WORCESTER POLYTECHNIC INSTITUTE

Elm Park School- 6th Grade Curriculum Development

Interactive Qualifying Project Report submitted in partial fulfillment of the degree of Bachelor of Science

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Abstract

Several studies have shown that elementary school students have a poor scientific identity that leads them to have negative attitudes toward science. Briefly, scientific identity is the characteristic of an individual that allows him/her to think and act following common scientific principles. A poor scientific identity in an educational environment would then mean that students might perform poorly in their science classes as a result. In order to improve students' scientific identity, this project implemented a curriculum based on interactive, hands-on activities. Since these activities allowed students to interact with each other and to learn from each other, our team expected to positively impact their scientific identity. To assess self-identity, this project attempted to show how sixth grade students perceive science after working through the activities that our team designed for them. The activities tied in with both the sixth grade's curriculum and an overarching lunar base theme. Both the curriculum topics and the lunar base theme helped to generate the questions for the students to analyze at the end of the activities. Through these questions and additional surveys handed out at the end of the activities, the team was able to assess student self-identity by looking at three aspects: attitude towards the activities, engagement in the activity, and student comprehension of the topics covered in the activity. Results from the evaluation questions and surveys showed that the majority of the students reported having positive attitude towards the team's activities, being engaged in the activities, and being aware of the scientific concepts of the activities. The team concluded that through the activities performed in this project, the students were able to maintain a high level of identity and confidence in their scientific environment.

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Introduction

Elm Park Community School is one of the many community schools that serve students from low income families in the city of Worcester. For the past few years it has been in danger of being taken over by state authorities due to the students' low performance in several of the courses taught in the school. Its students, the majority of them Hispanic immigrants, have recently struggled to reach passing grade level in reading and writing courses. Students have also shown major difficulties in handling math and science courses (Wilkes 2012). According to the Elm Park School Accountability Plan for the 2011-2012 period, students coming from low income and immigrant families have shown a decrease in learning in the ELA (English Language and Arts) Massachusetts Comprehensive Assessment System (MCAS) for 2011. The account also shows that learning growth in mathematics has also diminished, showing no improvement for the years 2010 and 2011 (Proctor et al., 2012). For this reason Worcester Polytechnic Institute (WPI) arranged for multiple teams to support curriculum development for the courses taught at the elementary school. These teams assisted the school by elaborating plans of action (further adding to the curriculum of courses), providing external resources to students, designing activities to be done in class, and assisting students with their classes during the course of the school year. Activities done by these teams were sponsored by the American Institute of Aeronautics and Astronautics (AIAA). The AIAA also supported the teams in developing an aerospace theme which had the students analyze the possibility of establishing a base for humans to live in, on the Moon. Students' development of their reading, scientific, and reasoning skills was encouraged by having them participate in this challenging program. The expectations at the end of each team's program were similar for all teams. The teams wanted to impact students by having them work through contests and projects which would make the students participate actively, write critically and analyze situations. In the end, the teams expected this impact to help students improve their attention span and engagement during class so that they could ultimately improve their grades.

As part of the set of teams that assisted Elm Park School, our team focused specifically on elaborating curricular activities for the 6th grade. Our team introduced a moon-base theme alongside the activities. Our team met weekly to discuss objectives, activities, and plans during the time that the project took place. Initially, our team decided to focus on enhancing the 6th grade curriculum by working with biology related activities that would encourage the students to work through several biological concepts. However, due to a rearrangement of the curriculum, the biology topics meant to be covered were scheduled for the last term of the 6th grade, which was after the last term of classes at WPI. For this reason, the team designed activities based mainly on the physical and earth science topics of the curriculum that were taught concurrently with the project.

As a final capstone activity, the team decided to hold a design project which marked the ending point of the series of activities done by our team. This project emphasized the factors necessary for a moon base to thrive on the moon. The students did research on each factor and described the way in which their own particular factor was to be applied on the moon. The project seemed to be a proper conclusion for the series of activities done throughout the academic year.

For the design project, students worked beyond their normal class sessions and received outside resources in order to determine a way to design a base to sustain human life on the moon. They were encouraged to think critically by performing hands-on activities connected to the lessons they learned in class and by looking at several resources that explained the unique characteristics of the moon. Because of the established curriculum arrangement, the team came to an agreement with the 6th grade teacher and the team's advisors so that the activities were based on the lessons taught during normal class time. The topics in the lessons included: light energy, radiation, electromagnetic spectrum, heat energy, electricity, forces and gravity, the solar system, and the atmosphere. In order to complete the final design project, students presented their own moon base design given the concepts they learned from the activities and the other resources (lectures and summaries) provided.

Background Concepts

Understanding some of the basic principles behind education was paramount for this project's formation. Out of the many concepts which pervade the field of education, the theory of constructivism served as this project's foundation for the elaboration of activities and the creation of evaluation methods. Piaget's theory of constructivism claims that a subject's knowledge can only be constructed through the subject's experiences (Bodner 1986). Jean Piaget, a Swiss psychologist and philosopher who focused his work on epistemology, (Munari, 1994) was an uncommon philosopher because of his developmental study approach with children, a practice that other philosophers considered a "sin" (Von Glasersfeld, 1995). It was probably because of this developmental approach that Piaget's theory found its way into the realm of education, as the theory offers a model which instructors have applied in education in order to help student learning (Von Glasersfeld 1995). Piaget's educational model of the theory of constructivism does not make an attempt to describe knowledge in terms of the accepted norms of what is "useful and required" knowledge, nor does it try to affect learning by transmitting knowledge directly from instructor to student (Bodner 1986; Von Glasersfeld 1995). Instead, the educational model of constructivism serves to "foster the art of learning" by providing experiences to students so that they can build knowledge in their own way (Von Glasersfeld 1995). Skinner also suggests that the theory of constructivism is further encouraged by the fact that good learning is reinforced by a well-designed activity, as it will provide an attractive and challenging experience which will only help to engage students into learning through experience (Skinner, 1984 ; Duffy & Cunningham 1996). Thus, the constructivist instructor conducting an activity should be able to argue that his/her student learns the activity itself because it provides the learning foundation for subsequent experiences in which the student will need to act similarly to that first experience with the activity.

The premises of constructivism include: knowledge resides in the mind; knowledge is constructed rather than acquired; and instruction or teaching supports the construction of knowledge rather than providing the knowledge. (Duffy & Cunningham 1996, Von Glasersfeld 1995). These premises have served as a study focus for various scholars. One such study argues that the constructivist approach is extremely useful in guiding students "to think like experts" (Vrasidas 2000). Because constructivism allows a much stronger emphasis on the cognitive process and the self-reflection skill than other models such as objectivism, Vrasidas argues that constructivism provides more opportunities for students to explore and expand their learning abilities (Vrasidas 2000). Von Glasersfeld, a radical constructivist, has also identified a few notions which are inherent to constructivism. He identifies two main factors which give the individual the tools to become an active constructivist. One of the factors he states as “re-presentation”, or the ability of an individual to be able to remind him or herself of a past experience (Von Glasersfeld 1995). In a more educational context, re-presentation would refer to the learner’s ability to revisit a past experience in which a particular subject was learned, and to apply the same cognitive process of that past experience to approach a novel yet similar situation. Von Glasersfeld also identified a second relevant factor in the constructivist approach. He recognizes the individual identity as the characteristic which gives the learner the ability to form conceptions of objects or terms which will be “re-presented” though the learner’s academic experience (Piaget 1937: *Constructions of Reality in the Child*; Von Glasersfeld 1995). In short, re-presentation and individual identity are both important factors in constructivist education. Each learner has a unique personal approach of problem solving (individual identity), which is based on the experiences which help the individual redefine, or reconstruct, a particular situation (cognitive re-presentation).

There are other methods in education that do not share the same ideas of the constructivist approach and which have also served as a model of teaching. Objectivism, which was mentioned earlier, has been a popular model in educational settings because it takes a more “straightforward” approach to learning. Objectivism’s premises tend to relate to the idea that there is an absolute truth (regardless of the individual’s point of view), and that the knowledge needed to understand that truth revolves around the individual (it does not lie within the individual’s mind) (Vrasidas 2000). According to Jonassen and Lakoff, objectivism only allows the individual to use symbols to represent the knowledge that surrounds him/her (Jonassen 1992a; Lakoff 1987; Vrasidas 2000). They also point out that there is only one correct understanding of a particular topic (Lakoff 1987). Thus, “learning” a particular topic would then mean that the individual changes his/her behavior in order to acquire the knowledge of that topic, regardless of the individual’s attitude towards the learning method. Objectivist educators believe that their goal towards learners lies in the idea of transmitting objective knowledge directly into the learner’s mind, a view which is opposite to constructivism’s main goal (Vrasidas 2000). Constructivist radicals would undoubtedly reject this view. Besides denying that knowledge is something almost tangible, as objectivists pose, constructivists would also reject the idea of having instructors provide their own knowledge to the learner. Constructivists would argue that objectivism would not necessarily teach learners how to acquire knowledge, because objectivism lacks the experiential learning approach. Yet, objectivists would argue against constructivists that the latter’s theory is lacking impartiality, and thus cannot be used as a teaching model because it lacks a common consensus of what knowledge is.

There have been studies suggesting that the two theories can sometimes work well together in a specific setting. In his “Constructivism versus Objectivism: Implications for Interaction, Course Design, and Evaluation in Distance Education”, Vrasidas recognizes that the objectivist theory and the constructivist theory offer advantages and disadvantages which can be combined to form a single powerful model. For Vrasidas, constructivism allows the student in distant education to act like an expert, thinking about several prescribed methods provided by the instructor in order to understand a particular topic. Yet Vrasidas argues that constructivism can sometimes be lacking in a reliable way to measure the understanding of the distant student. Prawat & Flonden also identify constructivism's main weakness in its "inability to evaluate learning" (Prawat & Flonden 1994; Vrasidas 2000). In addition, the fact that constructivism does not rely on establishing common objectives can make its application somewhat difficult (Eisner 1994: Vrasidas 2000). Vrasidas identifies objectivism as constraining the world and creating an objective reality for everyone. In this reality, he continues, is where all the individual conceptions are created (Vrasidas 2000). Objectivism can help provide common objectives for all students to follow and for instructors to evaluate learning. Objectivism can thus address some of the shortcomings which constructivism suffers from the most.

In his conclusion Vrasidas states that an instructor should not focus on one particular theory. Instead he states: "there are times that a more objectivist approach is appropriate and there are other times that a more constructivist approach is appropriate" (Vrasidas 2000). For educators however, the decision of which approach suits better any situation might not always be clear. In the modern world, certain considerations such as students' backgrounds, school context, working experience, and resources available, all affect the way in which teaching (and learning) will happen.

Modern Educational Environment

Educational settings in the modern world require more than just the adaptation of a particular educational model from a psychological or philosophical theory into the educational field. In science education in particular, several factors such as economic difficulties, social and ethnic status, K-12 learning experiences, and perceptions about science and scientists all affect the way in which young learners approach the scientific setting (Bhattacharyya 2011; Barab & Hay 2001; Catsambis 1995; Ferguson & Mehta 2002). Bhatacharyya et al. for instance, developed a study to understand the influence of summer camps on students of the African-American background. Bhattacharyya et al. performed this study in order to identify some of the factors that affect students' engagement in science. Starting from the hypothesis that ethnicity does have an effect on students' attitude towards science, Bhattacharyya et al. found out that only 21% of the African-American students held strong positive feelings towards science. However, their results showed that gender, teacher encouragement, and equity of access in science all strongly affected the way in which the students viewed science. Thus, Bhatacharyya et al. recognized that even though ethnic backgrounds might have an influence in science aversion by students, several other factors also affect students' attitude towards science (Bhattacharyya 2011). Without taking these factors into account, a positive attitude towards science might not always be facilitated by the use of any educational model. And without the proper attitude towards science, there might be a problem in science teaching and learning.

In the modern educational setting, students must meet several standards in order to assure that they meet the requirements of an evolving society. As society and education change throughout the years, these standards must also evolve. Yet, the model with which those standards are met needs to have a solid foundation, so that teaching and learning methods keep up with the rapid rise in knowledge. In the United States, the schooling system that defines the education methods is known as the K-12 school system. The K-12 system was developed in the middle of the 20^{th} century, just as mandatory education was established in the United States. K-12 schools follow the system of standards that was set by the US Congress in 2001 in the No Child Left Behind Act, which requires schools to perform national standardized tests (K-12 online). These tests not only measure student performance, but they also offer an impartial perspective as to how school teaching is being done. Since K-12 schools are mostly comprised of the public schools that receive funding from the government, these standardized tests have a great meaning to those schools. Failure to meet the standards in the tests could potentially mean the replacement of the teaching staff, or even the closing and takeover of the school by a governmental body (Linn et al., 2012). So, how do K-12 schools cope with the dangers of student failure in these standardized tests? Schools following the K-12 system follow some of the curriculum choices that the K-12 program delivers. Namely, K-12 programs offer help to instructors by providing them with materials and teaching methods to be used in a traditional classroom (K-12 online). These resources are provided by the Educational Testing Service (ETS) which has been in charge of supporting the K-12 system as well as other educational programs (ets.org). For the topics which have been discussed earlier however, a more suitable question would be: how do K-12 schools deal with students' increasing lack of interest towards science learning? As Bhattacharyya suggested, this should be a main focus in education, since knowledge-based economies rely heavily on the progress done in the sciences ("No Child Left Behind" 2012; Bhattacharyya 2011).

Efforts have been made to find a way to provide K-12 students with an educational model that will allow them to meet the requirements of the nation's standardized tests (especially those related to the sciences), and to provide them with a learning style which will help in their learning until well beyond their secondary education. As pointed out before, Von Glasersfeld gives instructors a starting point on his description of constructivism as a learning tool. Two of the concepts which he used to describe the constructivism model of learning, "re-presentation" and "individual identity", are two concepts which other scholars have expanded and applied in their studies. One such concept, identity, has been defined by Wylie in one of her discussions. Wylie describes identity first through the term "self-concept", which she defines as the "ideas and perceptions that the individual has about his/her abilities, accomplishments, faults, weaknesses, and values" (Wiley 1961; Guardo & Bohan 1971). Even though Wiley made a clear distinction between this meaning and the meaning of "self", to a constructivist this distinction in meanings would probably be considered incomplete. This is because as Von Glasersfeld stated, the empirical model of constructivism allows the individual to re-present (build upon past knowledge) experiences under the individual's identity (unique perspective) (Von Glasersfeld 1995). Thus, if self-concept refers to the individual's internal experience to construct his/her idea of self, then both "self" and "self-concept" can be related by this "experiencer-experience" relation. As such, Guardo et al. offer another thoughtful definition of self-concept which seems more in line with the constructivist way of thinking: self-concept as a construct is "from the point of view of the experiencer, the phenomenological feeling or sense of self-identity" (Guardo & Bohan 1971). Regardless of etymologies, if this definition is translated to the scientific setting, then self-concept is the set of ideas and perceptions that an individual has about his/her abilities when doing scientific inquiry: when testing, when formulating hypothesis, and when coming to a reasonable conclusion.

If self-concept can be translated into the scientific setting, then it can surely be the focus of an educational model which attempts to understand the scientific identity of the individual. Archer et al. provide a fair example of how the self-identity can be used to evaluate student progress relative to: attitude towards science, engagement in science, and comprehension of conceptual information related to science (Archer et al., 2010). Firstly, Archer et al. explain how attitude had been the subject of study in several works done before. These past works demonstrate how the attitude of students towards science affected students' interest in this subject. According to the National Assessment of Educational Progress and the Office for Public, in the United Kingdom, interest in science was found to be developed mostly in the early stages of childhood up to the age of 14 (Tai et al. 2006 ;Archer et al., 2010). Secondly, Archer et al. recognized that engagement is strongly grounded to the concept of identity. Identity in young students can have a great impact in the way that students engage themselves in scientific environments since, by having a strong scientific identity, students show can find scientific activities interesting and thus engage in them often. Therefore, engagement can be determined by looking at student behavior and can determine the way in which students picture themselves in a scientific environment (Archer et al. 2000). Finally, Archer et al. recognized that in order to demonstrate comprehension of a particular scientific topic, the students' achievements need to be observed. Assessing comprehension can then complement the assessment of attitude and engagement since by looking at comprehension instructors understand if students learn the scientific concepts properly. Thus, student comprehension can also help build student self-identity because with the learned scientific concepts students will feel comfortable to build upon their knowledge. And even though assessing comprehension seems to follow a more objectivist approach, it is still one of the most reliable ways to reflect on how students' cognitive structure is developed (van den Broek et al., 2005).

Scientific Identity Studies

The assessment of young students' scientific identity has been at the core of various studies. These studies use several methods to assess scientific self-identity in students belonging to a wide range of ethnicities, age groups and societies. Yet, these studies have managed to provide a foundation for the studies interested in understanding science identity in young students. Out of the many works that have been published that relate with science education, a few studies have been selected to provide a basis for our teams' project. This basis was centered on the notions in which: (1) the methodology of the study is related to the constructivist model in that it emphasizes assessing students' construction of self-identity; (2) the concepts of attitude, engagement, and comprehension (either together or alone) are a focus of study to determine student scientific identity; and, (3) the methods and results follow a more objectivist perspective in that they provide real, quantifiable data to measure the attitude, engagement, or comprehension of students. Below are a few examples of studies that have used these concepts as a tool to measure scientific identity and learning skills in students.

Trying to understand how students' attitude toward science can be improved is a matter which needs to be considered if students' scientific identity needs to be enhanced. Research has shown that elementary school children tend to be separated from the "scientific environment" since they are oftentimes not introduced to science at a young age and are not encouraged work in scientific activities (Osborne, Simon, & Collins, 2003; Pell & Jarvis, 2001; Ramsden, 1998). Students also seem to show an increasing lack of interest towards science as they move up from elementary school to secondary school (Bordt et al., 2001; Osborne et al., 2003; Pell & Jarvis, 2001; Piburn & Baker, 1993; Weinburgh, 2000). Several variables have been identified as affecting students' attitude in a negative way. Nadirova et al.

lists these variables: “uninteresting or unchallenging science lessons; student lack of awareness of the links between science and society and real-life applications of science; and, lack of inquiry-based, hands-on, cooperative learning methods in teaching science”(Nadirova & Burger, 2008). These observations point out that students are not only excluded from the science setting, but they are also being limited in their possibilities of performing scientific inquiry as a means to improve their grades and explore future careers.

For these reasons, Nadirova et al. attempted to understand the effects of attitude and identity in fourth graders. To assess the attitude that fourth grade students in Canada showed towards science, Nadirova et al. designed questionnaires to evaluate the differences in attitudes between two groups of students (project-based learning students in one and lecture-based students, or “control students” in the other). Ultimately, the questions in the questionnaires were grouped into six different factors of student attitude towards science. These factors were: (1) appreciation of science, (2) appreciation of the Science Center/Odyssium (a scientific and educational museum in Canada, currently known as the TELUS World of Science), (3) practical application of science, (4) confidence in learning science, (5) attitudes toward cooperative learning, and (6) difficulty of science. Through 5-point Likert scale statements in which answer choices ranged from “strongly agree” to “strongly disagree”, Nadirova et al. were able to determine if students had either a positive or negative attitude towards science. Statements such as “I would like to be a scientist”, “I usually do well in science”, and “Science is fun” helped determine the attitude and perception of students to their daily experiences with science. The study concluded that students attending the project-based school demonstrated more positive attitude levels toward science than those who attended the control schools. The authors concluded that the more positive attitude in the students attending the project-based school was mostly affected by the nature of their scientific learning environment: one in which their science learning was done through interactive and team-based projects. (Nadirova & Burger, 2008)

Besides attitude assessment, recent studies have shown how student engagement and student comprehension can be good indicators of student learning and personal development. Carini et al. focused on exploring the reasons why college students felt more or less engaged towards their courses (Carini et al. 2006). Even though this study was performed at the university level and did not have science learning as its focus, it does provide a good way to measure the correlation between engagement and learning. In this study engagement was determined by observing students’ performance in categories such as: “active and collaborative learning”, “level of work performed”, and “amount of reading and writing done by the student” (Carini et al. 2006). Carini et al. effectively indicated that the students who presented higher levels of engagement were the same students that obtained higher GPA’s in their classes (Carini et al. 2006). Another study that focused on assessing cognitive engagement (engagement related to the thought process involved to solve a particular problem) in fifth and sixth grade students shows how students fell under two distinct categories of engagement (Meece et al. 1988). These two categories corresponded to (1) students who placed a strong emphasis to the “task-mastery” (or those students whose cognitive engagement let them actively learn), and (2) students whose goals were focused on “task-completion” (finishing the task as quickly as possible) (Meece et al. 1988). Comprehension assessment in young students has also become the focus analysis in studies such as in van den Broek et al. Comprehension, according to their research, is the collection of actions that allow an individual to recall, infer, interpret and understand a particular piece of information or event. Their study shows how they evaluated preschoolers' comprehension based on their ability to recall words and sounds from an audio setup. After performing the activity, preschoolers, were asked to tell what sounds were made and how they were made. The study's conclusion determined that comprehension assessment can only be done in terms of the quality (or the "correctness" and "sense") of the answer, rather than the quantity (or the amount of information recalled which might not always be exact) (van den Broek et al. 2005).

Goals

Our team's goal was to positively impact students' scientific identity. Our team needed to look at a few specific aspects in order to affect students' scientific identity: student engagement in the activities designed by the team, comprehension of the concepts learned in the activities, and the attitude shown by the students towards the overarching moon-base topic. In order to achieve this goal, the team aimed to design and implement dynamic activities that would make the students participate actively by handling materials, acquiring data, analyzing results, and coming to a conclusion. From these activities, the team expected to attract students to the science topics of their sixth grade curriculum, enhance student participation in the experimentation and inquiry parts of activities, and foster an environment where the students felt comfortable working in science.

After performing the activities with the students, the team then aimed to assess students' attitude, engagement, and comprehension of scientific concepts. By categorizing responses to the surveys and activity questions, our team hoped to determine if students had gained a more positive scientific self-identity.

Methodology

The team's approach to fulfilling the objective of improving student interest toward science can be summarized as: (a) communication with school teachers and project coordinators; (b) creation and implementation of hands-on activities and activity assessment; and, (c) collection and analysis of student responses to evaluation questions.

Team Meetings

Team meetings with the 6th grade teacher and the team's coordinator allowed the team to brainstorm ideas, plan activities and schedule future meetings. Meetings with the team advisors let the team prepare long term plans and discuss potential activities. These meetings served as the team's weekly assessment to its work-in-progress, letting each member give input on activities and other ideas. Weekly schedule plans and activity reviews were the topics most often discussed in these meetings. Meetings with the 6th grade teacher on the other hand, helped in determining which subjects were to be covered via the planned activities. Moreover, it was with the 6th grade teacher that the capstone design of the moon base was planned and scheduled.

Instalab Development

Hands-on activities or "Instalabs", as known to the team, were made of two main components: the experimental part of the activity and the evaluation part of the activity. The experimental part was composed of all the actions needed for the students to accurately evaluate the hypothesis they developed prior to the beginning of the experiment. The activities were designed to have students interact with each other and think through the possible results in a scientific setting. It is expected for each student to at least be observant and take notes on the activity so that they have enough knowledge to work through the evaluation part of the activity. The assessment of student attitudes and engagement serves both to evaluate the students' comprehension on the subject matter, and to evaluate the activity's clarity through encouraging students to build knowledge.

Instalab Design Criteria

As well as impacting interest levels, comprehension and engagement, our team expected the activities to allow students to gain an overall understanding of the basic physical sciences which were to be presented to them during their fourth quarter. Our team also expected students to feel comfortable with life sciences topics which were further expanded through the moon-base theme.
Specifically, we designed Instalabs intended to teach students the concepts presented in the textbook "HSP Science: Physical Science" and the related standards (Table 1). Below is a table of the chapters and the most important concepts for students to learn for each chapter (Bell et al., 2009):

Table 1: Textbook Chapters with corresponding Instalabs and Related Standards

Chapters	Concepts to be learned	Corresponding Instalab	Related Standard #
Energy	Forms of energy, kinetic and potential energy transfer, waves, light behavior,	Electromagnetic Spectrum	1
Heat and Electricity	Thermal energy transfer, insulation, conduction, particle motion, temperature change as related to heat transfer, thermal equilibrium	Thermal Insulation	2,3,4
Forces and Motion	Action and interaction of forces, gravitational forces, position, direction of motion, speed, graphing and interpreting distance and time	Lunar Phase Modeling	5,7,8,9,11
The Universe – Near and Far	Earth-sun-moon interactions, phases of the moon, tidal forces, solar system and beyond, lunar and solar eclipses, tilt and revolution of earth, effects of the suns energy on temperature, atmosphere, water, and land	Lunar Phase Modeling Design Presentation	7,8,9,10,11
Earth's Weather Patterns	Atmosphere, weather, storm tracking, air pressure	Nitrogen Fixation	10

Alongside the physical science topics, students needed to become familiar with subjects related to other sciences. For example, students needed to understand the concepts of elements, matter, basic chemistry, plant biology, ecosystems, and the earth sciences.

Furthermore, our team tried to reach its objectives keeping in mind that students needed to learn their subjects according to the Science Standards from Massachusetts Frameworks (Science Standards from Massachusetts Frameworks). The list of these standards follows:

Figure 1: Physical Science Standards as presented in the Massachusetts Frameworks

Physical Science

1. Differentiate between potential and kinetic energy. Identify situations where kinetic energy is transferred into potential energy and vice versa.
2. Recognize that heat is a form of energy and that temperature change results from adding or taking away heat from a system.
3. Explain the effect of heat on particle motion through description of what happens to particles during a change in phase.
4. Give examples of how heat moves in predictable ways, moving from warmer objects to cooler ones until they reach equilibrium.
5. Explain and give examples of how the motion of an object can be described by its position, direction of motion, and speed.
6. Graph and interpret distance vs. time graphs for constant speed.

Earth and Space Sciences

7. Explain the relationship among the energy provided by the sun, the global patterns of atmospheric movement, and the temperature differences among water, land, and atmosphere.
8. Recognize that gravity is a force that pulls all things on and near the earth toward the center of the earth. Gravity plays a major role in the formation of the planets, stars, and solar system and in determining their motion.
9. Describe lunar and solar eclipses, the observed moon phases, and tides. Relate them to the relative positions of the earth, moon, and sun.
10. Compare and contrast properties and conditions of objects in the solar system (i.e., sun planets, and moons) to those on Earth (i.e., gravitational force, distance from the sun, speed, movement, temperature, and atmospheric conditions).
11. Explain how tilt of the earth and its revolution around the sun result in an uneven heating of the earth, which in turn causes the seasons.
12. Recognize that the universe contains many billions of galaxies, and that each galaxy contains many billions of stars.

Finally, our team expected to abide by the AIAA agreement that a moon-base theme would accompany our efforts to help students learn the concepts previously described. From the moon-base theme, we expected students to learn how to analyze scientific literature; read science, magazine and newspaper articles; write essays and reports summarizing scientific data or information; and make an attempt to understand the current advances in aeronautics technology.

Activity Assessment

Since our team attempted to make an impact on student learning through our activities, it was vital to establish a method of evaluating the impression that these activities had on the students. Our first evaluation method employed both Likert scale questions based on student perception of the activities, and “problem solving” questions requiring analysis and critical thinking, based on the activities. This method gave an idea of how well the activities were employed, as well as serving as a measuring tool to determine student self-identity and attitude. A secondary evaluation method employed by the team was an in depth assessment of the students’ journal responses to ascertain the engagement and comprehension levels demonstrated by the students. Responses were anonymously graded on the amount of data collected and their detail level to gauge engagement, while conceptual understanding and their organization was used to gauge comprehension. Each category was found to be either below standard, on standard or above the standard expected for sixth grade students.

Results on attitude and interest levels were recorded using an evaluation form beginning with the thermal insulation lab. Figure 2 represents the evaluation form. The question numbers correspond with the survey evaluation charts in the results section. Figure 3 represents the final survey delivered at the end of the design activity.

Figure 2: Instalab Likert Scale Student Survey

1. - 2. “I found this activity:”

Easy - Medium - Hard

Exciting - Neutral - Uninteresting

3. “I could explain this activity to another person:”

Agree - Somewhat Agree – Unsure – Somewhat Disagree - Disagree

4. “I was able to make hypothesis for this experiment:”

Agree - Somewhat Agree – Unsure – Somewhat Disagree - Disagree

5. “Working on these moon related activities encourages me to study science:” (Employed for the Nitrogen Fixation and Design Project only)

Agree - Somewhat Agree – Unsure – Somewhat Disagree - Disagree

Collection and analysis of the students’ responses to the activity and evaluation questions were done at the end of the design project. Answers to the surveys were examined so that the team could identify the different proportions of students that believed that our activities were useful to them. Question 1 and 5 were chosen to help evaluate student attitude. Questions 2, 3, and 4 were chosen to gauge students' confidence towards the presented materials. Furthermore, some survey questions also served to identify a change in student attitude towards the activities. Answers to activity questions in the journals were also observed and examined. This was done to further understand if students experienced any change in attitude towards science.

Figure 3: Final Likert Scale Student Survey

1. "Working on these activities encourages me to study science."

Strongly agree - Agree – Unsure – Disagree - Strongly disagree

2. "These activities have made me want to learn more about the moon and outer space."

Strongly agree - Agree – Unsure – Disagree - Strongly disagree

3. "I would like to be a scientist."

Strongly agree - Agree – Unsure – Disagree - Strongly disagree

4. "Science is boring."

Strongly agree - Agree – Unsure – Disagree - Strongly disagree

5. "I usually do well in science."

Strongly agree - Agree – Unsure – Disagree - Strongly disagree

Effectively administering the surveys proved to be difficult due to classroom dynamics. On many days, students were forced to leave part way through the activity for various reasons and therefore did not complete a survey. Because of this, there are inconsistent values for total survey numbers between activities. The data acquired from these surveys is presented in the results section. Students' journal responses were also graded to evaluate engagement and comprehension. Table 2 represents the teams grading rubric when reading through the student responses.

Table 2: Grading Rubric for Journal Evaluation

	Below Standard	On Standard	Above Standard
Data	Does not collect data	Collects Sufficient data	Collects Detailed data
Detail	Empty response	response on topic	Informative, detailed response
Concept	Does not convey main concepts	Correctly conveys main concepts	Elaborates on main concepts
Organization	Unorganized response	Minimally organized	Well organized,

		response in specified manner	comprehensive categorization of information

Supplemental Activities

The following activities provided no quantitative data for the team. They were completed to increase student interaction time and familiarize the team with the Elm Park community.

Science Fair Project

An additional segment of the curriculum was the guided design of experiment based projects in science and engineering. The students were tasked with creating a hypothesis and performing an experiment. A report detailing their process and results was produced for each project. The process began with the formulation of a testable hypothesis. Each student then designed and conducted an experiment with measurable variables and a control. The students used a variety of materials to make quantitative observations and draw conclusions from their results. The experiments were related to a wide variety of topics including astronomy, biology, gravity, energy, electricity and ecology. The team's role in this process was to provide topics in which the students could conduct further research as well as assisting in the experimentation process and research. The team also attended an afterschool session to help perform experiments and complete presentation posters for some of the projects.
Some of the topics proposed by the team included:

- Geotropism or the study of how gravity affects the growth of living things: Students could constrain the growth of plants horizontally and vertically to see how it impacts root & stem growth. Orientation could also be alternated on regular intervals to observe the adaptation of plants to differing gravitational forces. They could then relate this to growing plants in zero gravity and low gravity environments.

- The study of biomes and how students would grow plants in artificial climates: Plants could be grown by a window where it is cold with lots of light or in a warm, darker area, etc. The plants could even be sealed in a plastic container with water to create an artificial water cycle. Students could use this to determine the factors that control plant growth and what needs to be considered when designing a greenhouse (humidity, resources, etc.).

- How plants use light: Students could restrict the wavelength of light that plants receive using colored plastic, and determine which wavelengths are most important. Black paper could be used to restrict all light. This experiment could be performed on plants at different parts of their lifecycle (seedlings, buds, fully grown). This would help students relate color and light, and the effect of depriving plants of certain colors.

The students who performed the geotropism project were awarded 3rd place at the Worcester School city wide science fair, an achievement which had previously never before been earned by an Elm Park student.

Essay Contest

Another supplementary part of the curriculum was the team's involvement in a science based essay contest. The 6th grade students were prompted to write an essay about the purpose and mission of the new Mars rover, "Curiosity". The team evaluated the submitted essays and selected the best ones based on a rubric that focused on an understanding of mission goals, a detailed analysis and the inclusion of additional outside resources. A number of winners were selected by Dr. Fred Bortz and rewards were distributed to multiple students.

Results

Tower Hill Field Trip (Appendix A)

Our objective was to expose the 6th grade students to a traditional greenhouse and a variety of plants. The team anticipated that students would learn about the optimal conditions to grow a plant indoors while gathering experience and resources that could later be utilized to make informed decisions about designing their own greenhouses.

On January 10th, 63 students from the Elm Park 6th grade attended a field trip to the Tower Hill Botanical Gardens in Boylston, Massachusetts. The trip began with a keynote address from Dr. Marc Andelman. In his speech, Dr. Andelman spoke to the students about his experience designing a lunar base with Professor John Wilkes of Worcester Polytechnic Institute. He briefly described the multiple aspects they considered while designing their base and then went into further detail about their plan for providing a suitable lunar environment to grow plants in. The students were exposed to concepts such as irrigation, sunlight control and the filtration of harmful electromagnetic radiation. The grade was then divided into three smaller groups in order to cycle through three activities, lasting 40 minutes each. The first activity was a cataloging of the plants located in both the Limonaia (Lemon House) and the Orangerie. (**Error! Reference source not found.**) Students began the activity by describing the atmosphere of the room, taking into consideration the amount of space, the temperature, humidity, light and soil conditions. Students were then tasked with cataloging plants by a series of attributes including leaf type, texture, and color, plant height, the traditional biosphere each plant can be found in, and whether or not the plant could provide food. The students noted their findings in bluebooks distributed by the Elm Park teachers. These bluebooks acted as journals for the students to record their trip to Tower Hill for later investigation.

The second activity was an Interview with Tower Hill's Director of Horticulture. Prior to the field trip, students were guided in selecting interview questions to ask the director. The proposed questions centered around the thought of designing an artificial ecosystem, such as a greenhouse, and what requirements would need to be fulfilled in order to successfully grow plants. Questions involved light and water requirements, soil composition, plant types, humidity, nutrients, etc. Figure 4 represents the questions proposed by the students.

Figure 4: Student Proposed Interview Questions for Tower Hill Faculty

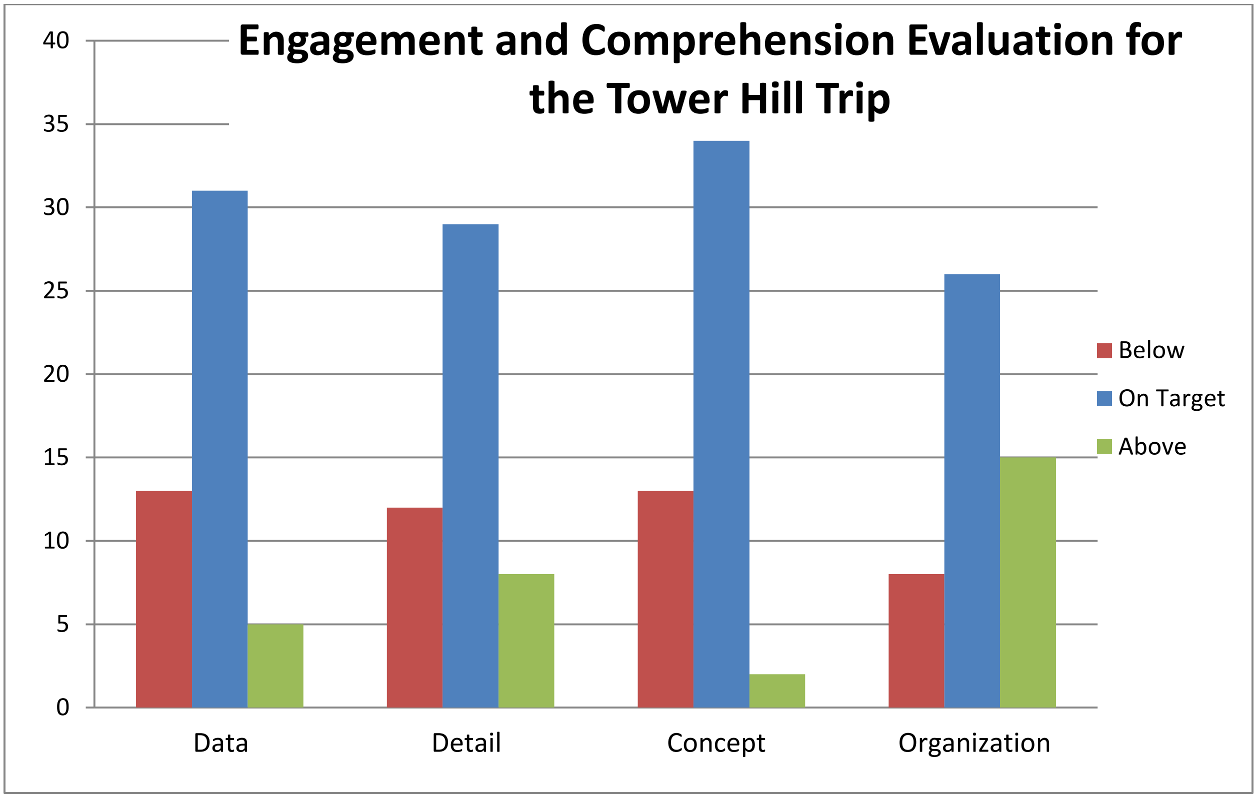
Interview Questions

1) What materials are needed to build a greenhouse?
2) How long did it take to construct the greenhouse?
3) What is a good length for a greenhouse structure?
4) What is a good width?
5) How do you help the plants get enough sunlight to survive?
6) What temperature should the greenhouse be for the plants to thrive?
7) What types of plants thrive best in the greenhouse?
8) How much energy does a greenhouse use?
9) How many days does it take for the plants to fully mature?
10) What type of nutrients and liquid does a plant need?
11) How long would it take for vegetables such as lettuce, green beans, tomatoes and cabbage to grow in a greenhouse?
12) What equipment do you need in a greenhouse such as light bulbs, lamps, electrical sources?
13) What tools are needed to maintain the greenhouse? Ex. Pots, soil, fertilizer, clipping tools.
14) How many times per day are the plants watered?
15) If you grow food producing plants, do you use pesticides?
16) Can plants grow without sunlight? If yes, how?
17) What types of plants grow best at Tower Hill?
18) Do the plants ever get diseases?
19) How much air is needed for the plants to grow successfully?
20) Do your greenhouses use solar power?
21) Which plants contain seeds?
22) Are there any ferns at Tower Hill?
23) How is the amount of sunlight controlled?
24) How much humidity is needed to maintain the greenhouse?

The intention was for students to retroactively relate the information collected during the interview to the lunar base theme. Students recorded the responses in their bluebooks. Once the interview was concluded, students were given the opportunity to ask Dr. Andelman and Professor Wilkes questions related to the moon.

The third activity in the cycle was a plant potting and dissection. Students were given the opportunity to pot cuttings of several houseplants of their choosing to take home. They were also given a chance to take a variety of seeds. Students recorded the types of plants and seeds they received in their bluebooks. After the potting, students were given the chance to view dissected plants. Microscopes were used to help students understand the internal components of each plant. Figure 5 displays the data collected from the notebook evaluation for engagement and comprehension.

Figure 5: Notebook Evaluation of Student Comprehension and Engagement for Tower Hill Activity



Observational Data

Students were very excited in the days leading up to the trip. Many of them had never experienced a greenhouse and were enthusiastic about performing the activities. The keynote address with Dr. Andelman began very well. He was very engaging and student interest levels seemed high. At one point, while explaining the virtues of cattails as both a food source and a production material, he passed out samples of the plants and the students seemed very interested in getting a chance to touch each sample. The impact of this experience was representative in the final design project, as many students recalled the cattails to include in their base design. By the end of the presentation it had been half an hour and many of the students seemed to be getting restless. Once Dr. Andelman concluded everyone quickly left to begin their assigned activities. The value of the presentation would have been much higher if students had been immersed in the subject material beforehand. Unfortunately, they had very little experience with the concepts. Dr. Andelman went in depth into his ideas about the lunar greenhouse and although he attempted to make the material accessible to the students, it was clearly lost on some of them. Despite this, the team still believes it was an effective introduction to the day.

Some complications arose during the interview. The Director of Horticulture was not available for the interview due to an emergency so a Tower Hill employee who had not had time to prepare for the questions was interviewed in her place. Ultimately, he was able to answer all of the student's questions and the answers were recorded. Unfortunately he did not have prepared answers so the impact of some of his answers was not as the team had been expecting. The students seemed much more interested in asking Dr. Andelman and Professor Wilkes questions about the moon and their lunar base. They easily filled the next 20 minutes with questions.

The third activity kept the interest of the students for longer than the planned 40 minutes. They began by selecting seeds and recording their choices in their bluebooks. Students were very enthusiastic about getting to bring things home with them. They especially liked the idea of choosing and potting their own cuttings to keep. At the end of the time period many students wanted to stay in the classroom and view more plants through the microscopes.

Instalabs

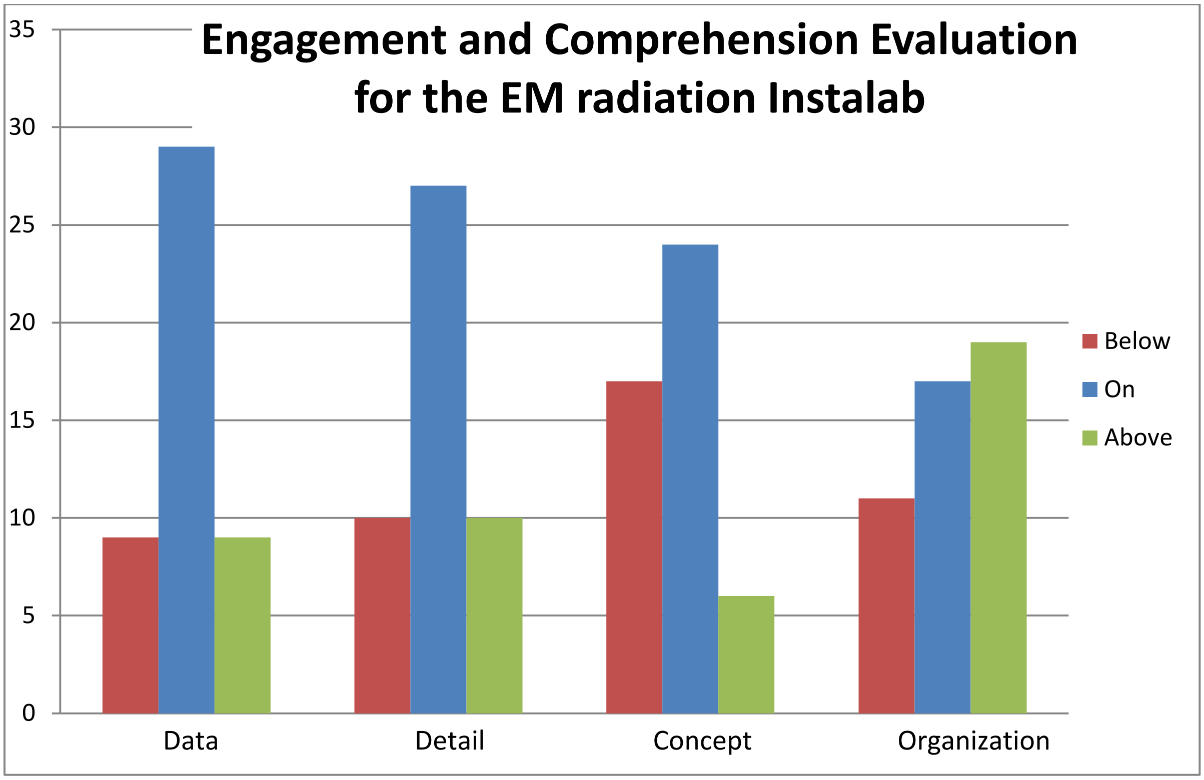
Working with the 6th grade science teacher, our team designed a series of small labs to be performed by the students in the classroom setting. Following all but the first lab, an evaluation survey was to be completed by each student.

Electromagnetic Spectrum Activity (Appendix B)

Our objective was to give students experience understanding and working with the electromagnetic spectrum. For this experiment we expected students to gain a firm understanding of the interconnectedness of the spectrum and the ability to filter out certain wavelengths using different materials.

Our activity began with a five minute video covering the entire electromagnetic spectrum. The class then broke up into two groups, one focusing on infrared rays and the other focusing on radio waves. The infrared group used a television and a remote. It was explained to the students that the remote emits infrared radiation to control the television. The students were then tasked with hypothesizing what materials will be able to block the infrared waves. The list of materials to consider included, white paper, black paper, flat foil, crumpled foil, plastic wrap, a human hand, a CD, a glass of water, colored plastic, tape , and a wall. The students then performed the experiments and tested each material, recording their results in their journals. A series of questions were asked to determine each student's comprehension of the activity. The students performing the radio activity went through similar steps. They were asked to hypothesize about which materials will block the radio waves. The materials include aluminum foil, plastic wrap, a cardboard box, a plastic box, and cloth. After each material was tested, the students answered a series of questions to further test their comprehension. Figure 6 displays the data collected from the journal evaluation for engagement and comprehension. A large majority of students were at or above the standards for all four categories measured. The team considered meeting the standards for Data collection an indication of task-completion, while meeting the standard for detail was taken as an indication of task-mastery; both suggested cognitive engagement. The team also considered meeting the standards related to concept understanding and data organization as indicators of comprehension of the topic of the activity.

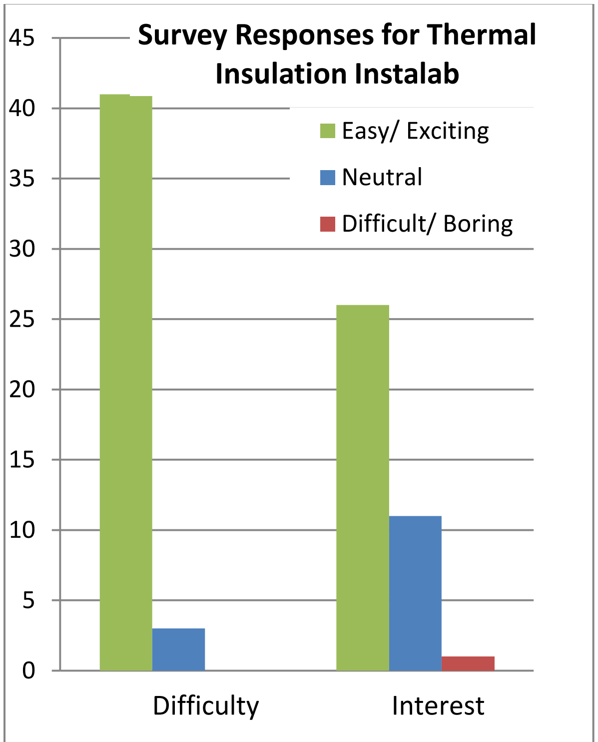
Figure 6: Results of Student Journal Evaluation for Electromagnetic Radiation Instalab. See Table 2 for grading rubric.



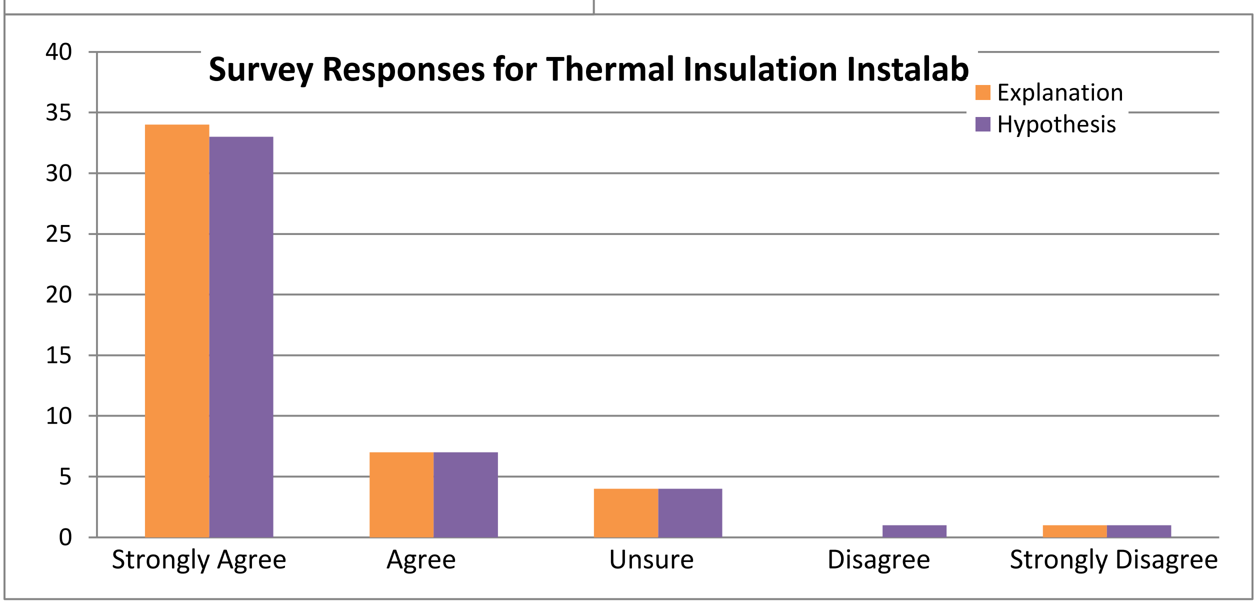
<u>Thermal Insulation Activity</u> (Appendix C)

Our objective was for students to observe the transfer of heat through different objects and develop a firm grasp on the concepts of insulation and conduction of thermal energy.

Figure 7: Results of Likert Scale Student Survey for Thermal Insulation Instalab
Many students did not answer the Interest question due to poor formatting. See Figure 2 for survey questions.

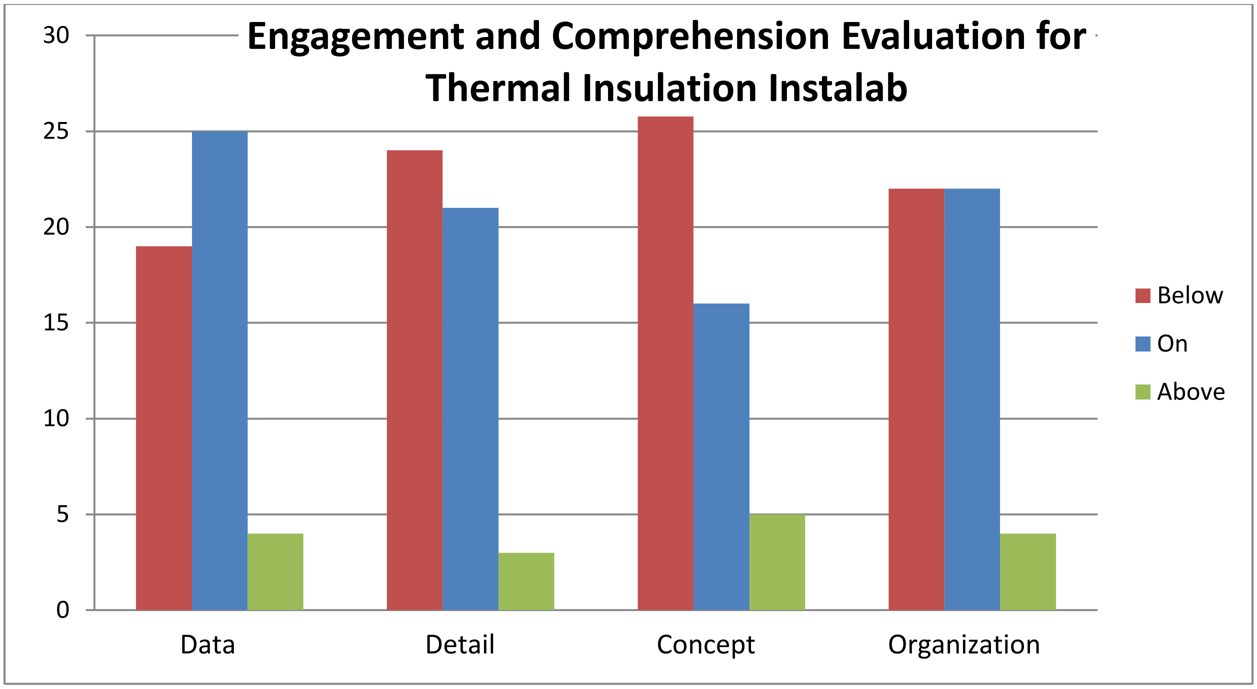


The activity began with students hypothesizing whether numerous materials are insulators or conductors of thermal energy. The materials included metal utensils, plastic utensils, a ceramic cup, a glass without water, a glass with water, a winter jacket, and a rock. The students then heated one side of each material using a hair dryer for thirty seconds. The amount of heat transferred through the object was recorded and each student decided if the material is an insulator or a conductor. The students were then asked to answer a few questions about insulating a lunar base that test their comprehension and problem solving skills.



The initial evaluation form was found to be confusing in that the second question was skipped by many of the students. In future labs, the evaluation form was edited to clarify each question. In any case, most of the students answered positively for each question. Figure 8 displays the data collected from the notebook evaluation for engagement and comprehension. A majority of students, 56%, did not meet the standard for conceptual understanding.

Figure 8: Results of Student Journal Evaluation for Thermal Insulation Instalab. See Table 2 for journal evaluation rubric.



It is interesting to note the large disparity between the students who found this activity easy and the number of students who fell below the conceptual understanding standard.

Lemon Battery Activity (Appendix D)
This activity was not performed in the classroom.

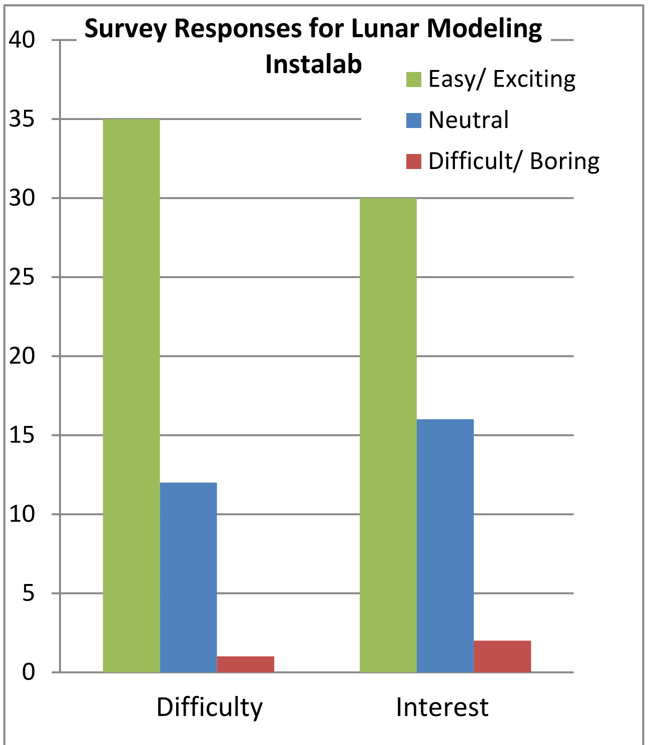
Our objective was for students to be able to identify the components of a battery, create a circuit using the provided materials and identify ways in which electricity can be generated. Unfortunately, this activity was not performed in class due to time restrictions.

The activity begins with a small presentation of background information and then students are asked to identify the parts of a standard AA battery. Students are then given a certain amount of lemons, zinc-galvanized nails, pennies, a light emitting diode and wire and tasked with creating a circuit to power the LED. The students are given a few minutes to attempt setting up the circuit using what they know about batteries and circuits. After about five minutes, the students are shown a working circuit and must identify what is causing the electricity to flow. They then attempt to complete their own circuit. Students are then asked a problem solving question to test their comprehension of the activity. They are asked to identify ways in which electricity is generated on earth. They then must think further about which methods would be applicable on the surface of the moon. Their responses are recorded in their science journals.

Lunar Phase Modeling (Appendix E)

Our objective was for students to develop a firm understanding of the lunar orbit and the moon's many phases. We also anticipated students identifying a suitable location for building a lunar base.

Figure 9: Results of Likert Scale Student Survey for Lunar Phase Modeling Instalab. See Figure 1 for survey questions.



Students used a flashlight and Styrofoam balls to recreate the orbit of the moon around the earth. This model was used to identify points on the lunar surface that receive an optimal amount of light and are therefore ideal building sites for a lunar base. Students took turns placing pins in locations they believed would receive the correct amount of light throughout the lunar day. The Styrofoam balls were revolved and more pins were added until students identified the best location. At the end of the activity, locations were shared among groups and comprehension was tested through a problem solving question. Figure 8 displays the results from the survey evaluation on attitude and interest. Results were mostly positive.

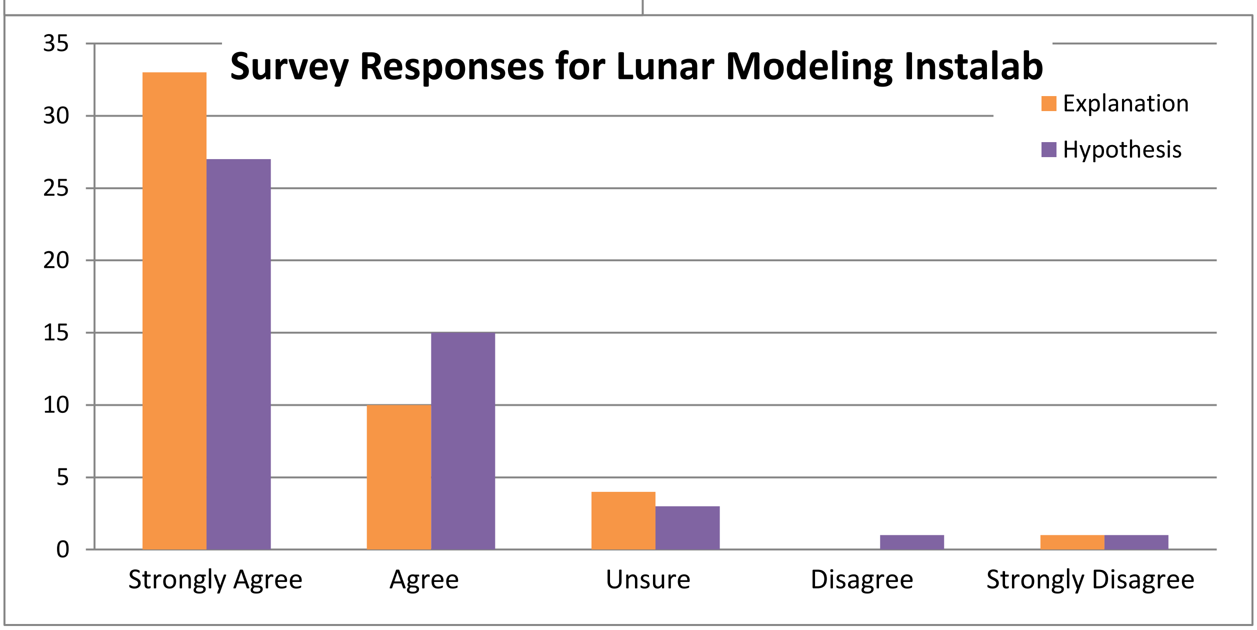
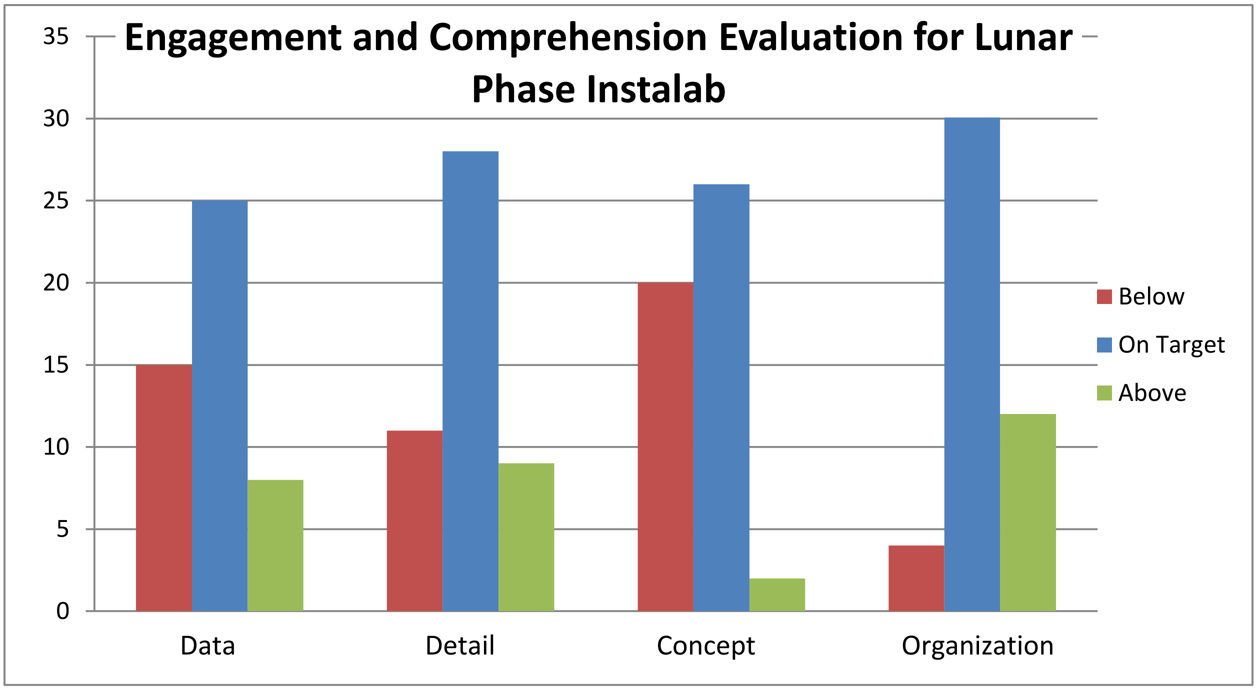


Figure 10 displays the data collected from the notebook evaluation for engagement and comprehension. A larger percentage of students met the standard in the journal evaluation for all four criteria than in the Thermal Insulation lab, suggesting the Lunar Phase activity was more successful.

Figure 10: Results of Evaluation of Student Journals for Lunar Phase Modeling Instalab. See Table 2 for journal grading rubric.



Contained Water Cycle

This activity was not performed in the classroom.

Our objective was for students to obtain first hand visual experience of the water cycle in an enclosed environment. By including plants in this activity, students would see what can go wrong in a biosphere situation and would be able to identify the issues that accompany designing an artificial lunar atmosphere. A clear relationship between plants and animals involving CO2 and O2 exchange would be presented and evaluated by the students. Unfortunately, this activity was not performed in class due to time restrictions.

Students will create three different systems for prolonged observation. One system will be sealed with just a container of water and allow the students to clearly observe the water cycle. One system will be sealed with a water container and a small plant. Students will be able to observe that plants need more than just water and sunlight from this system. The third system will be a plant in the open that is regularly watered. This system is the control and will show students that the earth's atmosphere is very good for growing plants.

Nitrogen Fixation Activity (Appendix F)

Our objective was for students to understand the importance of nitrogen in the growth process of plants as well as visualize the many components that make up the nitrogen cycle here on Earth. With this information, we anticipate students will be able to consider the nutrient requirements of plants when designing their lunar greenhouses.

Figure 11: Results of Likert Scale Student Survey for Nitrogen Fixation Instalab   See Fig. 2 for survey questions

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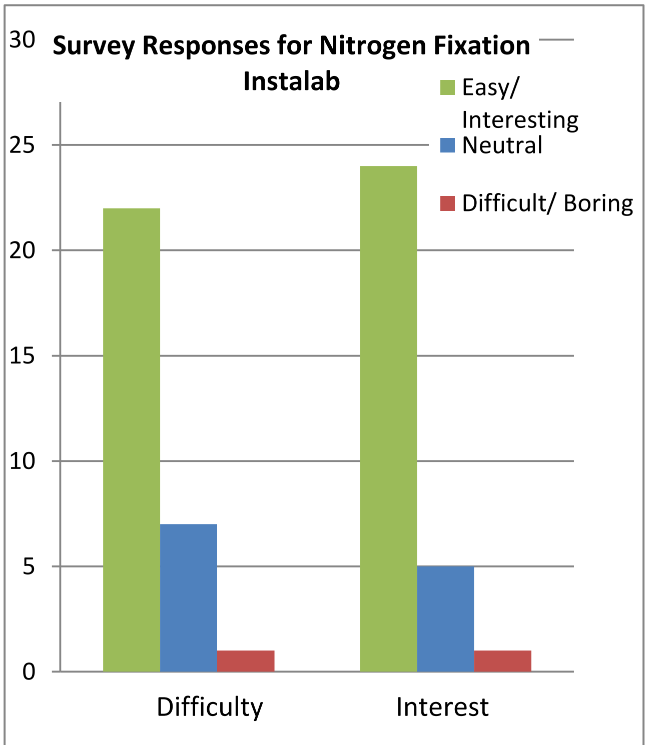


Students used a perlite and nutrient-lacking, dark soil combination to plant clover seeds in 4 different conditions. In the first, control situation the seeds were planted into the soil and watered with regular water. In the second condition, the plain seeds were watered with nitrogen infused water. In the third condition, the seeds were inoculated with rhizobium bacteria, which provide the seeds with a nitrogen source. In the fourth condition, rhizobium inoculated seeds were watered with the nitrogen infused water. The students were asked to design the experimental situation and were able to reproduce all the required conditions. The final results of the experiment demonstrated that plants need other factors than just water and sunlight to thrive.

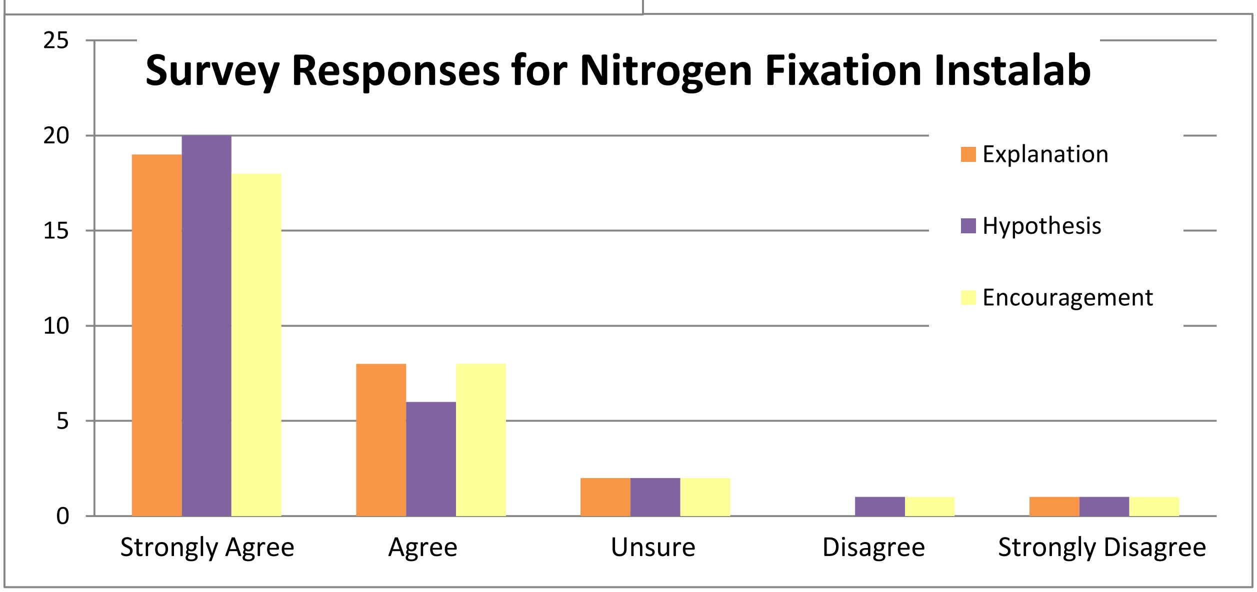
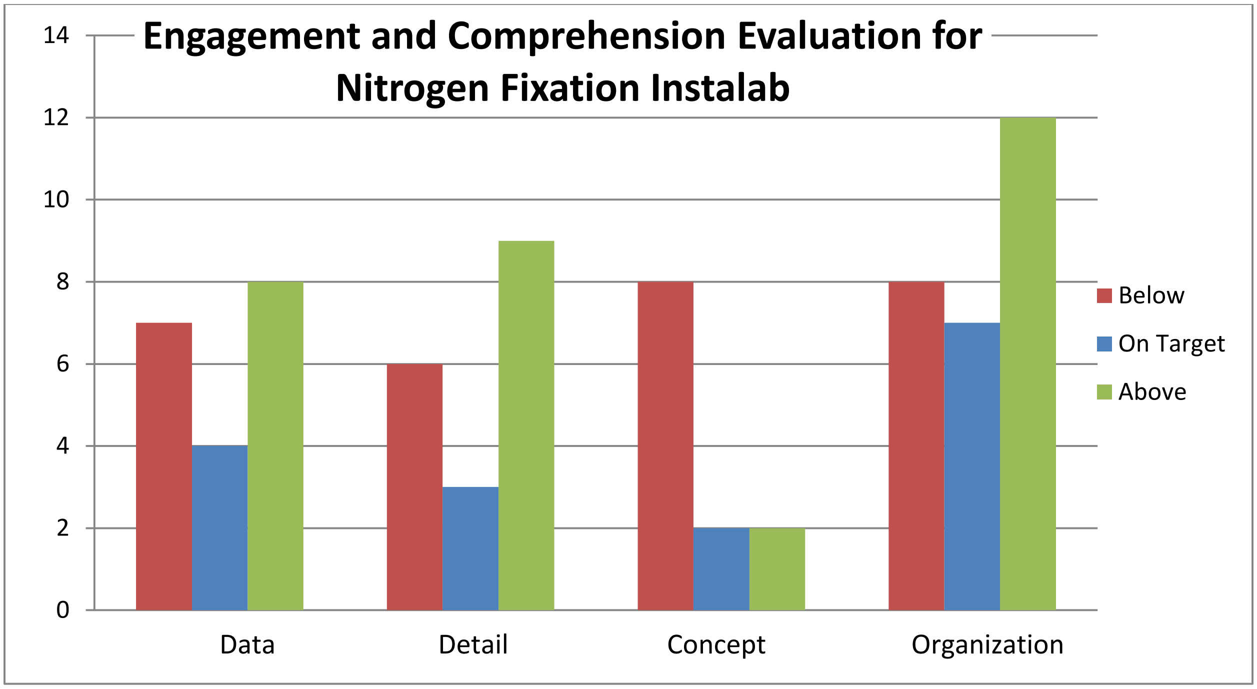


Figure 11 shows a high level of interest in this activity and a corresponding increase in strong agreement with the Likert scale questions. Figure 12 displays the data collected from the notebook evaluation for engagement and comprehension. Only one class was given the opportunity to answer evaluation questions in their journals.

Figure 12: Results of Student Journal Evaluation for Nitrogen Fixation Instalab. See Table 3 for journal evaluation rubric.



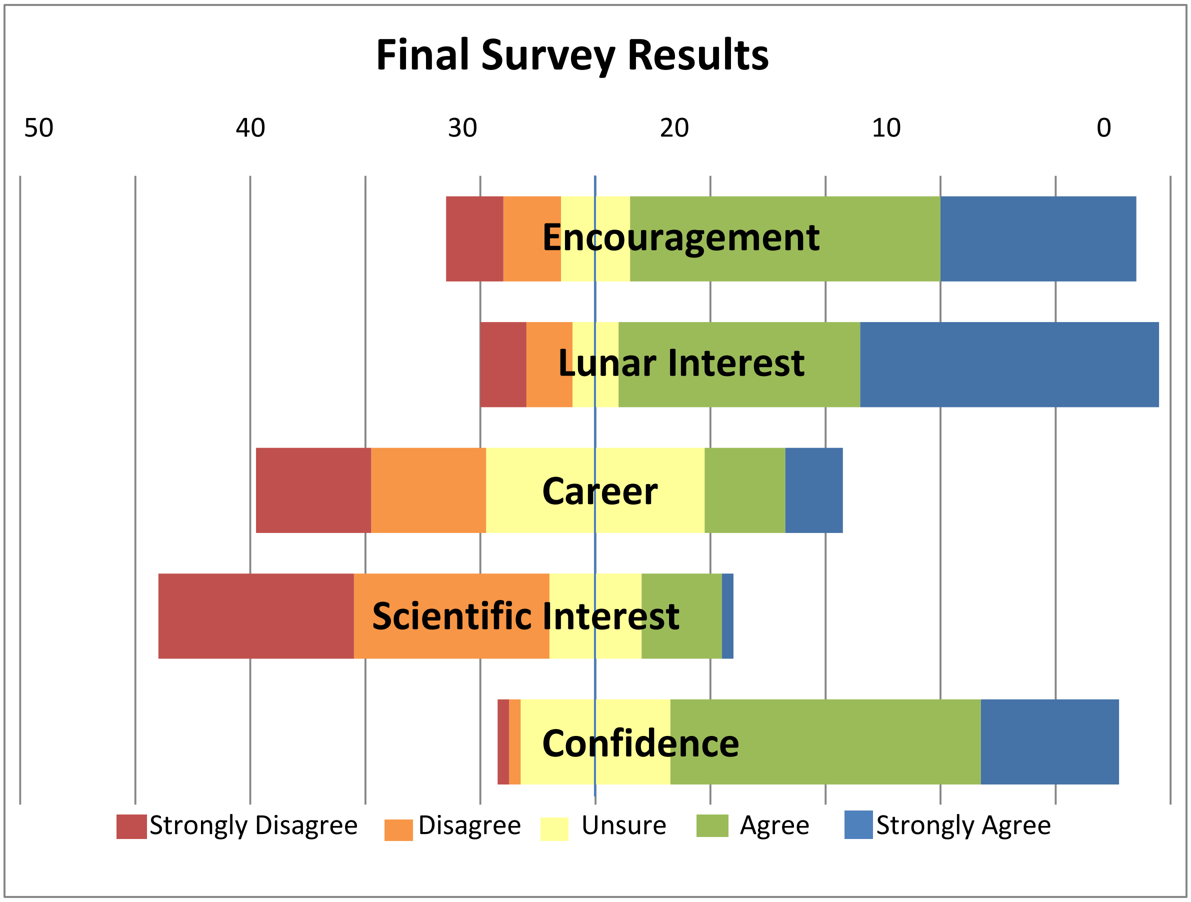
Capstone Design Project

Our objective was for students to apply all the previous knowledge gained over the term to consider various issues and design a realistic lunar base that takes into account the many limitations presented.

The student's capstone project was a design mission to conceptualize a lunar greenhouse and all the relating components. Students were required to consider certain factors including food growth, water treatment, air purification, thermal insulating, and light optimization, radiation shielding and power production. Students were divided into groups of 5 by the science teacher and each individual was given a factor to research. The teacher distributed the more academically inclined students among the groups so each group had at least one person with a high level of conceptual understanding.

The project week began with a PowerPoint presentation that detailed each of the factors (Appendix G). Students then broke into their groups to research their factors. Resources were provided in the form of scientific articles (Appendix H-L). Students worked collaboratively, discussing their ideas and selecting the best answers. The final result was a poster and accompanying presentation of each group's design (Appendix M). Each poster contained a central design description and a written consideration of each factor. Figure 13 displays the results for the final survey evaluation.

Figure 13: Results of Final Likert Scale Student Survey Performed After the Capstone Design Activity.



Questions 1-5 are represented by the separated, horizontal bars with the left half indicating negative responses and the right half indicating positive responses. See Figure 3 for survey questions.

We anticipated question 4, "Science is boring" having a large number of negative responses due to the wording and this is clearly displayed in the data. Surprisingly, question 3 also had a high number of negative responses. Despite being encouraged to study science by our activities, students still had little desire to pursue a career in science.

Discussion

This project provided the students with the tools to actively work in a scientific setting. The survey results show that throughout all the activities, the large majority of the students had high interest levels and believed that they understood the concepts presented in the activities. From these results, the team can conclude that the students had a good overall attitude to the topics covered in the activities. Student engagement, both cognitive and task-completion related, was shown to be high for the majority of the activities. Cognitive engagement, which was determined by looking at the “Detail level” in students’ journal responses, showed that the majority of the students did undergo a critical thinking process while acquiring and analyzing data.

Comprehension of the topics covered in each activity was also found to be high. The comprehension factors of “Organization” and “Concept” showed that the large majority of students fell in the on-target category. For “Concept” specifically, the team noticed that students showed a good level of understanding of the concepts of each activity. The concepts introduced in the Instalabs were later used to inform the students’ design projects. In fact, some students went beyond our team’s expectations by pointing out facts in their final design that our team did not provide them with.

Our team concluded that overall student self-identity with science was very high due to the results from engagement and comprehension evaluations. However, our team cannot compare its results against a control group because of the nature of the project, which required our activities to be performed with all three sixth grade classes in the school. Compared to other studies, such as Nadirova et al. or Carini et al., our team can say that this project was successful in finding a way to provide engaging science activities and assessing student involvement with each activity.

Tower Hill

The first activity being evaluated was the field trip to Tower Hill Botanical Gardens. For the purpose of the field trip and chaperoning, the team followed one group of students the entire day. The cataloging activity went very well. Students were allowed to roam the two greenhouse rooms with very little supervision and still, they remained engaged and active. The majority of students reached the standard for the amount of data taken, seen in Figure 5, while just 10% were able to surpass the standard and collect a significant amount of in depth data. Of the data taken, about 60% of the students reached the standard for detail. The fact that most of the students were able to produce an on topic, relevant response to the questions, indicates a high level of engagement. At one point students even began asking questions of one of the Tower Hill employees who was caring for the plants. By the end of the 40 minutes most students were finished with their activity sheet. The students who had not finished were generally engaged in a more exploratory nature. As for comprehension, very few students were able to achieve a grade above the standard for conceptual understanding because this activity was looking at observation gathering and very few students went beyond what was asked of them. Despite this, the activity lends itself very well to displaying the student’s organizational abilities because many of the questions asked students to provide a grouping of observations. Some students used Venn Diagrams to compare their plants and many students designed their own tables to categorize their information. Ultimately, we believe this activity worked fairly well as a kick off for our science curriculum but we think that with more class time before the trip, we would be able to further include the lunar concept rather than relying so heavily on Dr. Andelman.

Instalabs

Our first Instalab was the electromagnetic spectrum activity. Unfortunately this activity did not go entirely as planned. The video for the beginning of the activity was unavailable because of the school web blocker. Instead of viewing the video, an interactive web activity was read out loud to the students. This ended up taking longer than expected and was not as entertaining as the team would have liked. Due to time constraints the teacher requested that the experiments be performed as a class demonstration. Despite this setback, students still actively participated in hypothesis generation and a select few were allowed to help perform the experiment. A large majority of students achieved the standard for amount of data collected. This is most likely because the activity was presented as a demonstration. Students were guided through the process and given prompted opportunities to record their data. Many students were very surprised to see the results of each test. The students clearly found the infrared activity more interesting and remained engaged until the end. After the suggested materials were tested, students produced many more items they were interested in testing with the infrared waves. Only the infrared questions were asked of the students due to a lack of remaining time. Many of the students had very insightful ideas about using infrared waves under water and in outer space. The level of detail presented in their responses is very comparable to the amount of data collected. Again, the activity was performed as a demonstration and the students were given opportunities to discuss their ideas with the entire class. This would mean that information during the activity was shared and many students may have gotten their detailed responses from others. The high level of detail and data certainly indicates engagement among the students even though there was low level of exploration due to time constraints. The comprehension of the students is less clear. A large number, about 36%, of students, did not entirely understand the concepts presented in this demonstration and were consequently assessed as being below the conceptual standard. These students were unable to fully answer the evaluation questions and had difficulty conveying the idea that electromagnetic waves can be manipulated, blocked and reflected. Conversely, the majority of students were considered to be above the standard for organization. This activity included the listing of hypotheses, and many students were able to create neat, clearly labeled, comprehensive lists without prompting. The team was impressed with this level of organization and considers it a sign of comprehension of the hypothesis testing process.

The next Instalab was the thermal insulation activity. The team considers this activity to be one of the less successful activities. Unlike the electromagnetic spectrum activity, students were given the opportunity to perform the experiment in small groups and test their hypothesis first hand. Engagement appeared high, as each student wanted to operate the dryer and feel the materials to test for heat transfer. Unfortunately, the data presented in Figure 8 shows that many students did not complete the required amount of data collection for this activity. Multiple students failed to record whether each object was insulating or conducting the thermal energy, which was one of the major components. The majority of students fell below the standard for detail level, as well. We were hoping that students would be able to identify a degree of heat transfer through each object but most students just responded with a “yes” or “no”. Many of the student’s evaluation responses were also considered to be empty responses or answers that do not present any type of information. This may have been because the questions were too difficult, the activity was not presented well or the students may have felt rushed when actually heating the objects and taking observations. Another important thing to note is that 9 students left the room part way through the activity to attend another class and we classified most of those students as below target from their partial responses. Not accounting for the students’ inability to complete the assignment may have partially skewed the data. A majority, 56%, of students did not conceptually grasp this activity according to the journal evaluation. There was very little evidence of any type of understanding in their data collection and responses to the evaluation questions. Despite this, a large majority found this activity to be easy according to the data in Figure 7. This would indicate that the students believed they had a firm understanding of the concepts presented. From these results we believe that, although many students believed they understood the ideas, they were unable to display that understanding in their responses. This may have been because the evaluation questions were too difficult. Some students also seemed to have difficulty understanding the progression of the provided data chart. Perhaps a better explanation should have been provided. From these results the team believes, while this activity has value, it would likely need to be redesigned to achieve a better effect.

The third Instalab was the lunar phase modeling activity. Students were very involved in constructing the model and data collection. The hypothesis generation was a little less engaging. Students had difficulty understanding that the temperature changes at the lunar equator are a lot more intense due to alternating direct sun exposure and complete sun deprivation. Many students began the activity by placing multiple pins on different equatorial regions of the moon. They did not realize that the temperatures at the poles are less intense until they were told to pay attention to the light intensity. After some explanation most students were able to conceptually meet the standard. Still, about 42% of students did not meet the standard for conceptual understanding. Despite having to have a thorough explanation, Figure 9 shows that 73% of students rated this activity as easy. This may indicate an over confident view on their science abilities or perhaps they were considering the performing of the experiment and not the critical thinking component. Organizationally, this activity was fairly straightforward. Students were presented with a chart and tasked with filling in the data. Because of this, almost all the students met the standard of organization. Only 8% of students fell below the standard.

The final Instalab was the nitrogen fixation activity. Unfortunately, due to time constraints in the classroom, this activity was performed by only two of the three classes. The excluded period was able to use the other period’s plants to record data and produce conclusions. Moreover, only one of the groups that completed the activity was able to respond to the evaluation questions. Due to these restrictions, it is difficult to evaluate this activity based on the journal responses. Overall, the students seemed to really enjoy planting the seeds. A large majority of 80% found the activity exciting, which is a good indicator of high interest. None of the students realized that bacteria exist in the soil to fix atmospheric nitrogen into nitrogen available for the plants until they were given an explanation. When returning to the school in later weeks, the team observed that students were still actively engaged in watering the plants and a few students even planned to take some of the plants home. The team thinks this activity would have provided better results if it was performed with each class. It also may have been better to provide more guidance to the students when collecting data in the weeks after planting.

The team considers that the final design project was a success. When evaluating this activity, most of the data came from observations during the development phase and the presentations. The posters included a large amount of information, some of which was not covered in the formal presentation by the team. Many teams were eager to continue discussing their designs after the presentation and were able to go into much greater detail in one-on-one conversations with the team members. Some teams considered composite materials when designing their bases, while others thought about soil-less growing and hydroponics. This indicates that some students performed their own research and found extra resources to help design their lunar bases. Most of the student projects utilized the principles and concepts presented by the team in dealing with the factors but the level of detail and customization shows a certain level of critical thinking. A few teams proposed lunar rovers to collect ice from within the polar craters as a water source. The team found this to be a novel and intriguing way of dealing with the problem of water supply. The final survey, completed right after the design project presentations, showed a high number of positive responses and the expected negative response for question 4; “Science is boring”. It is interesting to note that, although most of the students were encouraged to study science from these activities, only about half of the students find science interesting enough to pursue a career in the field. The team believes it would be a benefit in future studies to ask this question at the beginning to have a before and after comparison.

Project Overview

Our team went through some minor setbacks that affected the planning and outcome of the project. One of the major problems was the lack of time encountered by the team during several phases of the project. The team had to organize its meetings according to the tight schedule that its members had. Sometimes this schedule translated to the activities themselves. For this reason, the team sometimes performed the same activity on different days. Another shortcoming which the team encountered was the exclusion of a couple of activities. Due to lack of resources and timing, two of the activities, the “Lemon battery activity” and the “Contained water cycle activity” were not done. The arrangement of the curriculum also made the team change some of its plans regarding the topics in the activities to be covered. This setback was minor however, as the team quickly identified the new concepts to be covered in each activity.

For future work involving curriculum design, our team would recommend some of the activities done in this project. Activities such as the “Lunar Phase Modeling” and the “Nitrogen Fixation” Instalabs allowed the students to cooperate and engage more than in other activities, such as the “Electromagnetic Spectrum” one. The team would also suggest a few things to be done before a new curriculum is put into action. Activities should be planned in advance in order to avoid issues with timing, materials, or student participation. Our team encountered a few problems with working with some of the materials prior to performing the activities in class. Because of this drawback our team did not perform the “Lemon Battery” activity. The inclusion of the supplemental activities was also found to be a great benefit to the team. Although no data was collected, we were able to familiarize ourselves with the classroom dynamics prior to conducting the Instalabs.

Our team would also encourage future projects to acquire student data and observations more closely. To do this, our team would suggest analyzing individual student performance throughout the project and applying additional survey questions to better assess scientific identity. Individual student analysis can be done by obtaining permission from the Institutional Review Board (IRB) at the beginning of the project. Survey questions could be better used to analyze more than students' attitudes toward science. For example, from Nadirova et al., survey questions such as "In science we answer questions by doing experiments" or "In science we do many different activities" could be used to understand students' perception of science in practical applications (Nadirova & Burger 2008).

The team's main objective of providing a curriculum to enhance scientific identity in the 6th grade class was met. Following constructivist ideas that encourage instructors and students to break from the conventional "lecture-only" type of classes, our team helped students learn the required concepts through the several interactive activities we designed. A more objectivist approach was taken to validate the way in which students learned the concepts of the activities. This validation helped the team understand how the students felt towards the activities and thus helped in the preparation of subsequent activities and the final design project. Supplemental activities, such as the Essay Contest, allowed students and our team to prepare for the tasks in the Instalabs and design project. Students' attitude and engagement remained positive even in these activities, as excelling students obtained prizes for their good writing and analytical skills. Given the results of the various evaluation questions and surveys, our team believes that working on all those activities, especially in the final design project, will allow the majority of students to approach science confidently in the future.

As Bhattacharyya et al. and Nadirova et al. have shown, professional life is constantly changing due to the rapid changes in science and technology (Bhattacharyya 2011; Nadirova & Burger 2008). Thus good professionals need to keep up with these changes by developing a good scientific identity at a young age. Hopefully, studies like Nadirova's, Bhattacharyya's, and this one will help to cause a positive change in the scientific identities of young students who will face even faster changes than the ones occurring now. Our team has a firm belief that the students of Elm Park Community School will have plenty of opportunities to apply their positively enriched scientific identity to keep improving their education throughout their lives and become professionals capable of adapting to the science and technology of the future.

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Appendix

Appendix A

CATALOGING PLANTS

Before you begin, write down some words that describe the room.

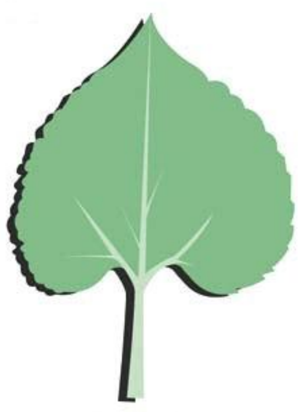
- How much space is there?
- What is the temperature like?
- How much light is there?
- What are the plants growing in?
- Come up with two of your own questions.

Find and draw **THREE** short plants that can fit in small spaces.

Find and draw **THREE** large plants that need a lot of room to grow.

Find and draw **SIX** different types of leaves. Use the words below to describe the type of leaf.

Also describe the color and texture of each leaf.



SIMPLE LOBED COMPOUND

Which plant is your favorite? Describe it. Why is it your favorite?

Find **TWO** plants that might provide food. Compare the two types of food in the included diagram. Come up with three of your own comparisons.

	Plant A	Plant B
Shape & Color		
Leaf Structure		
Do you cook it?		
How much sunlight does it need?		
What soil type does it grow in?		
Where is this plant normally found?		

Appendix B

Activity 1

Electromagnetic Spectrum

Part 1

5 minute video on the electromagnetic spectrum: http://www.youtube.com/watch?v=cfXzwh3KadE

Part 2

One group will be working with infrared waves and one will be working with radio waves. After 15 minutes the groups will switch.

Infrared Group

Students will work with a television and a remote to test the limitations of infrared technology. Using materials including plastic wrap, foil, paper and mirrors the students will learn what mediums infrared waves can transverse.

Using the table below students will predict whether or not the infrared waves will travel through the material. After making their predictions, the students will test each material and record their findings in a similar chart.

Material	White Paper	Black Paper	Flat Foil	Crumpled Foil	Plastic Wrap	Hand	CD
Prediction							
Material	Glass of Water	Colored Plastic	Tape	Wall	Other	Other	Other
Prediction							

The students will then use mirrors to attempt to redirect the infrared waves around an obstacle such as a wall. They will diagram their system for controlling the infrared waves in their lab notebooks.

Evaluation

What was the most surprising result from the infrared activity? Why?

Based on your research, if you were going to be controlling an underwater system, would you consider using infrared waves to send the signal? Why or why not?

Would you consider using infrared waves in space? Why or why not?

Describe/ draw your system for redirecting the infrared waves.

Can you think of other applications where infrared controllers might be useful?

Radio Group

Students will predict whether radio waves will be able to travel through certain materials. After their predictions are made students will tune a portable radio to a clear station and completely obstruct them with the specified materials. Students will record the results taking note of the degree of distortion or static in the radio station. They will then slowly remove the obstruction and determine at what point the station becomes clear again. Findings will be recorded in a similar chart.

Material	Aluminum Foil	Plastic Wrap	Cardboard Box	Plastic Box	Cloth	Other	Other
Prediction							

Evaluation

What was the most surprising result from the radio activity? Why?

Can you think of any objects that interfere with radio waves?

Do you think radio waves would be effective in space? Why or why not?

Why do you think radio stations are clearer when outside in the open as opposed to being inside?

Appendix C

Activity 2
Insulation Experiment

Introduction

What kinds of materials make good insulators? In this activity students will direct heat into different types of materials, such as metal utensils or small rocks. While heat is being directed to one side of the material, students will observe and take notes on how heat is transferred within the object. This will be done by carefully touching/feeling the side of the material that is not being exposed to heat. Students will then make observations on how quickly or slowly the heat is transferred within the material.

Materials

- Hairdryers
- Metal Utensils
- Plastic Utensils
- Ceramic cup
- Glass (with and without water)
- Winter Jacket
- Small rock
- Cooking mittens
- Notebook
- Pencils

Procedure

1. Make a table on your journal like the one shown below:
   For the **Hypothesis** column, write down whether you believe the item is an "Insulator" or "Conductor". Fill this column before moving to the next part of the activity.
   For the **Heat Transfer** column, write down "no", "little", "some", or "a lot" depending on how much heat transfer you detect. Fill this column as you do the experiment.
   For the **Insulator/Conductor** column, write down "Insulator" or "Conductor". Based on the results in the **Heat Transfer** column your team will determine if the item is a good insulator or not.

Item	**Hypothesis**	**Heat transfer**	**Insulator/Conductor**
Metal utensil			
Plastic utensil			
Ceramic cup			
Glass (without water)			
Glass (with water)			
Winter Jacket			
Rock			

Other:			
Other:			

2. With the hairdryer, direct the heat from the blower onto one of the items. Make sure the item is placed on a flat surface, and make sure the item itself faces the hairdryer on **one** side only (that means that you need not apply heat all around the material, you need to apply it only on one "face" of the item).
3. After about a minute, carefully remove the item from the flat surface using the cooking mitts. Place your hand above the item and "feel" the heat emanating from it. Turn the item around and try "feeling" the heat from the face that did not receive the heat from the hairdryer directly. If you cannot feel any heat by placing your hand above the object, try touching the object to see if it is somehow hot.
4. Write down the result on the table you made earlier. Did the object heat up on the face where the heat was directly applied? What about on the other side of the object? Was this what you predicted?
5. Repeat the experiment with each of the items listed on the materials section and take notes based on observations of how well the items heated up.
6. Any suggestions as to how objects should be heated are welcome! If you want to heat an object on one particular face do not be afraid to do so (but remember to tell your teacher first!).

Problem Solving

You have identified some materials that can act as insulators, now think of the following scenario: "You know that the average temperature on the surface of the Moon when it is sunny is about 107 degrees Celsius (about 225 degrees Fahrenheit) and that an average day (day/night cycle) on the Moon lasts 29.5 Earth days. A plan to create a small base on the sunny side of the Moon has been developed by NASA. They want you to help them think of the materials that could be used to maintain a healthy temperature to sustain human life within the base. "

Based on the concepts of insulation you just learned, consider the following questions:

1. Given the task of determining what materials are needed to build the walls and roof of the base, what materials would you choose? Why (do not consider cost or availability)?
2. Would you consider having a heating/cooling source inside your base? What would that source be (think of the heating and cooling sources we use on Earth)? How much thermal energy do you think it will radiate?
3. Speculate on what your base design would be if you were to build a base that would stand on the dark side of the Moon (temperatures might get as low as -153 degrees Celsius or -240 degrees Fahrenheit).

Appendix D

Activity 3

Lemon Battery Experiment

Introduction

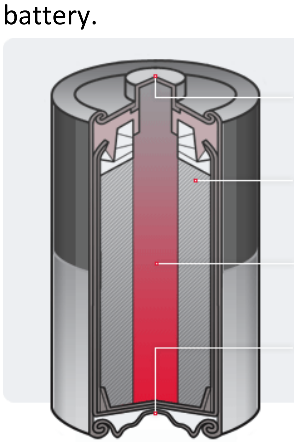
How is a circuit formed? In this activity students will create their own battery out of lemons and two metals which will serve as the electrodes in the circuit. Students will insert a zinc-galvanized nail and a copper-coated penny into the lemons and will then connect a series of these materials in order to light a small LED light. Students will make observations on how many lemons are needed to turn on the light, the amount of voltage in the lemons series, and the parts of a battery in general. Later they will identify ways in which electricity is generated from different sources outside of chemical energy.

Materials

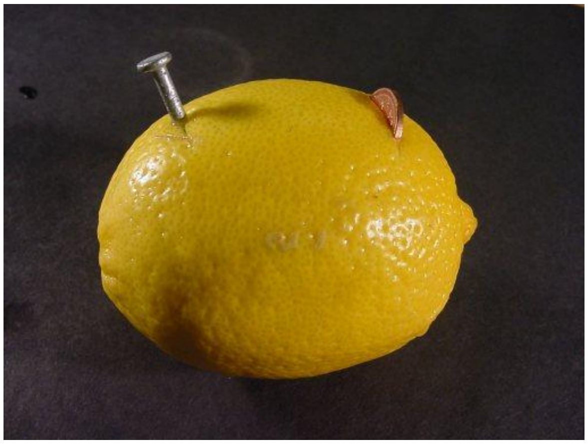
- Lemons
- Zinc-galvanized nails
- Copper coins (pennies)
- Set of alligator clips
- Notebook
- Pencils

Procedure

1. It is known that batteries have the following components: positive electrode, negative electrode, electrolyte solution (most of the times it is an acidic solution), and an external load. The negative electrode provides the battery system with electrons which travel through the electrolyte medium and into the positive electrode. If a “load” is attached to the battery, the electric current that passes through the circuit will have an effect on the “load”. Think of ways in which batteries affect “loads” in everyday life (think about batteries in a remote control or in a car, how do these objects work?).
2. For this part of the activity identify the parts of the battery that you would find in a standard AA battery.



3. Now, begin building your battery by inserting a nail into a lemon. Follow this by inserting a penny halfway into the lemon.
   The lemon should look like this:

4. Continue inserting nails and pennies into the remaining lemons because it will be very likely that you will need more than one lemon to turn on the LED light. Work with your teammates to speed up the process!
5. Grab a few lemons (about three or four) and make a "nail-penny" connection using the alligator clips. For the next part of the activity you will create a closed circuit. How many lemons do you think you will need to turn on the LED light?
6. Connect the remaining ends of the alligator clips to the wires of the LED light. If enough voltage is created between the series of nail-penny connections, the LED light will turn on. If the light does not turn on, try making as many nail-penny connections as necessary. If you have a voltmeter with you, can you determine the amount of voltage needed to light up the LED?

Problem Solving

You just witnessed the way in which a closed circuit provides electrical energy to a small LED light. You know that batteries function as closed circuits to provide electrical energy to objects, and you know that the chemical energy inside the lemon is transformed into electrical energy for the LED light to use and light itself up. Take a look at the following problem:

1. You have observed how chemical energy in lemons gets converted into electrical energy and then into light energy in a small LED light. Other devices use different sources, such as heat energy and water motion, to get the energy needed to generate electricity. Make a list of all the sources/devices you can think of that can generate current electricity (HINT: You might want to take a look at your book!).
   Having identified a few ways in which you can generate electricity, answer the following:
   "If given the task to design an electric generator on the Moon, which one from the ones in your list would you choose? Why? Think about the materials you would need and how the generator would work. Remember that some materials need to be taken from Earth and some might already be on the Moon! (Hint: Ask your teacher or her assistants about the Moon's details).

Appendix E

Activity
Moon Lighting Activity

Introduction

How does the sun shine on the moon? How can the phases of the moon be visually identified? In this activity students will see how the lighting on the moon is affected by its position relative to the sun. Students will manipulate different Styrofoam balls and lamps to simulate the lighting of the sun on the moon. They will be able to observe how the moon is always illuminated regardless of its position relative to the earth. Afterwards, students will think about the best place for humans to establish a base on the moon. Based on the experiment and additional information provided to them, students should be able to determine an adequate spot on the moon to establish such a base.

Materials

- Styrofoam Balls (different sizes)
- Metal wires
- Different colored push-pins
- Lamps
- Markers
- Cups
- 25in x 30in paper sheets
- Notebook
- Pencils

Procedure

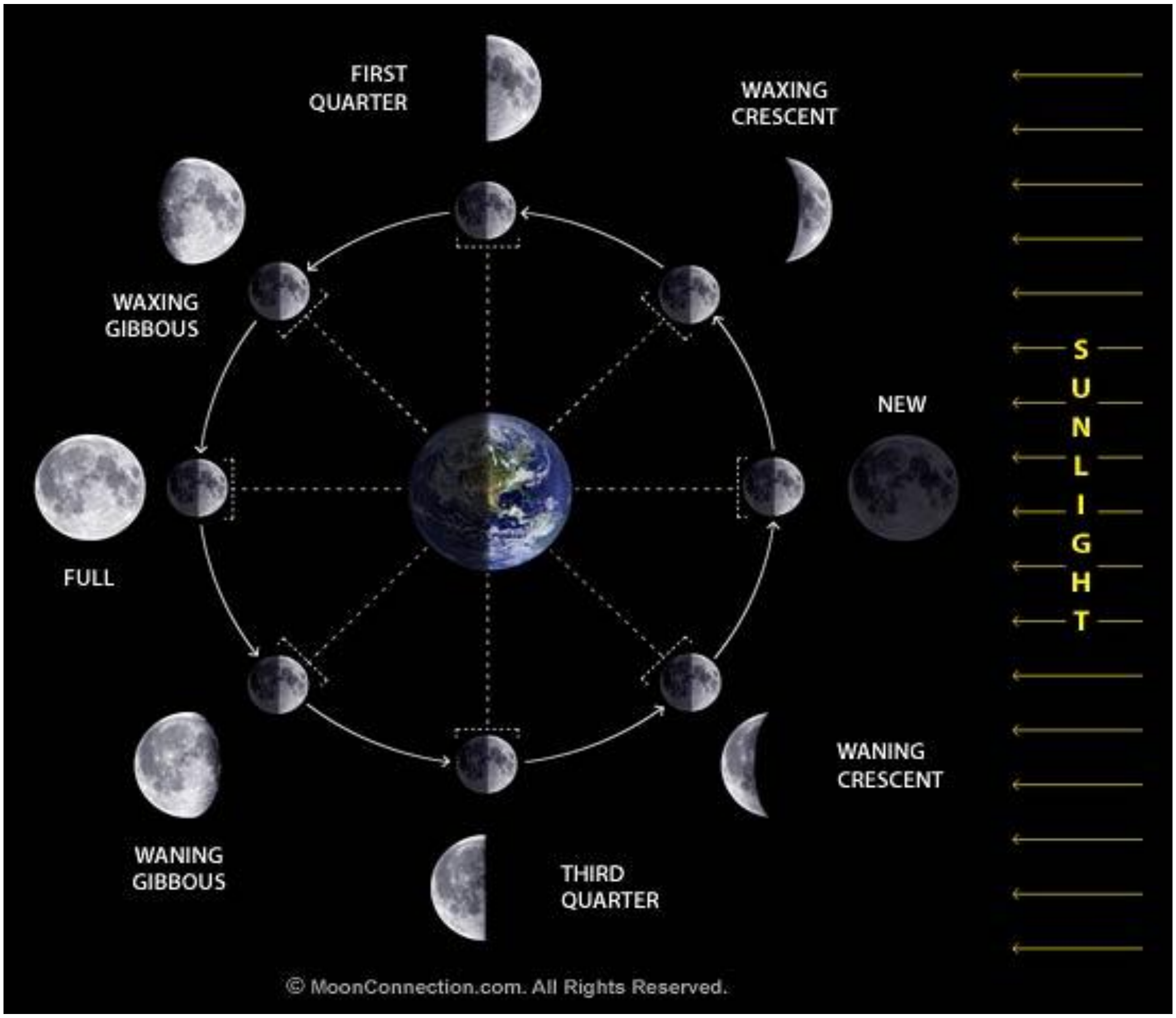
7. For this activity, you and your classmates will try to identify the best spot on the moon that can sustain human life given the extreme temperatures found on the moon. You will observe how the moon's rotation about the earth makes lighting on the moon a topic worth considering if one is attempting to establish a base on the moon. You will take notes on what you observe. Later, you will compare observations with your teammates to come up with a consensus as to where your team would place the base.
   To begin with, paste the following table on your journal:

Pin Color	**Location**	**Lighting at Day 0**	**Lighting at Day 7**	**Lighting at Day 14**	**Lighting at Day 21**	**Lighting at Day 28**

Because each team member will want to identify their own pin, it is recommended that each team member chooses a colored pin to use throughout the activity. Locations on the table will be written relative to the equator marked on the "moons".

8. Get a big Styrofoam ball. Attach a wire to its side. This ball will represent the earth. Place the "earth" on top of a plastic cup and place the cup on top of the paper sheet.
9. At the other end of the wire, attach a small sized Styrofoam ball. This ball will represent the moon. Notice that a line has been drawn on the "moon". This line is the equator of the moon, and you should attach the moon to the wire in such a way that the equator is parallel (or almost parallel) to the surface on which you are working. The "moon" should be attached so that the "earth" does not block any light coming at the "moon".
10. Make sure the markings on the paper sheet are correctly set. Markings should be set for "0 days", "7 days", "14 days", "21 days", and "28 days", the latter being on the same spot as "0 days". What does it mean to have the last marking labeled as "28 days"? What is the significance of this number?
11. Having prepared the paper sheet, plug in the lamp and light it up. The lamp will represent the sun. Make sure it faces the "0 days" mark on the paper sheet (Be careful not to look directly at the lamp since it emits very strong light!). Rotate the earth and moon system so that the moon is closest to the lamp, on the "0 days" mark.
12. Making sure that the moon, the earth, the lamp, the paper sheet, and the cup holder are all well placed, have each team member put a pushpin on the spot on the moon where they believe it will be best to establish a base. Remember to justify why you chose that spot!
13. One of your team members can now begin slowly rotating the "moon" about the "earth". Begin at the "0 days" mark and move it toward the "7 days" mark. Continue the rotation to the subsequent marks.
14. At each mark observe what happens to the lighting on the moon and record the kind of lighting that hits each pushpin on the table provided at the beginning of the activity.
15. Once the moon reaches the "28 days" mark (or "0 days" mark), turn off the lamplight and answer the following:
    (a) Knowing that the sunny side of the moon experiences average temperatures of 107 degrees Celsius (224 Fahrenheit) and that the dark side of the moon experiences average temperatures of -157 degrees Celsius (-250 Fahrenheit), on which spot would your team establish the base if you were to consider temperature's effects **only** ? Explain why. (Think about temperature ranges on earth, boiling and melting temperatures of water, and the devices you would need to maintain healthy temperatures for plants and human beings.)
    (b) Consider now that your base will **only** need sunlight for plants and other uses: which of the spots your team identified would be the best one to establish a base?
    (c) If your team takes into account that they will choose the base location based on temperatures and lighting, which of the spots would be the best one to serve as the base's location? Why? (Think about the amount of time that the moon receives sunlight on each "face" and the temperature considerations you made in the previous question.)

Phases of the Moon



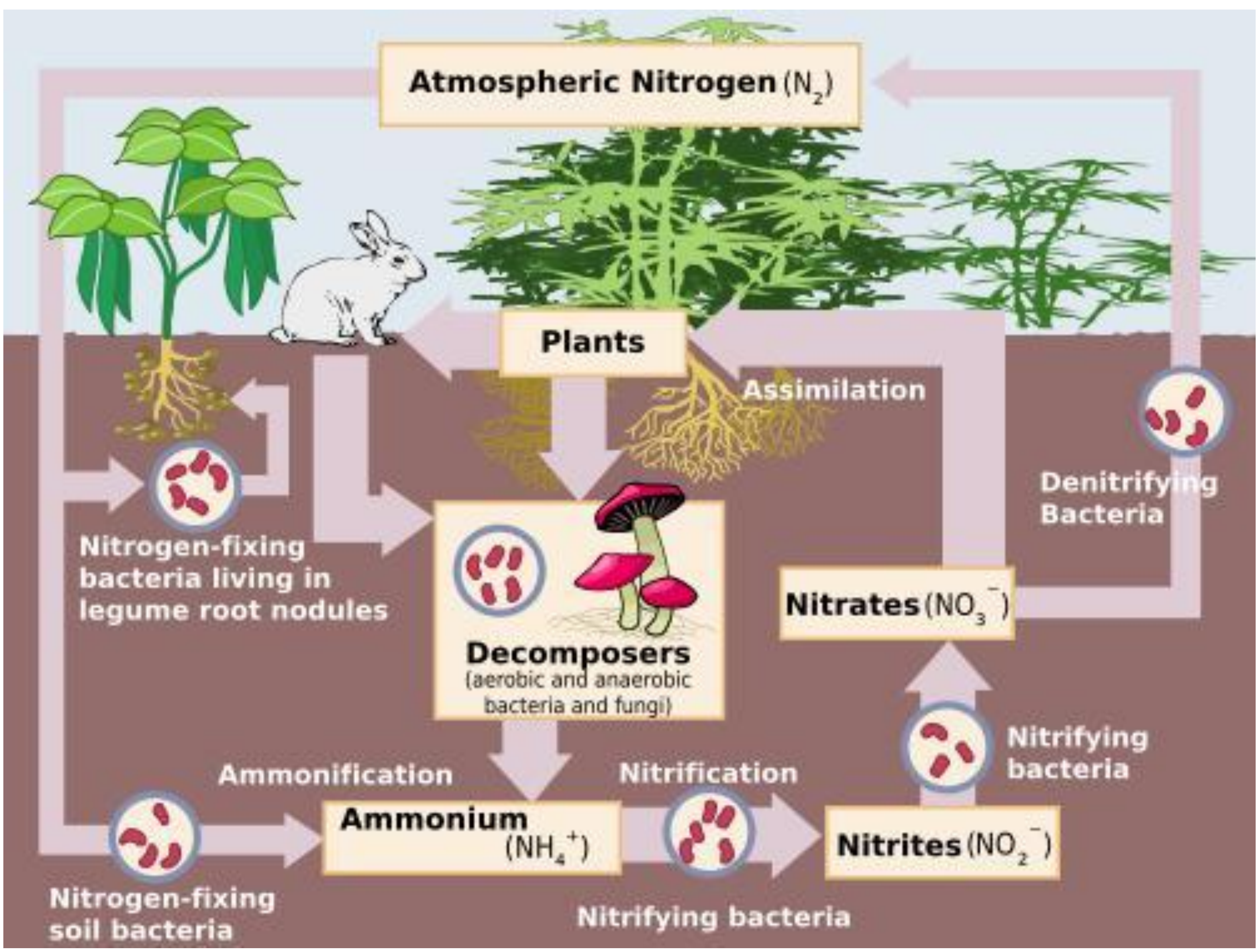
Appendix F

Earth's Nitrogen Cycle

All living things require nitrogen- compounds to survive. Luckily, air is 79% nitrogen. But most organisms can't just take their nitrogen from the air. How do plants get the nitrogen they require? In this activity, students will discover how bacteria living in the soil, and even on the roots of some plants, is capable of 'fixing' nitrogen, or converting it into usable forms.

Materials

- Small pots
- Watering can
- Low nitrogen potting soil
- Clover seeds
- Rhizobium innoculum
- Small re-sealable plastic bags
- Measuring spoon
- Nitrogen fertilizer
- Beaker



Innoculating the Clover Seeds with Rhizobia

1. Collect a small handful of clover seeds from the container and pour half of the seeds into each re-sealable plastic bag.
2. Using the measuring spoon, add ¼ teaspoon of water to each plastic bag. The water will help the rhizobium innoculum to stick to the clover seeds. Although you won't be adding rhizobia to both batches of seeds, you want to treat the seeds as similarly as possible, that is why you add water to both batches of seeds. Label *one* of the plastic bags: *rhizobia coated*.
3. Pour approximately 1/4 teaspoon of the rhizobium innoculum into the plastic bag labeled *rhizobia coated*.
4. Seal both plastic bags and shake to thoroughly mix the water, clover seeds, and (in one of the two bags) the rhizobium innoculum.
5. Spread out two paper towels on a flat, dry surface. Pour each plastic bag of seeds on to its own paper towel. Be careful to not contaminate the uncoated seeds with rhizobia. Label the paper towel with the rhizobia coated seeds.
6. Wait a few minutes for the seeds to dry before proceeding to the planting part of the procedure.

Planting

1. Put equal amounts of soil in each pot. The soil should be about a half inch from the top of the pot.
2. Using a permanent marker, label the pots:
   a. *no nitrogen added*; 2 pots
   b. *nitrogen fertilizer*; 2 pots
   c. *rhizobia*; 2 pots
   d. *rhizobia + nitrogen fertilizer*; 2 pots
3. Plant 15 seeds in each pot, being careful not to mix seeds.
   a. In the pots labeled *"no nitrogen added"* and *"nitrogen fertilizer"* plant untreated clover seeds.
   b. In the pots labeled *"rhizobia"* and *"rhizobia + nitrogen fertilizer"* plant the rhizobia coated clover seeds.
4. Place plants near a sunny window.
5. Set a schedule for watering. Soil should be kept moist.
6. Water the "no nitrogen added" and "nitrogen-fixing bacteria" pots with regular water. Water the "nitrogen fertilizer" pots with 7 drops of fertilizer for every 1 liter of water.
7. Clover will sprout in just a couple of days.

Collecting Data

8. As the plants sprout, record which pots are growing the fastest? Which have the tallest clovers? Which pots have the highest plant density?
9. After these measurements are complete and the clover has matured, carefully remove each plant from the soil and shake off any excess soil from the roots.
10. Measure the total biomass of each plant, and the ratio of root length to plant length.
11. Graph the suspected nitrogen levels in each category (no nitrogen added, nitrogen fertilizer, rhizobia, and rhizobia + nitrogen) and the average biomass of the clover grown in each category.

Which category do you think had the highest levels of nitrogen? Which category produced the greatest biomass of clover? Was there any noticeable difference in the health or appearance of the clover grown with or without nitrogen fertilizer? Did inoculating the clover with rhizobia affect either the nitrogen levels in the soil or the total biomass?

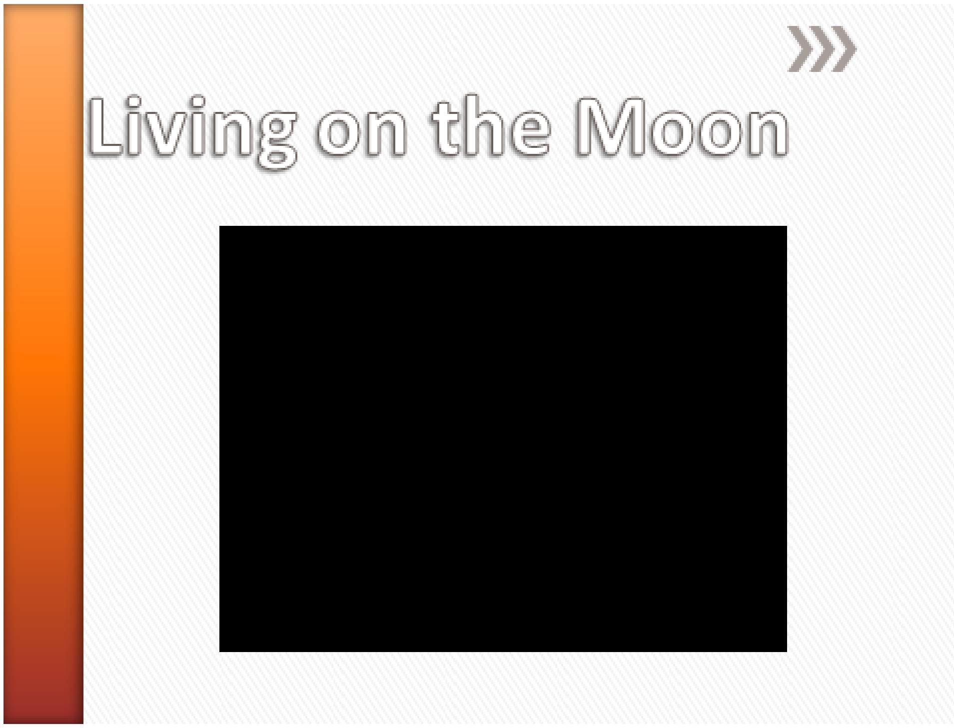
Questions

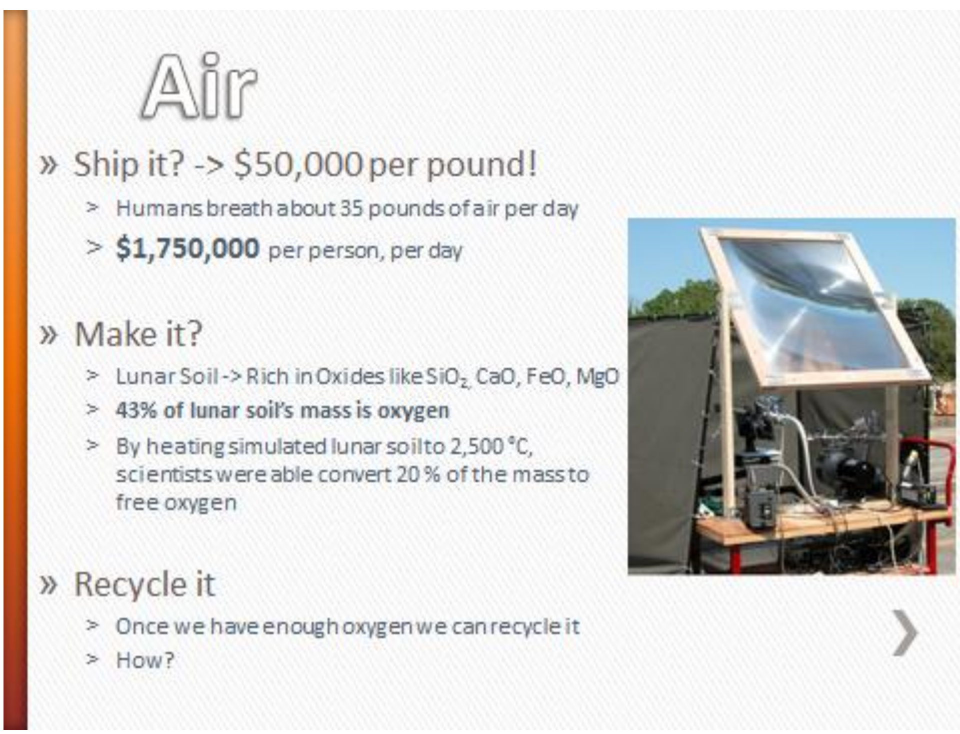
Humans don't get their nitrogen from bacteria in the ground. Where do we get the nitrogen we require?

Not very much nitrogen is found on the moon's surface. What little there is gets deposited there by solar winds. Rather than constantly shipping nitrogen to the moon, maybe we would try to recreate the nitrogen fixing cycle. What components would we need to make sure that both plants and humans get the nitrogen they require?

Appendix G

Capstone PowerPoint Presentation





Water

» Ship it? -> $400,000 per gallon

- Drinking, washing, bathroom, watering plants…. **that's a lot of $$$**

» Find it?

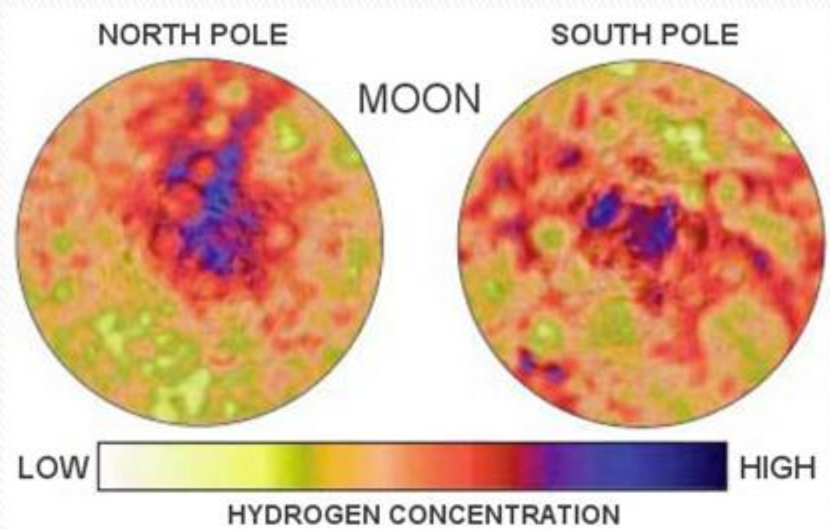
- Evidence of frozen water in polar craters

» Make it?

- Small amounts of **frozen water in lunar soil** accumulate in shadowed craters
- Microwaving simulated lunar soil to -50 °C allowed the water ice to sublimate
- The vapor could be condensed and then scraped of like frost

» Recycle it

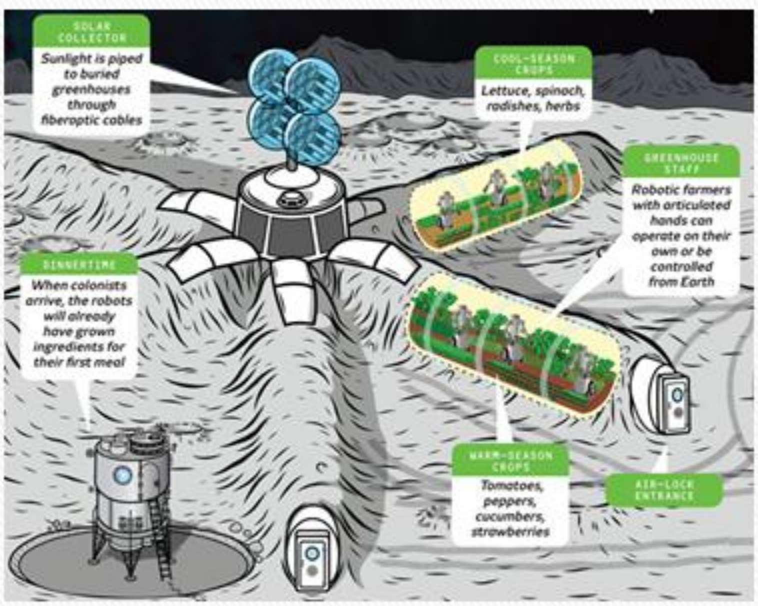
- Condensation in the air we breath out and water from our waste can be purified into drinkable water
- About 1 gallon of water can be extracted and purified from waste every hour



Hydrogen levels may show us where we can find deposits of frozen water

Food

- Send rations
  - Current astronauts eat dehydrated food
- Grown fruits and vegetables to supplement
  - Provide about half the required calories
- Hydroponics
  - Plants would get all their nutrients from a water solution and not from dirt



Energy

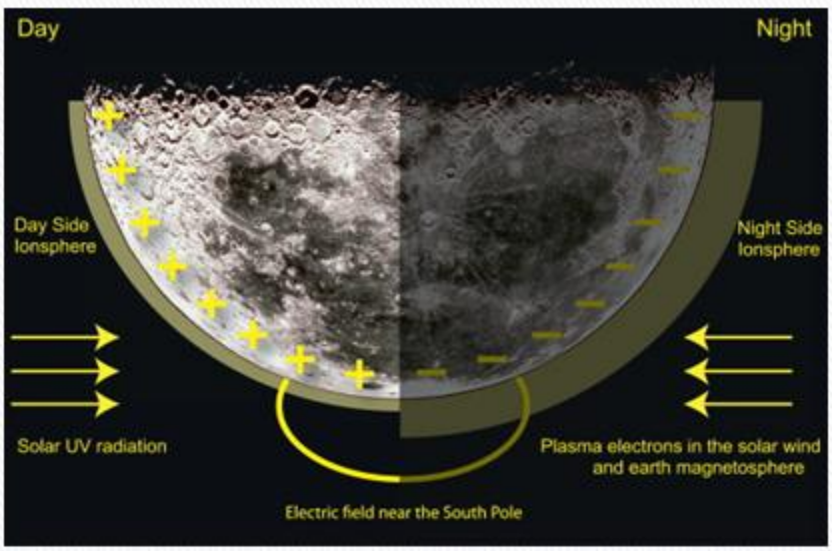
- Solar power
  - Needed materials can be found on the moon
  - 354 hours of night!
    - What would we do without sun?
- Nuclear Power
  - Good power to weight ratio
    - We'd need to bring the materials
  - No need to worry about sunlight

Temperature

- Huge temperature variation at the equator
  - 107 °C in the day (226 ° F)
  - -153 °C in the night (-243.4 °F)
- Each day is almost **4 weeks** long
- Regolith layer for insulation
  - A base completely underground would maintain a temperature of around -23 °C (-9 °F)
- Certain locations have much better temperature range
  - North pole (-40 °C to -60 °C)

Radiation

- Continuous cosmic radiation
  - Electromagnetic radiation
    - Microwaves to gamma rays
  - Ionizing radiation
- Standard radiation shielding
  - Heavy metals
- Compacted regolith
  - 2 meter layer
  - Make bricks out of dust using microwaves
- Meteoroid impacts



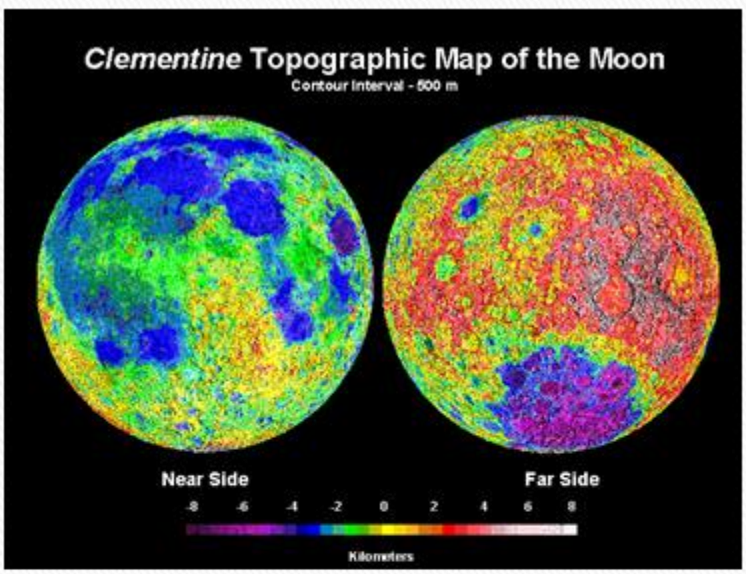
Radiation hits the moon from both the sun and the earth

Light

- Artificial light
  - Requiresa power source

- Sunlight can be sent underground using fiber optic cables or large transparent tubes

- Polar craters provide almost constant light
  - Peaks of eternal light



Topographic maps show the high and low points on the moon. The highest points are around craters at the north and south poles.

Appendix H

Breathing Moonrocks

An early, persistent problem noted by Apollo astronauts on the Moon was dust. It got everywhere, including into their lungs. Oddly enough, that may be where future Moon explorers get their next breath of air: The moon's dusty layer of soil is nearly half oxygen.
The trick is extracting it.

Lunar soil is rich in oxides. The most common is silicon dioxide (SiO_2), "like beach sand," says Cardiff. Also plentiful are oxides of calcium (CaO), iron (FeO) and magnesium (MgO). Add up all the O's: 43% of the mass of lunar soil is oxygen.

Scientists working on a technique that heats lunar soils until they release oxygen. "It's a simple aspect of chemistry," he explains. "Any material crumbles into atoms if made hot enough." The technique is called vacuum pyrolysis--*pyro* means "fire",*lysis* means "to separate."
"A number of factors make pyrolysis more attractive than other techniques," Cardiff explains. "It requires no raw materials to be brought from Earth, and you don't have to prospect for a particular mineral."

Simply scoop up what's on the ground and apply the heat.
In a proof of principle, Cardiff and his team used a lens to focus sunlight into a tiny vacuum chamber and heated simulated lunar soil to about 2,500 degrees C. Ilmenite is an iron/titanium ore that Earth and the Moon have in common. Actual lunar soil is too highly prized for such research now.

Above: A lens focuses sunlight onto a vacuum chamber filled with simulated moondust, producing oxygen and "slag."
In their tests, "as much as 20 percent of the simulated soil was converted to free oxygen," Cardiff estimates.
What's leftover is "slag," a low-oxygen, highly metallic, often glassy material. Cardiff is working with colleagues at NASA's Langley Research Center to figure out how to shape slag into useful products like radiation shielding, bricks, spare parts, or even pavement.

Appendix I

Building a Moon Base: Challenges & Hazards

So, we want to go to the Moon. Why? Because the Moon is an ideal “staging post” for us to accumulate materials and manpower outside of the Earth’s deep gravitational well. From the Moon we can send missions into deep space and ferry colonists to Mars. Tourists may also be interested in a short visit. Mining companies will no doubt want to set up camp there. The pursuit of science is also a major draw. For whatever reason, to maintain a presence on this small dusty satellite, we will need to build a Moon base. Be it for the short-term or long-term, man will need to colonize the Moon. But where would we live? How could we survive on this hostile landscape? This is where structural engineers will step in, to design, and build, the most extreme habitats ever conceived…

Understanding how the human body will adapt to life in low-G and how new technologies will perform in a location close enough to home will be not only be assuring to lunar colonists and astronauts, it will also be sensible. Exploring space is dangerous enough, minimizing the risk of mission failure will be critical to the future of manned exploration of the Solar System.

So where do you start when designing a moon base? High up on the structural engineers “to do” list would be the damage building materials may face when exposed to a vacuum. Damage from severe temperature variations, high velocity micrometeorite impacts, high outward forces from pressurized habitats, material brittleness at very low temperatures and contact with high energy cosmic rays and solar wind particles will all factor highly in the planning phase. Once all the hazards are outlined, work can begin on the structures themselves.

The Moon exerts a gravitational pull 1/6th that of the Earth, so engineers will be allowed to build less gravity-restricted structures. Also, local materials should be used where and when possible. The launch costs from Earth for building supplies would be astronomical, so building materials should be mined rather than imported. Lunar regolith (fine grains of pulverized Moon rock) for example can be used to cover parts of habitats to protect settlers from cancer-causing cosmic rays and provide insulation. According to studies, a regolith thickness of least 2.5 meters is required to protect the human body to a “safe” background level of radiation. High energy efficiency will also be required, so the designs must incorporate highly insulating materials to insure minimum loss of heat. Additional protection from meteorite impacts must be considered as the Moon has a near-zero atmosphere necessary to burn up incoming space debris. Perhaps underground dwellings would be a good idea?

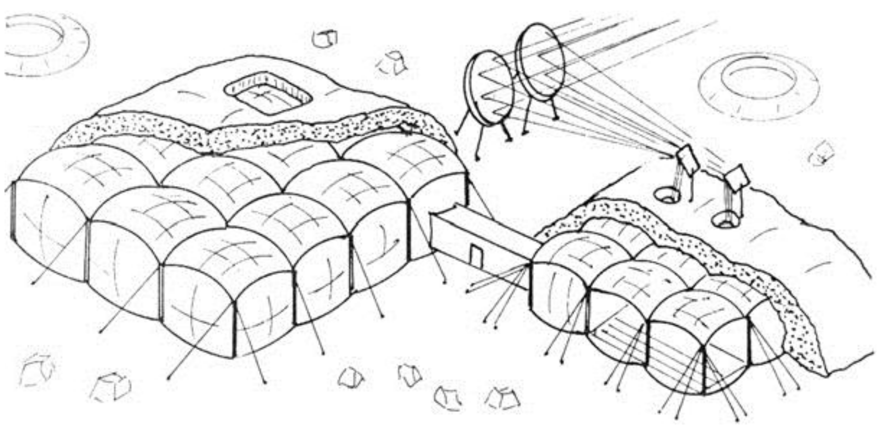
Appendix J

Building on the Moon: Habitat Concepts

Plans are afoot to build a manned base on the Moon. As you probably would have guessed, there are quite a few hazards and dangers with sending humankind back to establish lunar “real estate”. However, once our intrepid lunar colonists begin to build, the hazards will become less and development will accelerate. This is all very well, but how will we gain that first foothold in the lunar regolith? What will be the best form of habitat structure that can be built to best suit our needs? These questions have some obvious and not-so-obvious answers from the structural engineers already publishing their ideas and building prototypes…

Many types of structure have been proposed for lunar colonies. However, the main focus for mission planners center on cost and efficiency. Structures made on Earth, while possible, would have to be very lightweight to allow for easy launch out of the Earth’s deep gravitational well. It is generally believed that the first bases to be established on the lunar surface will be built on Earth, but once a base of operations is set up, with human (and perhaps robot) workers/settlers, local materials should be mined and habitats built on the Moon. Some of the structures currently being considered are detailed below.

Inflatable designs



Inflatable habitats have always been a favorite, optimizing living space whilst using lightweight materials. As the Moon has no atmosphere any habitat would need to be highly pressurized to simulate the Earth’s atmosphere and atmospheric gas quantities. Due to the gas pushing outwards, these structures should remain inflated. Assuming the material of the inflatable is strong enough, risk of collapse should be low.
There is however a massive problem with inflatables. In an environment as vacuum-like as the Moon’s, there is little protection from micrometeorites (small, natural space rocks or manmade space debris). Catastrophic depressurization could occur if a high velocity projectile causes a weakness in the membrane. There are some solutions, such as

covering the inflatable habitats with a layer of protective regolith, and extensive fail-safes will need to be put in place.

One design uses inflatable “pillows” to create a cube shape (rather than the more natural spherical shape). Many of these pillows can be aligned and added on to create a growing settlement. Protection from micrometeorites and solar radiation would be provided by regolith.

Erectables

Classic erectables have been tested and are an established form of construction. With a focus on ease of assembly, one plan involves sending components into a low Earth orbit. A frame can be easily erected and act as a shape by which to base the design of a simple habitat. Once complete, the module could be shipped to the Moon where it will be controlled into a soft landing. This method uses existing technology and may be one of the more feasible concepts of beginning a Moon base. A basic structure could also be constructed on the lunar surface in a similar fashion.

Local materials

Ultimately, it is hoped that a settlement on the Moon will have the ability of mining local materials, and remaining self-sufficient. This degree of autonomy would be required if a thriving Moon base is to succeed.

Appendix K

Lunar Greenhouse Could Grow Food for Future Moon Colonies

A new collapsible "greenhouse" could be the key to growing fresh and healthy food to sustain future lunar or Martian colonies, a recent project found.

Scientists at the University of Arizona's Controlled Environment Agriculture Center (CEAC) are experimenting with growing plants without the use of soil. Instead, they are trying to demonstrate that potatoes, peanuts, tomatoes, peppers and other vegetables can be grown in only water?a process known as hydroponic growth.

The team built a prototype lunar greenhouse in the CEAC Extreme Climate Lab that is meant to represent the last 18 feet (5.5 meters) of one of several tubular structures that would form part of a proposed lunar base.

The tubes would be buried beneath the moon's surface to protect the plants and astronauts from deadly solar flares, micrometeorites and cosmic rays. As such, the buried greenhouse would differ from conventional greenhouses that let in and capture sunlight as heat. Instead, these underground lunar greenhouses would shield the plants from harmful radiation.

Greenhouse basics

The membrane-covered greenhouse module can be collapsed down to a 4-foot-wide disk for easy storage during interplanetary travel. It would be fitted with water-cooled sodium vapor lamps and long envelopes that would be filled with seeds, primed to sprout hydroponically.

"We can deploy the module and have the water flowing to the lamps in just ten minutes," Phil Sadler, president of Sadler Machine Co., which designed and built the lunar greenhouse, said in a statement. "About 30 days later, you have vegetables."

The contraption will rely on robot-like components to grow its organic life. Algorithms to analyze data collected by attached sensors and a control system to optimize performance are in the works.

"We want the system to operate itself," said Murat Kacira, an associate professor of agricultural and biosystems engineering at the University of Arizona. "However, we're also trying to devise a remote decision-support system that would allow an operator on Earth to intervene. The system can build its own analysis and predictions, but we want to have access to the data and the control system."

In fact, the engineers can take cues from an existing analog on Earth?a similar CEAC food-production system has been operating at a South Pole research station for the past six years.

The South Pole Growth Chamber, which was also designed and fabricated by Sadler Machine Co., provides fresh food to the U.S. South Pole Station in Antarctica, which is physically cut off from the outside world for six to eight months each year.

Several ideas used in the development of the lunar greenhouse were inspired by the functioning South Pole Growth Chamber.

Other applications

Another important aspect of the greenhouse design is the effective and efficient use of resources, which would be crucial on a lunar base.

"On another planet, you need to minimize your labor, recycle all you can and operate as efficiently as possible," said principal investigator and CEAC director Gene Giacomelli.

In developing such a system, there will likely be applications for our planet as well, he said. "All that we learn from the life support system in the prototype lunar greenhouse can be applied right here on Earth."

Carbon dioxide is fed into the prototype greenhouse from pressurized tanks, but astronauts would also provide CO2 at the lunar base simply by breathing. Similarly, water for the plants could be extracted from astronaut urine, and the water-cooled electric lights might be replaced by fiber optic cable?essentially light pipes?which would channel sunlight from the surface to the plants underground.

Giacomelli said the research could also lead to plant colonization in another traditionally hostile environment?large urban centers.

"There's great interest in providing locally grown, fresh food in cities, for growing food right where masses of people are living," Giacomelli said. "It's the idea of growing high-quality fresh food that only has to be transported very short distances. There also would be a sense of agriculture returning to the everyday lives of urban dwellers. I think that idea is as exciting as establishing plant colonies on the moon."

Appendix L

NASA Advances Water Recycling for Space Travel and Earth Use

Water is one of the most crucial provisions astronauts need to live and work in space, whether orbiting Earth, working at a lunar base or traveling to Mars. The Water Processor Assembly developed by the Marshall Center will improve water recycling on the International Space Station.

Would Columbus have reached the New World if his ships could not carry enough water for their crews? Would Lewis and Clark have made it to the Pacific if they had no fresh water along the way?

The answer is probably no, because water is just as precious to explorers as it is to everyone on Earth. Water is one of the most crucial provisions astronauts need to live and work in space, whether orbiting Earth, working at a lunar base or traveling to Mars. That's why NASA is following several different but complementary avenues at four agency centers to develop dependable ways of recycling water.

"Developing innovative life support technologies will reduce risks associated with human space exploration," said Eugene Trinh, director of the Human System Research and Technology Program, NASA Headquarters, Washington. "We are working to improve technology used onboard the International Space Station (ISS) and have several research projects under way for future missions to the moon and Mars."

ISS crewmembers must save as much water as possible. Each is given about two liters daily. They stretch the ration by collecting, cleaning and reusing wastewater, condensate in the air and urine. A new technology to improve recycling on the ISS is being developed by engineers at Hamilton Sundstrand Space Systems International, Inc., Windsor Locks, Conn., and researchers at NASA's Marshall Space Flight Center (MSFC), Huntsville, Ala. The Water Processor Assembly (WPA) will be the first major hardware delivery of the Regenerative Environmental Control Life Support System. The WPA and the Urine Processor Assembly make up the Water Recovery System (WRS), which feeds the Oxygen Generation System. These combined systems will support up to a seven-member crew.

"The Water Processing Assembly can daily produce 35 gallons of potable recycled water," said Bob Bagdigian, MSFC Regenerative Environmental Control and Life Support System Project Manager. After the new systems are installed, annual delivered water to the ISS should decrease by approximately 15,960 pounds, about 1,600 gallons. The WPA is scheduled for delivery in 2008.

Water purity is also important. Chemical and microbial contaminants make it unappetizing or unhealthy, and it can clog complicated fluid systems. The Aerobic Rotational Membrane System (ARMS) research project at NASA's Kennedy Space Center (KSC), Fla., may help. "We're trying to move toward a biological treatment method using bacteria to help cleanse the water," said Tony Rector, Dynamac Corporation bioprocess engineer at KSC. The KSC prototype shop fabricated a model of the system. It is being tested inside KSC's Space Life Sciences Laboratory, and Rector and colleagues designed it.

At NASA's Ames Research Center (ARC), Moffett Field, Calif., a water recycler enabling reuse for three years without resupply is being developed on a timeline to fit into exploration plans, according to ARC scientist Michael Flynn. A preliminary engineering development unit can hourly recycle 13.2 pounds, about one gallon, of waste into drinkable water.

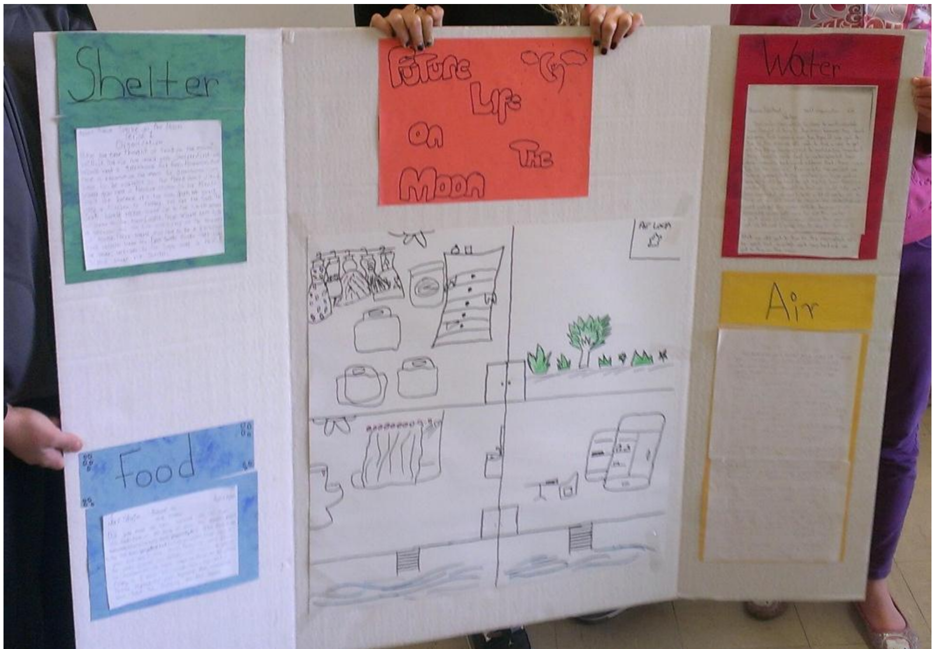
"If we were going to Mars tomorrow, this is the water treatment system astronauts might well use," Flynn said. He is developing it in cooperation with Water Reuse Technology, Inc., Garden Valley, Calif. "This unit can enable a six- person crew to shower, wash clothes and dishes, drink water and flush toilets over three years without resupply," Flynn said.

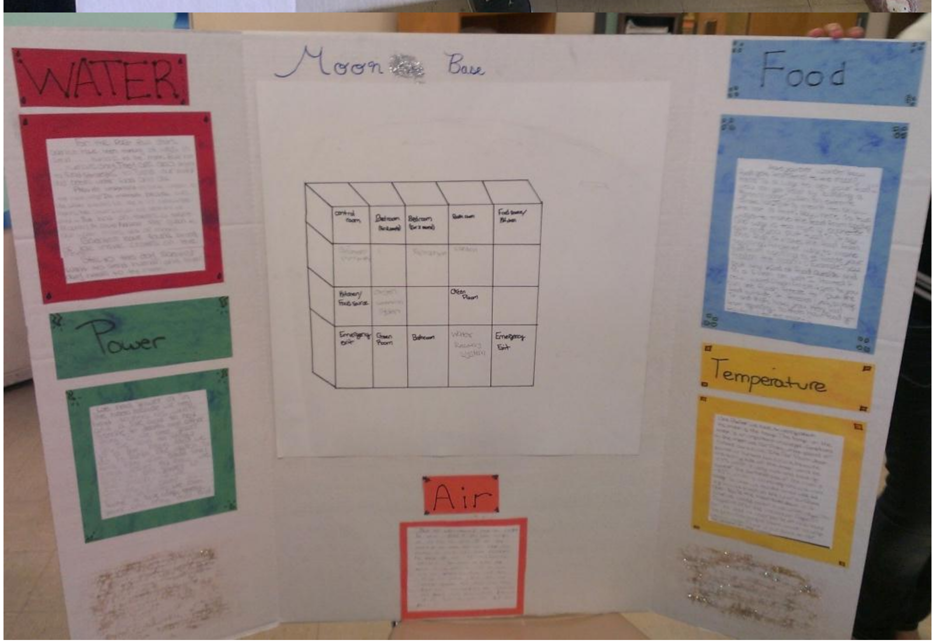
Engineers at NASA's Johnson Space Center (JSC), Houston, are developing technology to help astronauts live in space. They are studying biological water processors to minimize their size in space habitats. JSC microbiologist Leticia Vega describes her work as making biological water processors modular, so they can be easily removed and cleaned. Researchers are also identifying soaps that rapidly degrade at high concentrations. Cleansers, like shampoo and soap, affect the size of systems, because of the time it takes for them to break down. Researchers are studying ways of optimizing size of ion exchange beds used for the final purification of water.

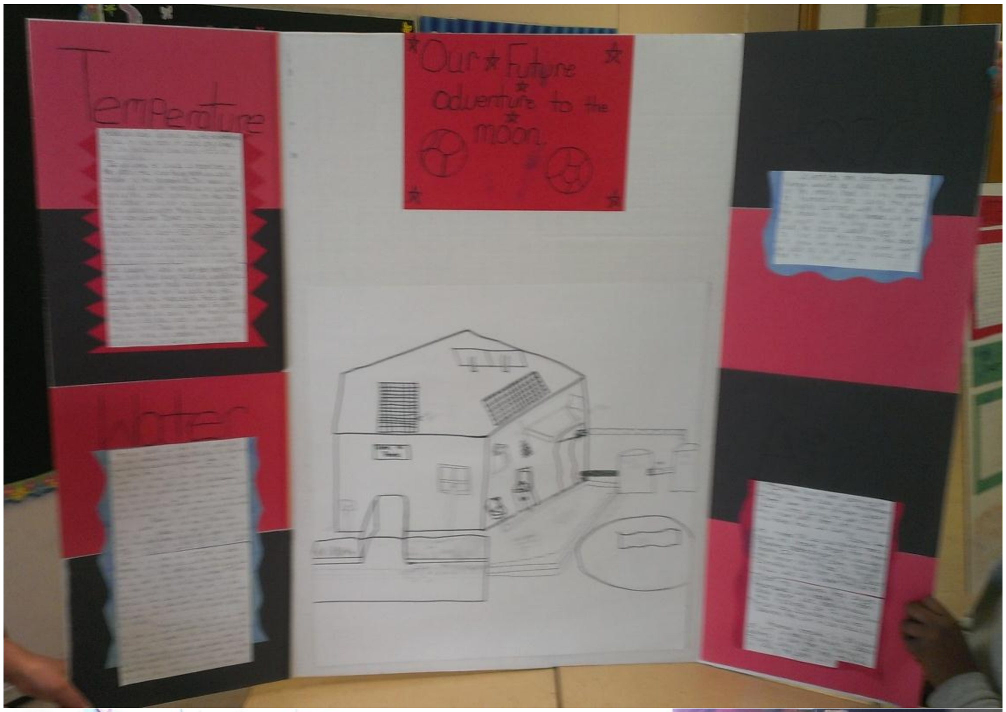
Water recycling technologies developed by NASA will undergo combined water recovery systems testing at JSC to meet exploration timelines. Many of these recycling technologies may have Earth-based uses. NASA is working with the Expeditionary Unit Water Purification Program of the U.S. Office of Naval Research and Bureau of Reclamation to explore ways to use recycling in remote locations.

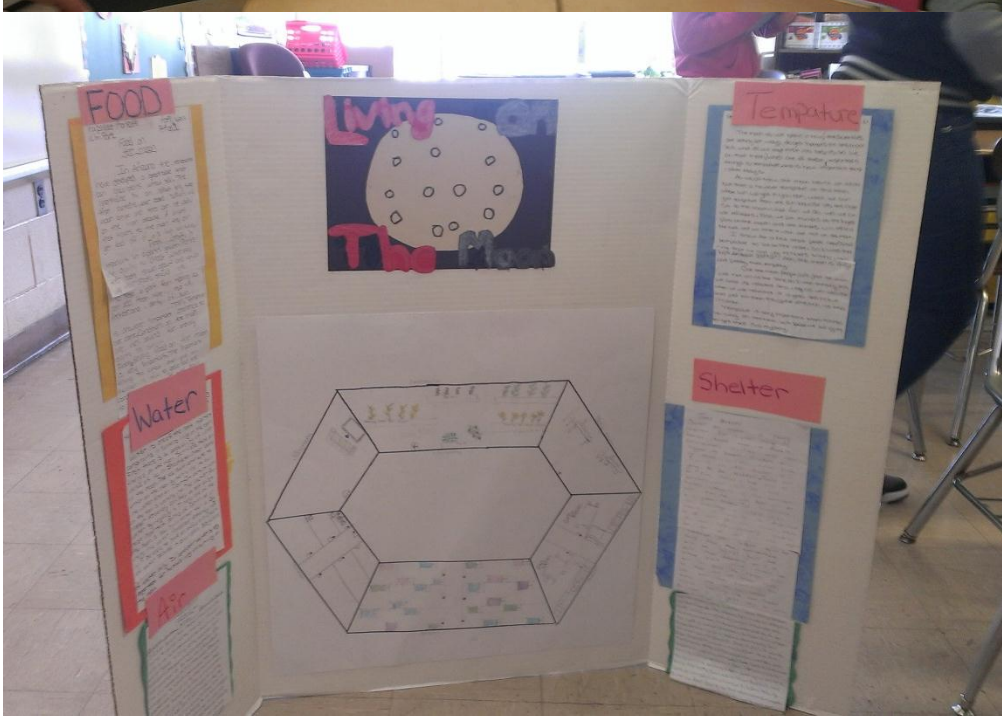
Appendix M

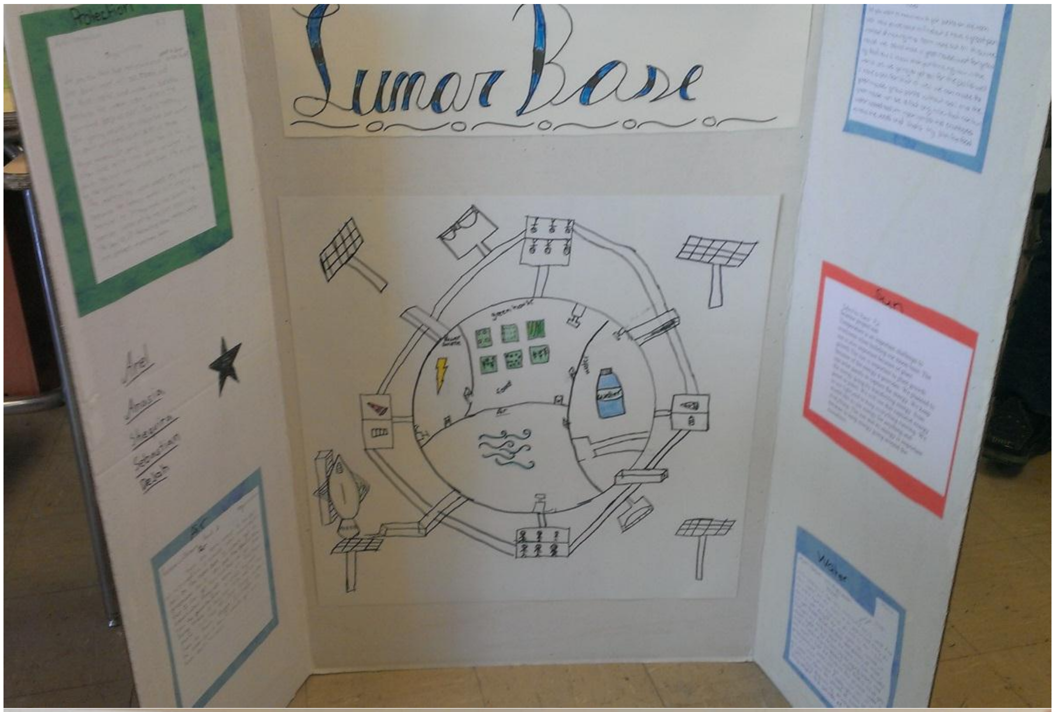
Students' Design Posters

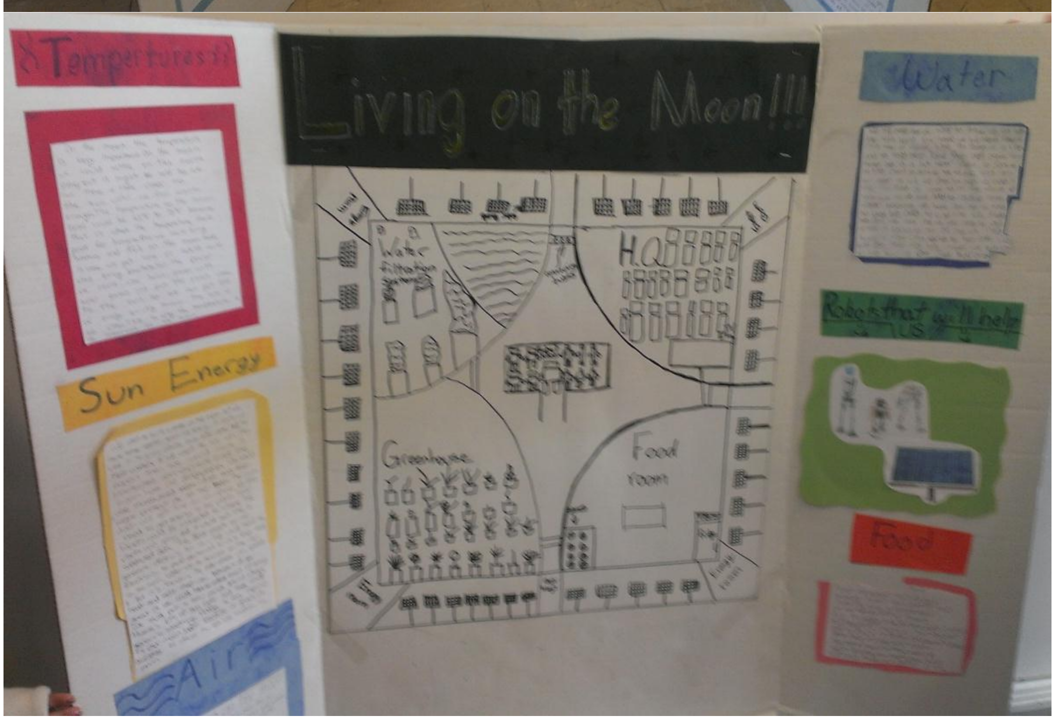


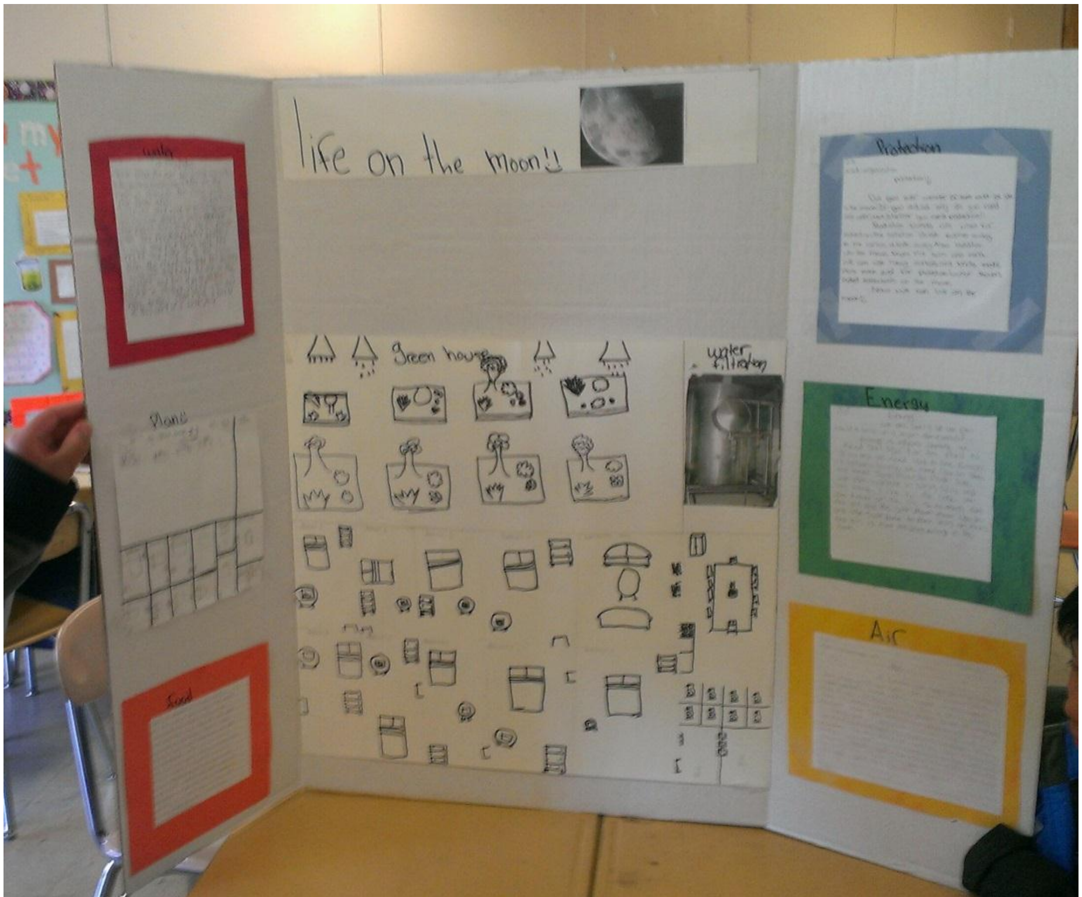


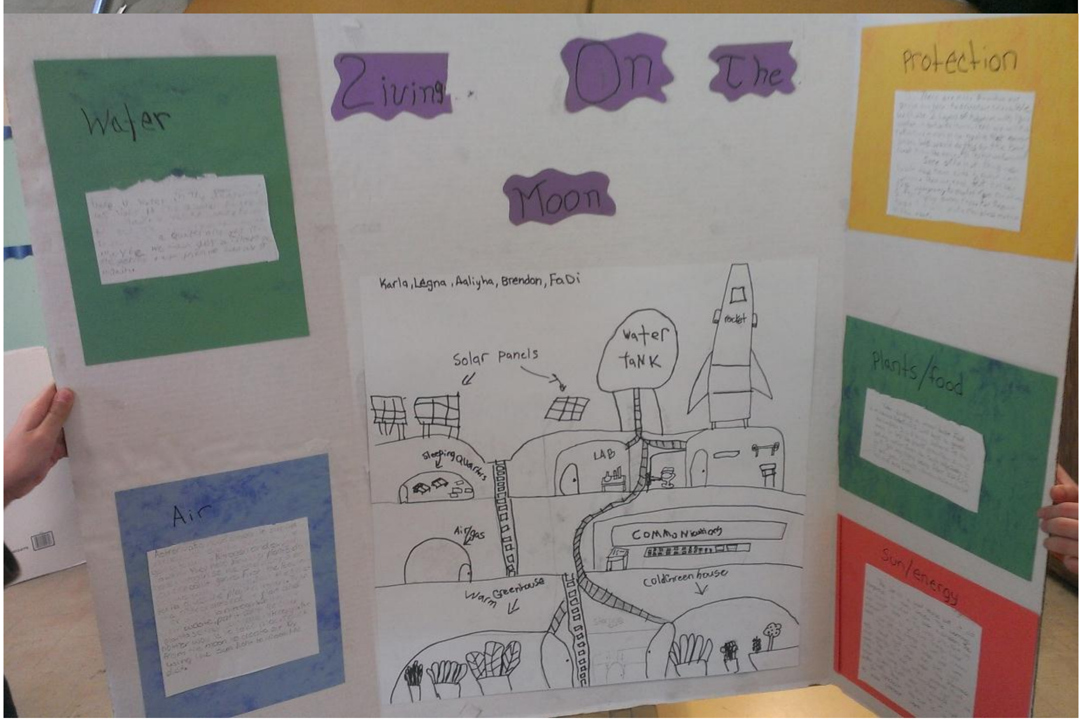

Temperature
Our Future adventure to the moon
Water

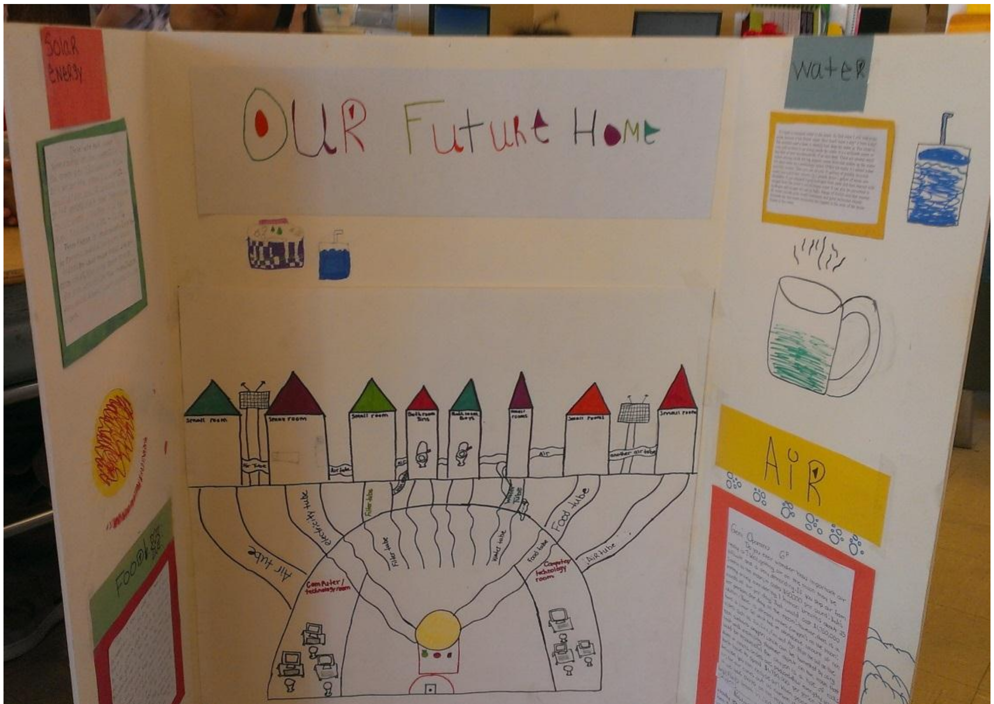

FOOD
Living on The Moon
Water
Air
Shelter

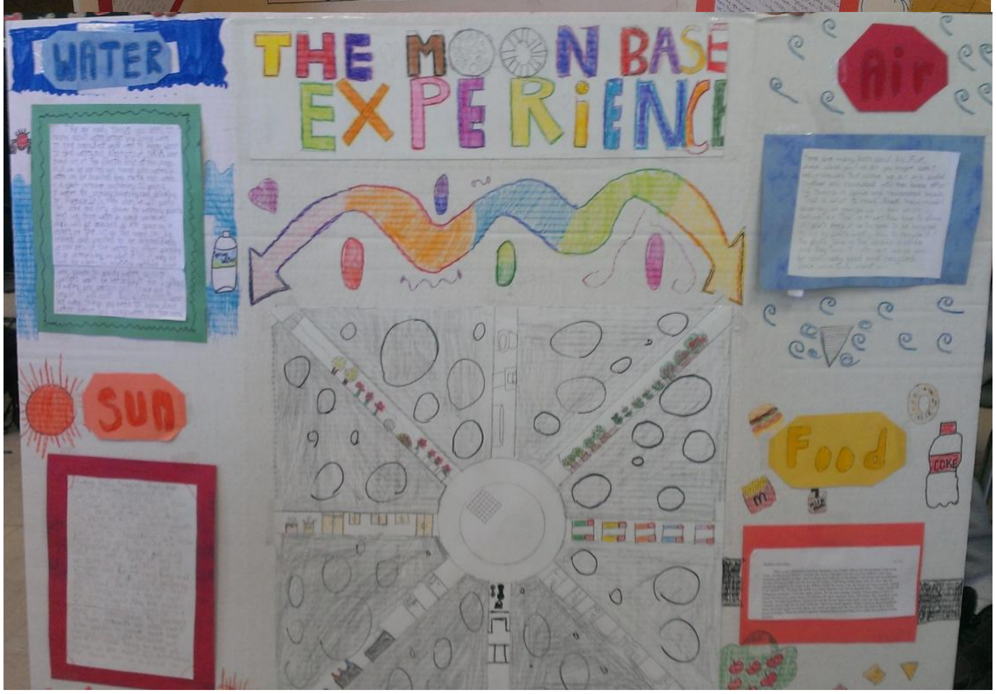

Lunar Base
Sun
Water


Temperturas
Living on the Moon!!!
Water
Sun Energy
H.Q
Greenhouse
Food room
Food
Air

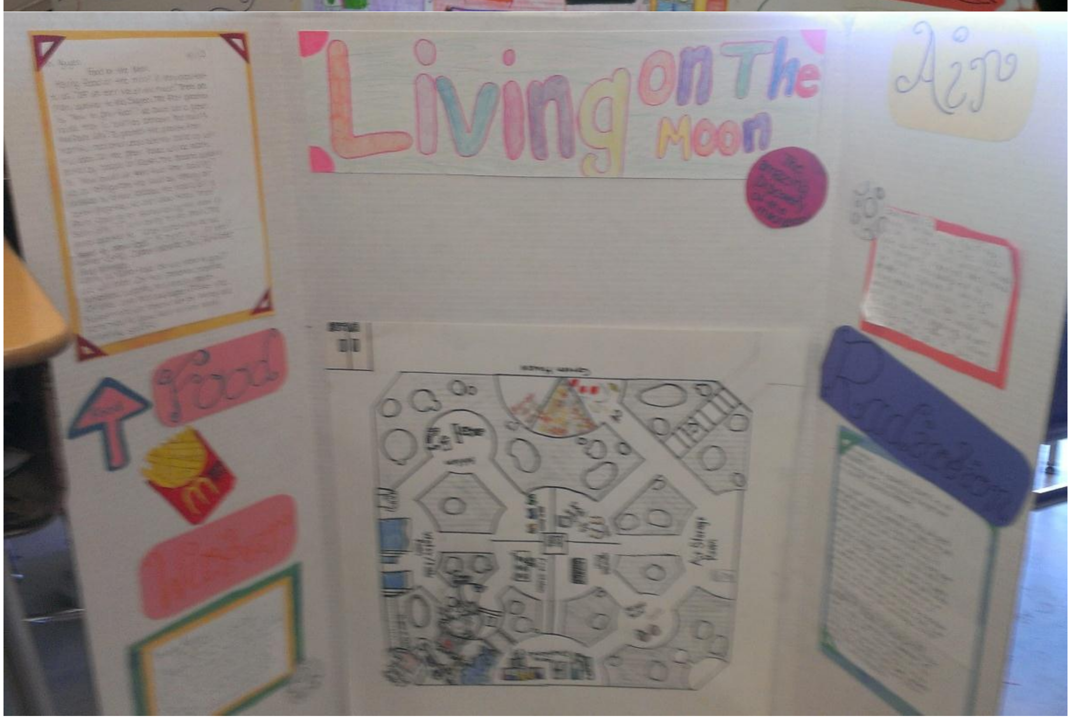

life on the moon!!
Protection
Green house
water filtration
Energy
Air


Living On The Moon
Water
Air
Protection
Plants/food
Sun/energy
Karla, Legna, Aaliyha, Brendon, FaDi
Solar panels
water tank
rocket
LAB
Warm Greenhouse


Solar energy
OUR Future Home
water
AiR
Food
Air tube
Food tube


WATER
THE MOON BASE EXPERIENCE
Air
SUN
Food
COKE


Our future home


Living on The Moon
Air
Food
Radiation