Addendum to Proposed Lunar Base Simulation Exhibit

An Interactive Qualifying Project Report

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Abstract

This project supplements the IQP *A Proposal for an Educational Lunar Base Simulation Exhibit* from the 2014-15 academic year. The original project proposes to repurpose the basement of the Worcester Memorial Auditorium into an educational exhibit for students in grades 5-8 simulating a base established on the moon. The proposed exhibit consists of five sub-exhibits, each explaining different STEM concepts from the Massachusetts Curriculum Standards Framework through hands-on activities. This project adds two sub-exhibits to the overall exhibit with STEM related activities. The activity of the first sub-exhibit is geared toward younger students, building clay models of the moon and the earth while comparing and contrasting their layer compositions. The second sub-exhibit activity is more advanced; students assemble and launch model space shuttles and learn several aerodynamic concepts in physics and mathematics.

Table of Contents

Introduction

The STEM (Science, Technology, Engineering, and Mathematics) standards in elementary and middle school curricula have always lacked in comparison to other subjects due to a lack of resources and innovative ways to teach the standards. These subjects usually require resources such as labs, individual computers, and other things that are not readily available to all schools. The key to improving the STEM education is to present the material in an interesting and interactive way that will engage students in the concepts. Improvement of STEM education will benefit students in improving standardized test scores and helping them to be better prepared for furthering their education after the eighth grade.

This purpose of this project is to add two hands-on activities to a previously completed project *A Proposal for an Educational Lunar Base Simulation Exhibit*, explaining several standards from the MA STEM curriculum framework. The goal of the original project was to expose students to many key STEM concepts involved in a simulated lunar base. The students would learn these concepts through hands-on activities and experiments taking place in multiple sub-exhibits inside one large exhibit built in the basement of the vacant Worcester Memorial Auditorium. The large exhibit would be a created to give the students the experience of living on a base on the Moon's surface. Each sub-exhibit would detail a different aspect of the lunar base including a greenhouse, mission control room, and moon-walk on the lunar surface. Each would have an activity or experiment that fits the theme of the sub-exhibit and teaches at least one standard from the STEM curriculum.

This project adds two more activities to be conducted in an undetermined part of the overall lunar base exhibit with the intent to expose students to even more STEM standards. One of the activities involves using modeling clay to model the layers of the Earth and the Moon. It corresponds with Earth and Space Science, grades 6-8 Learning Standard 2 of *Massachusetts Department of Education STEM Curriculum (2006):* "Describe the layers of the earth, including the lithosphere, the hot convecting mantle, and the dense metallic core." This activity explains the differences and similarities between the compositions of the Earth and the Moon. After building clay models, students will be able to name and compare the thickness, physical state, and elemental make-up of each layer of the Earth and Moon. The composition of the layers can also help explain the scientific belief that the Moon was once part of the Earth that broke away after a large meteor struck Earth. The models that the students create will be small enough to take home.

The second activity involves students building model rockets from kits and launching them. From this activity, the students will learn several different subjects in physics and mechanics, including Newton's three laws of motion, aerodynamics, energy transfer, and the four forces that act on aircraft and spacecraft. The students will also learn the different parts of a rocket and what role each part plays during the rocket's flight. The activity demonstrates how a space shuttle carrying astronauts and other components of the lunar base launches from the Earth's surface into outer space. It covers several concepts listed in the Physical Science and Technology / Engineering portions of the *Massachusetts Department of Education STEM Curriculum*.

Background Information

This section details the Earth Science and Physics concepts that students will learn while conducting the Earth and Moon Layers Activity and the Building a Rocket Activity. It also lists the parts of a model rocket.

Moon's Layers

The following content about the layers of the Moon should be explained to students by a teacher or Lunar Base Exhibit employee prior to conducting the Earth and Moon Layers activity. After the activity, students should be able to distinguish the different layers of the Moon and compare their thicknesses using their clay models. The moon has three distinct layers: the crust, mantle, and core. The outermost layer of the moon is the crust, consisting of rock called regolith. The crust is approximately 37 mi (60 km) thick on the side of the moon that faces Earth and approximately 62 mi (100 km) thick on the opposite side. The regolith rocks found on the moon's crust are similar to rocks found on the earth's crust. The only known difference is that the regolith contains more aluminum and titanium. Scientists have discovered that this layer of the moon is mainly composed of silicon (Si), iron (Fe), magnesium (Mg), oxygen (O), calcium (Ca), titanium (Ti) and aluminum (Al). The crust of the moon also has some magnetism like the crust of the earth.

The layer below the crust is the mantle, which is divided into two parts. The upper layer of the mantle is the rigid lithosphere. It is estimated to be about 620 mi (998 km) thick. The lower part of the mantle is the asthenosphere. The asthenosphere is not rigid like the lithosphere and its innermost parts are hot enough to flow. This layer is capable of transmitting seismic waves which are known to cause "moonquakes". The mantle is believed to be composed mostly of minerals called olivine, orthopyroxene and clinopyroxene.

The innermost layer of the moon is the core. This layer is very small and its thickness is only about 225 mi (362 km) or less. The moon's core makes up less than 5% of the total mass of the moon and is believed to be partially molten, with the inner core being solid and the outer core liquid. The composition of this layer is believed to be iron, nickel (Ni), and sulfur (S).

Earth's Layers

The following differences in the Earth's layers should be explained to students prior to the Earth and Moon layers activity. Students should be able to use their clay models of Earth to distinguish between its layers as well as discover similarities in the layers of Earth and the Moon. The Earth is composed of four different layers: crust, mantle, outer core, and inner core. Scientists believe that as the Earth cooled the heavier, denser materials sank to the center of Earth and the lighter materials rose to the top layer. Because of this, the topmost layer, the crust, is made of the lightest materials, such as rock-basalts and granites, while the innermost layer, the inner core, consists of heavy metals like nickel and iron. The Earth's crust is very thin in comparison to the other layers. It is about 3-5 mi (5-8 km) thick under the oceans (oceanic crust) and about 25 mi (32 km) thick under the continents (continental crust). The Earth's crust is broken into many pieces called *plates*. The plates "float" on soft mantle located below the crust. The movement of the plates is called *plate tectonics.* These plates usually move along smoothly, but sometimes they stick together and build up a lot of pressure. The pressure build-up causing the plates to bend until they snap, causing earthquakes. The elements present in the Earth's crust are oxygen, silicon, aluminum, iron, calcium, magnesium, potassium (K), and sodium (Na).

The crust and the upper layer of the mantle together make up the rigid lithosphere. Like the moon, this is the upper mantle. Below the lithosphere is the asthenosphere, the lower part of the mantle that flows and moves the plates of the Earth. The mantle is the largest layer of the Earth, about 1800 mi (2900 km) thick. It is mostly composed of magnesium and iron.

Many geologists believe that the asthenosphere flows because of convection currents. Convection currents are caused by the extremely hot material at the deepest part of the mantle rising, then cooling, sinking again and then heating and rising, repeating the cycle over and over.

The core of the Earth is like a ball of very hot metals at the Earth's center. The outer core is so hot that it is in the liquid state. The outer core is about 1400 mi (2300 km) thick. It is composed of melted nickel and iron. The inner core of the Earth has temperatures and pressures so high that the nickel and iron metals are not able to move like a liquid, but are forced to vibrate in place as a solid. The inner core is about 800 mi (1300 km) thick.

Aerodynamics of Aircraft

Prior to the rocket activity, students should be exposed to the concepts of aerodynamics and the four basic forces involved in aerodynamics. They should learn that these forces exist for all objects in the air and are what make the rockets fly. *Aerodynamics* is the study of the motion of air and the relative motion between air and objects in the air. Model rockets rely on aerodynamics to fly properly, just as butterflies, birds, and airplanes do. The flight performance of any model rocket is the result of the combined effects of the four basic forces acting upon it. The four basic forces that operate on any object moving through air are lift, drag, gravity (weight), and thrust.

Lift is the force that is created when air moving over the top of an object, such as an airplane wing, moves faster than the air moving beneath it. There is less force (air pressure) against the top than beneath the object. This creates a force which lifts the object. It is generated by *relative wind*, which is the motion of air in relation to an object.

Drag is the friction force experienced by any object moving through air as the air slides or drags past it. A larger or rougher surface creates more drag. More drag is also created by increasing speed. It can be minimized, but it cannot be eliminated completely.

Gravity is the force that pulls down on any object near the Earth's surface. It acts through the center of gravity of any object. The amount of gravity is proportional to the object's mass and inversely proportional to the square of the distance between the object and the Earth's center. Drag and gravity limit the height a model rocket can reach. Smooth surfaces and less weight on the model can help minimize the effects of drag and gravity.

Thrust is the forward force exerted on a flying object. It is produced by the engine of a model rocket. Gravity must be overcome for the model rocket to ascend vertically, so the thrust has to be greater than the model's weight in order for it to lift off.

Newton's Laws of Motion

Newton's three laws of motion are involved in the launch and flight of model rockets. Teachers of Lunar Base Exhibit employees should explain to students these three laws and give examples to help them visualize the laws' concepts. The first law states that a body at rest will remain at rest and a body in motion will remain in motion at a constant speed in straight line as long as no other force acts on it. This law is the Law of Inertia. The second law states that if an unbalanced force acts on a body, the body will accelerate (move faster or slower); the magnitude of the acceleration is proportional to the magnitude of the unbalanced force, and the direction of the acceleration is in the direction of the unbalanced force. Newton's third law states that whenever one body exerts a force on another body, the second body exerts a force equal in magnitude and opposite in direction to the first body. This law relates to the equal action-reaction principle.

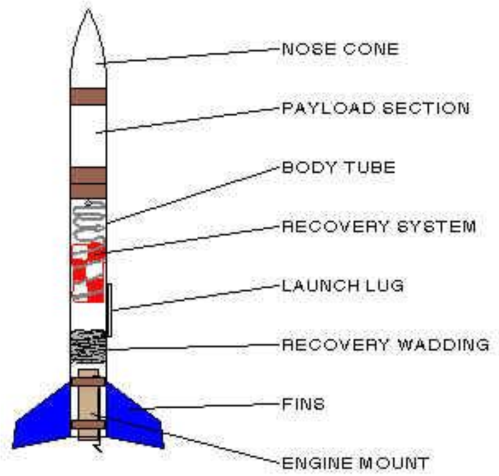
Kinetic Energy and Potential Energy

Energy is neither created nor destroyed, but it is transformed. This is an important concept to understand when launching a rocket. A rocket never gains or loses energy during flight; the same amount of energy always exists, but in different forms. During the flight of a rocket, chemical energy is transformed into mechanical energy, heat, light and sound energy. In a model rocket, there is so little light and sound energy that they may be ignored. Part of the mechanical energy is transformed to the kinetic energy of the rocket's motion. Another part of mechanical energy is transformed into heat energy caused by the friction of the rocket moving through the air. Another part of the mechanical energy is transformed into the kinetic energy of individual air molecules as they are deflected by the rocket (drag and lift). Part of that kinetic energy is transformed into the potential energy of the rocket as it ascends higher and higher into the air. Part of the stored chemical energy is released as waste heat energy during the combustion of the rocket's engine. These concepts about energy transformation should be explained to students before they set up and launch their model rockets.

Parts of a Model Rocket

It is important that each student assembling and launching a model rocket know the function of each part of the rocket. Each part should be clearly identified and its purpose should be explained to the students by whomever is conducting the rocket launches. The *nose cone* is the foremost surface of a model rocket, generally tapered in shape for streamlining. The nose cone is usually made of balsa or lightweight plastic. The *recovery system* is a device use in a model rocket for the purpose of returning it to the ground safely. The recovery system usually works by creating drag or lift to oppose the acceleration of gravity, such as the deployment of a parachute. A *body tube* is a specially wound and treated cardboard or lightweight plastic cylinder used to make the fuselage (airframe) of a model rocket. A *launch lug* is a round, hollow tube which slips over the launch rod to guide the model during the first few feet of flight until it reaches enough airspeed to allow the fins to operate. The *fins* are aerodynamic surfaces projecting from the rocket's body to stabilize and guide the rocket. The *engine* of a model rocket is a miniature non-metallic solid fuel rocket motor that contains propellant. It may also contain a delay element and an ejection charge. The engine is designed to exert enough force to accelerate the rocket during flight and activate the recovery system at the peak of the flight. The *weathercock* is a part of the rocket used to turn into the wind, away from a vertical path.

The *thrust phase* is the period of time during which the propellant in the engine is burning and the rocket motor is producing thrust. The *coasting phase* is the period of time immediately after the thrust phase when the propellant has burned out and precedes the ignition of the ejection charge of the engine, during which the rocket coasts upward on its momentum. The *recovery phase* is the period of time following the deployment of the recovery system which allows the rocket to drift slowly and safely back to the ground. The *apogee* is the peak height of the rocket's flight. Students should be able to identify each part of the rocket as well as each phase during the rocket's flight. They should also understand that some of the parts affect the rocket's aerodynamics and stability.



Parts of a typical model rocket.

Forces on a Spacecraft

Although the same four forces act on a spacecraft as on an aircraft, there are some important differences in how the forces are applied. These differences should be described to the students so that they fully understand that while a space shuttle travels through the vacuum of space on its way to the Lunar Base on the Moon, forces have a different effect on it than when it travels through the Earth's atmosphere. On an aircraft, the lift force is used to overcome the weight (gravity force). On a spacecraft, thrust is used to oppose weight. On many spacecrafts, lift is used to stabilize and control the direction of flight. Most of the aerodynamic forces on an aircraft are generated by the wings and the tail surfaces. For a spacecraft, the aerodynamic forces are generated by the fins, nose cone, and body tube. For objects in both the air and space, the aerodynamic forces act through the center of pressure while the weight acts through the center of gravity. While most aircraft have lift that is greater than drag, the drag of a spacecraft is usually much greater than the lift. The magnitude and direction of the forces acting on an aircraft usually remain fairly constant, but the magnitude and direction of the forces acting on a spacecraft can change dramatically during a typical flight.

Layers Activity Proposal

Modeling the Layers of Earth and the Moon (grades 5-6)

At the end of the project, students should be able to:

- identify the layers of the Earth and Moon and their thicknesses, including the inner core, outer core, mantle, and crust
- understand that the inner cores of the Earth and Moon are solid due to tremendous pressure and the outer cores are molten, and exist in a "liquid" state
- understand that the lithospheres (upper mantles) of both planets are rigid and the asthenospheres (lower mantles) of both planets flow
- identify the elements present in the Earth's and Moon's layers
- compare and contrast the layers of the Earth and the Moon (thickness, physical state, elements, etc.)

Materials:

- Clay (13 colors, 3 oz each: Red, Orange, Light Orange, yellow, green, light blue, blue, purple, light purple, dark pink, pink, brown, black, white) Play-Doh 24-pack includes all colors needed.
- String
- Ruler
- Rolling pin

Procedure:

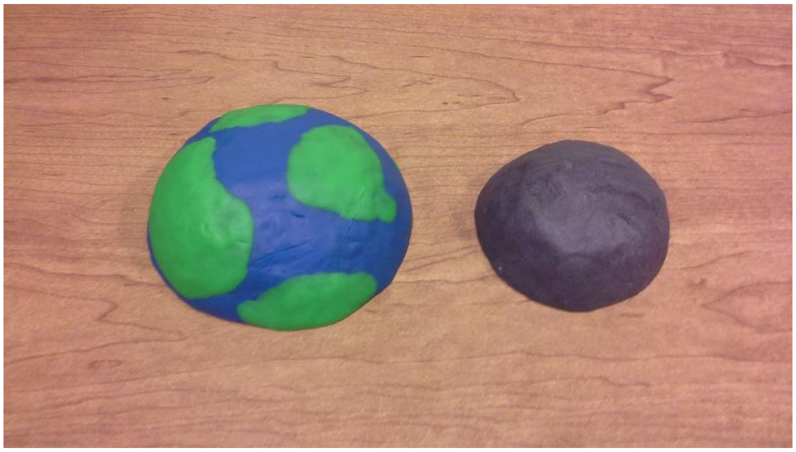
1. For Earth's Layers: roll about one-third of yellow clay into a ball about 1-2 cm in radius (2-4 cm in diameter). This will be Earth's inner core.
2. With rolling pin, flatten light orange clay until sheet is about 2 cm thick. Wrap sheet around yellow clay ball. This will be Earth's outer core.

3. With rolling pin, flatten orange clay until sheet is about 1-1.5 cm thick. Wrap this sheet around light orange clay ball. This will be Earth's lower mantle.
4. With rolling pin, flatten red clay until sheet is about 1-1.5 cm thick. Wrap this sheet around orange clay ball. This will be Earth's upper mantle.
5. With rolling pin, flatten brown clay into a very thin sheet that is about 0.5 cm thick. Wrap this sheet around red clay ball. This will be Earth's crust.
6. With rolling pin, flatten light blue clay into a very thin sheet that is about 0.5 cm thick. Wrap this sheet around brown clay ball. This is not a layer, but for decorative purposes. It represents Earth's oceans.
7. Take apart small pieces of the green clay and flatten pieces into random shapes. Mold shapes onto light blue clay ball. These shapes represent the Earth's continents.
8. Cut a long piece of string, twine, or dental floss (about 32 cm). Wrap string around center of Earth and pull all the way through. Pull apart two halves.
9. For Moon's layers: roll about one-fourth of pink clay into a ball about 0.5-1 cm in radius (1-2 cm in diameter). This will be Moon's inner core.
10. With rolling pin, flatten dark pink clay until sheet is about 1 cm thick. Wrap sheet around pink clay ball. This will be Moon's outer core.
11. With rolling pin, flatten light purple clay until sheet is about 1.5-2 cm thick. Wrap this sheet around dark pink clay ball. This will be Moon's lower mantle.
12. With rolling pin, flatten purple clay until sheet is about 1-1.5 cm thick. Wrap this sheet around light purple clay ball. This will be Moon's upper mantle.
13. With rolling pin, flatten blue clay into a very thin sheet that is about 0.5 cm thick. Wrap this sheet around purple clay ball. This will be Moon's crust.

14. Roll half of white clay and half of black clay together until clay is gray. With rolling pin, flatten gray clay into a very thin sheet that is about 0.5 cm thick. Wrap this sheet around blue clay ball. This is not a layer, but for decorative purposes. It represents Moon's lunar surface.
15. Cut a long piece of string, twine, or dental floss (about 32 cm). Wrap string around center of Moon and pull all the way through. Pull apart two halves.

Results:

Each layer should be clearly defined in the models. The Earth's outer core (light orange) should be the thickest layer and the crust (brown) the thinnest. The Moon's lower mantle (light purple) should be the thickest layer and the crust (blue) the thinnest. The Earth model pictured is about 9.5 cm in diameter and the Moon model is about 6.5 cm in diameter.


Completed clay models of layers of Earth (left) and Moon (right)

Rocket Launch Activity Proposal

Assembling and Launching Model Rockets (grades 7-8)

At the end of this activity, students will be able to:

- Name and identify the four basic forces operating on any object in the air: lift, drag, thrust, gravity
- Explain how these forces apply to flight sequence
- Explain Newton's three laws of motion
- Identify the parts of a rocket
- Assemble and launch a model rocket
- Identify the forces acting on any object in outer space
- Know the difference between kinetic and potential energy and how one is converted to the other

Materials:

- Color the Sky™ Rockets Model Rocket Kit from Estes-Cox Corp.

*The Color the Sky™ Rockets Model Rocket Kits come with pre-*assembled *19.8 in. "crayon" rockets in 12 different colors. The rockets can reach up to an altitude of 200 ft with B engines.*

- Estes B4-2 Engine

The Estes B4-2 engine is single stage engine designed for model rocket flight. This engine is a standard engine designed for flights in rockets weighing less than 4 ounces, including the engine.

- Astron II™ Launch Pad and Controller

  Fully assembled controller with 17 ft (5.2 m) of cable

Procedure:

1. Insert a B4-2 engine into the body tube.
2. Twist on the fin unit.
3. Attach the shock cord to the nose cone.
4. *The launch pad should be set up by an adult supervisor*. Measure off a 100 ft baseline from the launch pad. Mark the end of the baseline with a marker (cone or flag). Demonstrate where each student must stand during the launch (behind the baseline).
5. When it is each student's time to launch, the student gives the rocket to the adult supervisor. The supervisor slides the rocket onto the launch rod and hooks up the system's micro-clips. The students and supervisor should go out to the 100 ft baseline marker.
6. All the students do the countdown: 5, 4, 3, 2, 1, 0. The supervisor then presses the launch button on the controller.

7. When the rocket reaches its apogee, the parachute recovery system will activate and the rocket will descend to the ground. The student should recover the rocket where it lands.

Recommendations:

After each student launches a rocket, teachers or adult supervisors can give each student a worksheet to help solidify their knowledge in the concepts of aerodynamics, Newton’s laws, energy transfers, and the parts of a rocket.

Some suggestions of worksheets:

- Provide a blank picture of a rocket and have students label each part.
- Provide a worksheet with different scenarios and have students identify which one of Newton’s three laws of motion each scenario represents. (Ex: astronauts and objects in near zero-gravity environments do not move unless a force acts on them, a rocket is propelled through outer space by the force of combustion of propellant in the engine).
- Give a problem where a rocket is unable reach its destination and have students determine how the problem could be solved. (Ex: increase thrust, reduce drag, reduce weight, alter placement of fins to guide rocket, etc.)

Results:

By putting together the rockets and launching them, the students see first-hand the flight of a rocket, from launch pad to apogee and back to the ground. They also have the opportunity to see and touch each part of the rocket and learn how each part contributes to the rocket’s flight. With after-launch worksheets, students can demonstrate their knowledge of the concepts of aerodynamics, Newton’s laws, and energy transfers.

Rocket Red Color the Sky™ Rocket

References

Condensed MA STEM Curriculum Framework Standards

- *From Earth and Space Science, grades 6-8 Learning Standard 2 of Massachusetts Department of Education STEM Curriculum (2006):*

  Describe the layers of the earth, including the lithosphere, the hot convecting mantle, and the dense metallic core.

- *From Physical Sciences, grades 6-8 Learning Standard 1 of Massachusetts Department of Education STEM Curriculum (2006):*

  Differentiate between weight and mass, recognizing that weight is the amount of gravitational pull on an object.

- *From Physical Sciences, grades 6-8 Learning Standard 11 of Massachusetts Department of Education STEM Curriculum (2006):*

  Explain and give examples of how the motion of an object can be described by its position, direction of motion, and speed.

- *From Physical Sciences, grades 6-8 Learning Standard 13 of Massachusetts Department of Education STEM Curriculum (2006):*

  Differentiate between potential and kinetic energy. Identify situations where kinetic energy is transformed into potential energy and vice versa.

- *From Technology/Engineering, grades 6-8 Learning Standards 6 of Massachusetts Department of Education STEM Curriculum (2006):*

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

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

A Typical Model Rocket
https://courses.washington.edu/engr100/All_Sections/Rocket/HTML%20Handouts/01a_hnd_Typical_model_rocket.htm

Clay Model Earth Teacher Instructions
http://www.volcanoesalive.com/Lessons/VA%20Unit%202/2_2Clay_Model_Earth.pdf

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http://planetfacts.org/layers-of-the-moon/

Massachusetts Department of Education STEM Curriculum (2006)
http://www.doe.mass.edu/frameworks/current.html

Oregon State Univerity Easrth Science Lessons: Lesson #1 The Earth's Layers
http://volcano.oregonstate.edu/earths-layers-lesson-1

Physics and Model Rockets: A Teacher's Guide and Curriculum for Grades 8-11
http://www2.estesrockets.com/pdf/Physics_Curriculum.pdf

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http://www.space.com/17777-what-is-earth-made-of.html