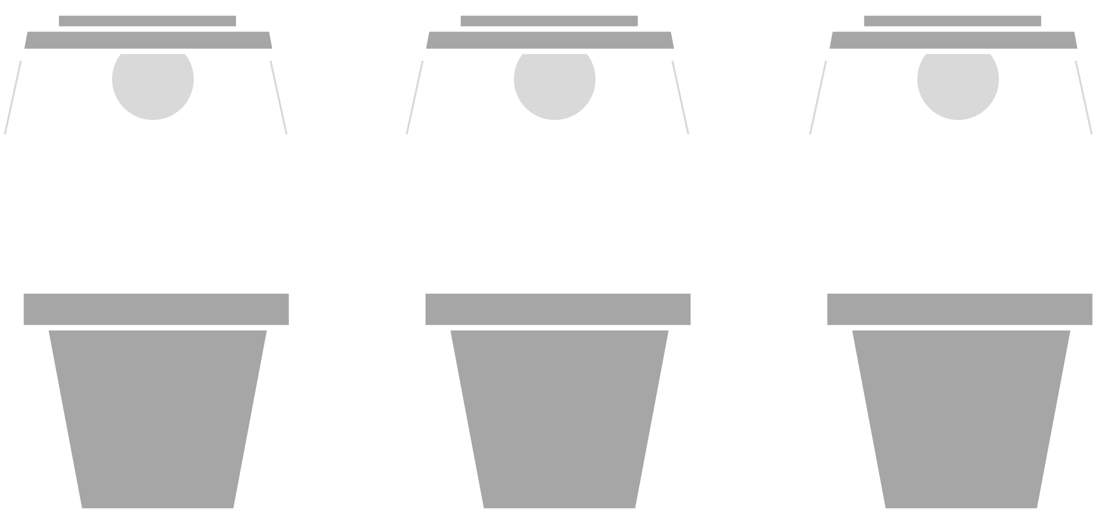
One of the first things we need to make this experiment work is a *control*. A control in this experiment will test how the plant grows under normal conditions—that is, how the plant will grow on Earth in 24-hour solar cycles.

However, all the other variables in the experiment must be kept the same. If we change too many variables, we will not be able to determine which one caused the changes we see. Therefore, factors like CO_2 and temperature must be kept the same for all three scenarios. *Only the amount of sunlight per plant should change.*

What is the independent variable in this experiment?

What is the dependent variable in this experiment?

Make a hypothesis about how each plant will grow.



24-hour Cycles (Control) | **14-Day Cycles** | **Continuous Sunlight**

C.5 Post-Field Trip Activity

Food-Producing Plants

Name: ______________________________ Date: ________________

The following table lists twelve plants that could be grown on the moon and their nutrition facts. Use the information in this table to choose plants to bring to the moon.

Plant (Per 100g portion)	CO_2 Type	Temp. (°C)	Yield (ton/ha)	Energy (Cal)	Protein (grams)	Vitamin Richness	Grows Natively In:
Maize	C4	20-25	9	**370**	9	Rich	North America
Rice	C3	25-30	15	360	7	Rich	East Asia
Wheat	C3	10-25	9	330	13	Medium	China
Potato	C3	10-30	**44**	80	2	Medium	North America
Cassava	C3	25-30	27	160	1	Medium	Brazil
Soybean	C3	10-15	4	150	**13**	Rich	East Asia
Sweet Potato	C3	15	33	90	2	Poor	South America
Sorghum	C4	20	13	340	11	Poor	Tropical Regions
Yam	C3	30-35	23	120	2	Rich	Africa, Asia
Plantain	C3	25	8	120	1	Medium	Tropical S.E. Asia
Cattails	C3	25-30	34	60	5	Poor	Any Wetlands
Taro	C3	25-35	6	140	2	Rich	S.E. Asia

Notes

C3 plants are more efficient than C4 plants in temperatures below 30°C (85°F). Above that C4 plants are more efficient.

C4 plants have advantages in droughts, low nitrogen environments, and low CO_2 environments.

Some Good Sources of Protein (circle three you think would be best to have on the moon)

Fish
Worms
Quinoa
Lentils
Tempeh
Beans (Black, Kidney, Mung, Pinto),
Spirulina (a seaweed-like algae that grows in lakes)
Hemp Seeds
Soy beans
Pumpkin Seeds
Asparagus
Cauliflower
Peanuts
Almonds
Broccoli

Post-Field Trip Activity

Name: ______________________________ Date: _________________

Answer the questions below using the nutrition facts from the table of **Staple Food Plants**.

a. List your 2 favorite staple plants to eat if you were to be on the moon for a year and these would be half of what you get to eat day after day. Then we will if your group members agree and see how healthy they are.

_______________________ _______________________

b. List 2 plants that are high in calories (produce energy) that you would want to bring with you on the moon:

_______________________ _______________________

c. List 2 plants that are high in protein that you would want to bring with you on the moon:

_______________________ _______________________

d. List 2 plants that are very vitamin rich:

_______________________ _______________________

e. You can take a plant that is good to eat but not protein rich if you also take along a good source of protein to make up for it. Which of the protein sources listed below the table would you take? List the two of these you would prefer.

_______________________ _______________________

Describe one attractive plant that you saw at Tower Hill that would make you feel at home:

Leaves: _________________ Kind (tree, bush, shrub, grass): _________________

Color: __________________ Flower (if any): ____________________________

____

Plants need certain things to grow healthily.

What things would do you make different in your two greenhouses? Circle them.

Carbon Dioxide (Although C4 plants need less CO_2 than C3 plants)

Heat (What temperature is best? Was it originally from a warm place or a cold place?)

Light (How long do they need daylight? Do they bloom in the spring or late summer?)

Nitrogen (Only some plants, called *legumes*, can take nitrogen out of the air. All other plants must absorb it through their roots.)

Water/Soil Mix (Some plants need more water and can even grow in water without soil. Others need soil, for example to be able to grow straight up to get sunlight.) Moon dust cannot be used as soil since it can't hold water, has aluminum in it (poisonous for plants), and is not acidic enough for plants.

Picking Plants for Your Own Greenhouse

You have two greenhouses in your moon base of different sizes. Looking at the plants you have chosen above, which plants will you put in each greenhouse? Remember, all the plants in each greenhouse will have to grow at the same temperature. What will the temperature of each greenhouse have to be? (You might have to leave some plants behind on Earth if they don't fit in either greenhouse)

The following plants can be used to make some of these useful items. Draw a line connecting at least two plants to a useful item.

Plants: Sun flower, papyrus, bamboo, hemp, flax, chili pepper, cattails…

Some things you will need on the moon: medicines, spices, cloth, paper, rope, padding, rubber, glue, baskets, wood…

Plants in the Bigger Greenhouse:		Plants in the Smaller Greenhouse:	
Bigger Greenhouse:		Smaller Greenhouse:	
Temperature:	CO_2 Level:	Temperature:	CO_2 Level:

C.6 Activities by Cost

Activity	Material	Price	Quantity	Total
Earth Phases	Cookies	$2.50	4	$10.00
			Total:	**$10.00**
Energy	Plastic Acrylic Sheets	$22.00	3	$66.00
	Hotwheels Cars	$1.55	3	$4.65
	3-Pack Hotwheels	$2.85	1	$2.85
			Total:	**$73.50**
Forces and Motion	Hotwheels Track	$35.00	1	$35.00
	5-Pack D Batteries	$2.50	1	$2.50
			Total:	**$37.50**
Field Trip	Full Bus	$200.00	1	$200.00
	Handicap Bus	$50.00	1	$50.00
	Tower Hill Admission	$7.00	52	$364.00
	Seeds	$3.00	8	$24.00
	Pencils	$0.55	52	$28.60
	Postcards	$0.50	52	$26.00
			Total:	**$692.20**
Post-Field Trip	AeroGarden Plant Kit	$62.99	3	$188.97
	AeroGarden Small Plant Kit	$15.95	3	$47.85
			Total:	**$236.82**
Electricity	Propeller	$20.00	1	$20.00
	8-Pack AA Batteries	$7.99	1	$7.99
	6V Battery	$6.99	1	$6.99
	9V Battery	$2.30	1	$2.30
			Total:	**$37.28**

Appendix D

Field Trip to Tower Hill Botanical Gardens

D.1 Plants at Tower Hill Botanical Gardens

The student team took a trip to the Tower Hill Botanical Garden greenhouses the week before the field trip to take down names of as many relevant-looking plants as they could find. Following is a list of the plants we recorded. There are dozens more plants in both greenhouses that were not recorded.

Plants in the Limonaia

- Hellebore
- Vanilla Wattle
- Dragon Wing Pink Begonia
- Spotted Laurel

- Meyer Lemon
- Fragrant Olive, *Osmanthus fragrans*
- Flowering Maple
- Modoc Cypress
- Black Bamboo
- Desert Fan Palm
- Primrose Jasmine

Plants in the Orangerie Greenhouse

- Calamondin Orange
- ‘Cara Cara’ Orange, *Citrus sinesnsis*
- Little Ollie, *Olea europaea*
- Wild Guava
- Beefsteak Plant
- Common Olive
- Papyrus
- Kumquat, *Fortunella hindsii*
- Croton
- Asian Wonder Bamboo
- Elephant Ear
- Cow’s Horn
- Mickey Mouse Plant

D.2 Tower Hill Handout

Plant Types and Characteristics

Name: ______________________________ Date: _________________

C3 VS. C4 PLANTS

C3 Plants	C4 Plants
Photosynthesis takes place throughout leaf	Photosynthesis takes place in inner cells
Cooler, humid environments	Warmer, drier climates
Ex. Wheat, barley, potatoes	Ex. Fourwing saltbush, corn

Table 1: C3 vs. C4 Plants

PLANT GROUPS

Mosses

Leafless, Stemless, Leafless Plants

- Only one or two cells thick
- Life cycle with two generations
  - One stage is sexual reproduction, in which egg and sperm cells join to form a new moss plant
  - In the asexual reproduction stage, a new plant is formed from the spores of the stalk of the sexually produced moss

Ferns

Seedless Plants

- 350 million years old
- Were the most popular plant on Earth during the time of the dinosaurs
- Over 12,000 species discovered
- Found mostly in tropical environments like rainforests
- Ferns also grow in two generations
  - One is the sexual generation
  - The asexual generation reproduces by spores produced on the undersides of the ferns' leaflets

Gymnosperms

Seed Plants

- Plants with seeds
- Types of gymnosperms:
  - Conifers, ex. Pine trees
  - Ginkgoes
  - Cycads,
  - Gnetophytes
- Conifer embryos grow from sexual reproduction inside the cones of the trees and grow into new trees after falling to the ground

Angiosperms

Flowering Plants

- Flowering plants
- Most plants today are angiosperms
- All angiosperms produce fruits. Types of fruits:
  - Berry, ex. Watermelon, blueberries, tomatoes
  - Aggregate fruits, ex. Blackberries
  - Droop, ex. Plums, cherries, peaches
  - Pome, ex. Apples and pear
  - Multiple fruit, ex. Pineapples
- Angiosperms reproduce through sexual reproduction
  - Pollen from the anther in the stamen of one plant travels to the stigma in the pistil of a different plant
  - Pollination can happen through birds, bats, insects, or wind
- There are two types of angiosperms: monocots and dicots

Monocots	Dicots
One seed leaf	Two seed leaves
Flower petals in multiples of three	Flower petals in multiples of four or five
Parallel leaf veins	Netlike leaf veins
Fibrous roots	Taproots

Table 2: Monocots vs. Dicots

Asexual Reproduction	Sexual Reproduction
Doesn't require a partner	Requires a sperm and egg from each partner
Offspring are genetic copies	Offspring are combinations of parents' genes
Leads to less genetic diversity	Leads to more genetic diversity

Table 3: Asexual vs. Sexual Reproduction

FAMILIES

Kingdom	*Phylum*	*Class*	*Order*	*Family*	*Genus*	*Species*

Mallow Family

Ex. Cotton, okra, cocoa tree

Legume Family

Ex. Beans, lentils, peas, peanuts

Grasses Family

Ex. Bent, carpet, buffalo

Arum Family

Ex. Cabbage, lilies, elephant foot yam

Rue Family

Ex. Orange, lemon, kumquat

Chenopod Family

Ex. Spinach, beets, pigweed

Composite Family

Ex. Daisies, chrysanthemums, dandelions

D.3 Tower Hill Scavenger Hunt (Version 1)

Moon Base Scavenger Hunt

Name: ______________________________ Date: _________________

You're traveling to the moon with a group of astronauts to live on a moon base. One of the biggest parts of the moon base is the greenhouse. Since the plants will be your main resources for most of the things you need on the moon base, you should pick plants from the Tower Hill greenhouse to bring to the moon that will be useful. Find plants that match each description below.

LIMONAIA

1.1. You need a good smelling plant to cover up the smell of sweat in the main areas of the moon base. Which plant could you bring?

a. Hellebore b. Vanilla Wattle c. Primrose Jasmine d. Other: _________

1.2. You need a very stiff, strong plant to build some furniture for your room. Which plant could you bring?

a. Desert Fan Palm b. Black Bamboo c. Modoc Cypress d. Other: _____

1.3. During their free time, some of the astronauts enjoy making paintings. You want to make a painting of a sunset using the following colored paints. Which plants have flowers of the following colors?

Pink: _________________________ Yellow: _________________________

1.4. I have dark green elliptical shaped leaves with yellow spots. What plant am I?

1.5. I'm named after a mythical creature. I have pretty pink flowers with a yellow center. What plant am I?

1.6. I am a popular palm tree classic to South California, Las Vegas, and Northwest Mexico. What am I?

ORANGERIE

2.1. You need a plant with a lot of long, straight fibers to make paper on the moon to make notebooks. Which plant could you bring?

a. Kumquat b. Papyrus c. Common Olive d. Other: ___________

2.2. One of the most important uses of the greenhouse on a moon base will be growing food for yourself and the astronauts. List all the plants you find that produce food.

Plant Name	Food Produced

2.3. You need a very pretty plant to make the greenhouse remind you of Earth when you get homesick. Which plant could you use?

____

____

D.4 Tower Hill Scavenger Hunt (Version 2)

Moon Base Scavenger Hunt

Name: ______________________________ Date: _________________

You're traveling to the moon with a group of astronauts to live on a moon base. One of the biggest parts of the moon base is the greenhouse. Since the plants will be your main resources for most of the things you need on the moon base, you should pick plants from the Tower Hill greenhouse to bring to the moon that will be useful. Find plants that match each description below.

LIMONAIA

1.1. You need a good smelling plant to cover up the smell of sweat in the main areas of the moon base. Which plant could you bring?

a. Hellebore b. Vanilla Wattle c. Primrose Jasmine d. Other: _________

1.2. You need a very stiff, strong plant to build some furniture for your room. Which plant could you bring?

a. Desert Fan Palm b. Black Bamboo c. Modoc Cypress d. Other: _____

1.3. During their free time, some of the astronauts enjoy making paintings. You want to make a painting of a sunset using the following colored paints. Which plants have flowers of the following colors?

Pink: ________________________ Yellow: ________________________

ORANGERIE

2.1. You need a plant with a lot of long, straight fibers to make paper on the moon to make notebooks. Which plant could you bring?

a. Kumquat b. Papyrus c. Common Olive d. Other: ___________

2.2. One of the most important uses of the greenhouse on a moon base will be growing food for yourself and the astronauts. List all the plants you find that produce food.

Plant Name	Food Produced

2.3. You need a very pretty plant to make the greenhouse remind you of Earth when you get homesick. Which plant could you use?

___

___

2.4. I have magenta and black leaves. You may mistake me for a piece of meat. What plant am I?

2.5. I'm named after the horns of one of the animals you get milk from. I am very pointy so be careful! What plant am I?

2.6. I am a South African, but you would think I would have been made in Disney Florida. I am located near a table. I have yellow flowers. What plant am I?

D.5 Tower Hill Scavenger Hunt (Version 3)

Moon Base Scavenger Hunt

Name: ______________________________ Date: _________________

You're traveling to the moon with a group of astronauts to live on a moon base. One of the biggest parts of the moon base is the greenhouse. Since the plants will be your main resources for most of the things you need on the moon base, you should pick plants from the Tower Hill greenhouse to bring to the moon that will be useful. Find plants that match each description below.

LIMONAIA

1.1. You need a good smelling plant to cover up the smell of sweat in the main areas of the moon base. Which plant could you bring?

a. Hellebore b. Vanilla Wattle c. Primrose Jasmine d. Other: _________

1.2. You need a very stiff, strong plant to build some furniture for your room. Which plant could you bring?

a. Desert Fan Palm b. Black Bamboo c. Modoc Cypress d. Other: _____

1.3. During their free time, some of the astronauts enjoy making paintings. You want to make a painting of a sunset using the following colored paints. Which plants have flowers of the following colors?

Pink: _________________________ Yellow: _________________________

ORANGERIE

2.1. You need a plant with a lot of long, straight fibers to make paper on the moon to make notebooks. Which plant could you bring?

a. Kumquat b. Papyrus c. Common Olive d. Other: ___________

2.2. One of the most important uses of the greenhouse on a moon base will be growing food for yourself and the astronauts. List all the plants you find that produce food.

Plant Name	Food Produced

2.3. You need a very pretty plant to make the greenhouse remind you of Earth when you get homesick. Which plant could you use?

____

____

2.4. I have huge bright green, heart shaped leaves. I'm named after a big animal's ear. What plant am I?

2.5. I am located in a pot on the ground. I have long skinny leaves and pandas love to eat me! What plant am I?

2.6. I am a very unique plant without flowers. I may only have leaves, but they are pink, green, and yellow. What plant am I?

Appendix E

Essay Contest

E.1 Essay Contest Prompt

SIXTH-GRADE SPACE EXPLORATION ESSAY CONTEST

The New England chapter of the American Institute of Aeronautics and Astronautics is 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," along with additional research materials. Read through the materials given, then write an essay that answers the following prompt:

> A little over a year ago, the rover Curiosity landed on Mars, marking the beginning of a new adventure and another chance to learn more about the "Red Planet". Two other rovers, Spirit and Opportunity, landed in 2004. Spirit is no longer operational, but Opportunity still provides us with valuable data. Describe the differences among the rovers Spirit, Opportunity, and Curiosity, including their tools, their power sources, and their goals. What challenges did NASA have to overcome when preparing to land on Mars?

Your essay must be between 500 and 1000 words. You must use at least one of the other provided sources beyond the chapter, and you must cite those sources.

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 and outside sources, and shows your understanding of it. Your essay will be judged by the criteria stated in the attached rubric. 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 one week after the essay is assigned. The essays will then be judged by Dr. Bortz and a committee of WPI students. A finalist from each school will be selected to attend an awards ceremony where the three best essays will be announced. The authors of those essays will each receive a copy of *Seven Wonders of Space Technology*, autographed by Dr. Bortz.

If you have any questions about the contest, talk to your teacher or send an email to WPI Contest Coordinators at essayIQP2013@wpi.edu.

E.2 Essay Contest Scoring Rubric

Category	5	4	3	2	1	Scale
Scientific Accuracy	All questions are answered accurately and completely.	Most questions are answered accurately.	Half of the questions are answered accurately.	A few of the questions are answered accurately.	No questions are answered.	1.5
Spelling and Grammar	Correct spelling and grammar used throughout the essay.	Few spelling and grammar mistakes.	Some spelling and grammar mistakes.	Many spelling and grammar mistakes. Essay is difficult to read.	Severe spelling and grammar mistakes. Essay is almost unreadable.	1
Organization	The introduction is interesting. The body supports the focus. The conclusion works well. Transitions are used.	The essay is divided into an introduction, a body, and a conclusion. Some transitions are used.	The introduction or conclusion is weak. The body needs a paragraph for each answer. More transitions are needed.	The introduction, body, and conclusion all run together. Paragraphs and transitions are needed.	The essay should be reorganized.	1
Comprehension	Used many specific details correctly and shows complete understanding. Used two or more sources.	Used many specific details correctly. Used two or more sources.	Used some specific details. Used two or more sources.	Used some specific details. Only one source used.	Used few or inaccurate details. Only one source used.	1.5

E.3 Essay Contest Scores

All Sixth Graders' Essay Contest Scores 2014

Student	Scientific Accuracy	Spelling and Grammar	Organization	Comprehension	Weighted Total Score
E.M.	5	4.5	5	5	**24.5**
H.R.	5	4.5	4.5	5	**24**
M.O.	5	4.5	4.5	5	**24**
G.H.	5	4.5	5	4.5	**23.75**
13	5	3.5	5	5	**23.5**
34	5	3.5	4	5	**22.5**
42	4.5	5	4	4.5	**22.5**
40	5	4.5	3.5	4.5	**22.25**
14	4.5	4	3.5	5	**21.75**
35	4	3	5	4.5	**20.75**
37	4.5	3	3.5	4.5	**20**
48	4	2.5	4	4	**18.5**
25	3.5	2.5	4	3.5	**17**
52	3	3	3.5	3	**15.5**
30	3.5	2.5	3	2.5	**14.5**
28	3	2.5	3	2.5	**13.75**
38	3	2	3	2.5	**13.25**
6	4	1	1.5	3	**13**
8	2	3	1	2.5	**10.75**
5	1	1	4.5	1.5	**9.25**
53	1.5	2	2	1	**7.75**
21	2	1	1	1	**6.5**

References

[1] Elm Park Community School in Worcester, Massachusetts, *City-Data.com*. 2014.

[2] Elm Park Community, *Century 21*. School Information, 2014.