Seeing the Moon

Using Light to Investigate the Moon

A Series of Inquiry Activities created for Chandrayaan-1's Moon Mineralogy Mapper Instrument

Through the hands-on inquiry based activities of *Seeing the Moon*, 5th to 8th grade students experiment with light and color, collect and analyze authentic data from rock samples using a reflectance spectrometer, map the rock types of the Moon, and develop theories of the Moon's history. The activities are divided into three primary "modules," with each module including open inquiry, demonstrations, hands-on activities, and a discussion to synthesize the students' understanding.

Content Objectives

Students will:

- Compare the characteristics of light of specific wavelengths to white light
- Demonstrate how spectra can be used to identify and map minerals and rocks
- Create a mineralogic map of the Moon based on data they collect
- Synthesize information about the Moon's topographic features and mineralogy to develop a hypothesis on the Moon's geologic history
- Describe why the spectra taken by the Moon Mineralogy Mapper / Chandrayaan-1 will obtain more information about the Moon than any observations to date

Inquiry Objectives

Students will:

- Develop descriptions, explanations, predictions, and models using evidence
- Use appropriate tools and techniques to gather, analyze, and interpret data
- Communicate scientific procedures and explanations
- Recognize and analyze alternative explanations and predictions

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Background

The Moon's Formation and Evolution

The current theory that best expains the scientific evidence is the "Giant Impactor Theory". In this model, early in the history of the solar system, the Earth collided with a small planet (approximately half the current size of Earth. The impacting planet was destroyed in the collision. Some rocky debris from that impactor, and less from the Earth, were hurled out into orbit around Earth. This material accreted — came together — to form the Moon. Some models suggest our Moon may have formed in as few as 10 years.

<u>Early Stages: A Magma Ocean</u> — As the rocky materials orbiting Earth accreted, the Moon grew larger and hotter. This heat formed an ocean of magma.

The evidence for a magma ocean comes from the layering of the Moon's interior. The uppermost part of the Moon's crust is mainly the rock anorthosite, which is primarily made of a single mineral, plagioclase feldspar. This rock forms the "lunar highlands," the bright white, heavily cratered regions we see on the Moon. Deeper parts of the Moon's crust and mantle include larger amounts of other minerals, such as pyroxene and olivine. As the magma ocean cooled and crystallized over a period of 50 to 100 million years, light-weight minerals such as plagioclase floated to the top, while denser minerals (such as pyroxene and olivine) sank. The oldest rocks collected by the Apollo astronauts are 4.5 billion years old, which is thought to indicate when the Moon solidified.

<u>Big Impacts, Big Basins</u> — Early in our solar system's history, the Moon and all other planetary bodies, were bombarded by large asteroids. These left scars; giant basins such as Imbrium, Crisum, and Serenitatis, hundreds of kilometers across, occur where they struck the Moon. The upturned rims of these basins form mountain chains on the lunar landscape. The impacts broke apart the rocks at the surface of the Moon and fused them into impact breccias, which are rocks made of angular, broken fragments, finer matrix, and melted rock. Impact breccias collected by the Apollo astronauts provide scientists with ages of formation of the basins, ranging from 3.8 to 4.0 billion years ago. By 3.8 billion years ago, this period of intense bombardment came to a close; since then, asteroid impacts have been much smaller and less frequent.

<u>Basin Filling</u> — Billions of years ago, the Moon was still hot, warmed by radioactive decay of unstable isotopes of elements, impacts, and left-over energy from the giant impact that formed it. Pockets of hot mantle material slowly rose to the surface, melting and forming lava as they moved up to lower pressures. This lava erupted through fissures, cracks in the lunar surface, many of which were created by earlier impacts. The lava flooded across the lowest regions on the lunar surface: the giant impact basins. It crystallized quickly, forming a dark, fine-grained volcanic rock, basalt. The

large, smooth, dark regions we see on the Moon are the basaltic "lunar maria." They are smooth because they are less cratered than the lunar highlands. The smaller number of craters suggests that these regions have not been impacted as frequently and therefore are younger. Maria basalts have been dated to be between 3.1 and 3.8 billion years old. Gradually, as the Moon cooled, volcanism ceased.

All of these lavas are basalts, but there is a wide range in their minerals and compositions, because the lavas formed in different places (and from different mantle rocks) inside the Moon.

Recent History — For the last billion years, our Moon has been geologically inactive. It has no atmosphere, flowing water, or life to erode or disturb its surface features. Only impacting meteoroids, a few spacecraft, and the footsteps of 12 humans have reshaped its surface. The data returned by orbiting spacecraft and by the Apollo program reveal much about the formation and evolution of our Moon and, in turn, of our own Earth. Resurfacing processes active on Earth have obscured its early history of formation, differentiation, and asteroid bombardment. New spacecraft missions will help scientists piece together the details of history and evolution of the Moon — and Earth — and will lead to an understanding of lunar processes and distribution of resources in preparation for prolonged human habitation of the Moon.

Human Exploration of the Moon

Between 1969 and 1972 six manned Apollo missions brought back 382 kilograms (842 pounds) of lunar rocks, core samples, pebbles, sand and dust from the lunar surface. Each trip to the Moon took about 3 days to reach the Moon and another 3 days to return. These samples have been analyzed by scientists to better understand the Moon’s composition, formation, structure, and geologic history. The Apollo explorations covered only 95 kilometers (60 miles) of the Moon's surface – a small percentage!

A New Age of Discovery

The United States has set new goals for the Moon: NASA plans to return to the Moon by 2020, as the launching point for missions beyond. To achieve this, NASA will send human mission back to the Moon as early as 2015, with the goal of living and working there for increasingly extended periods of time. In order to achieve these goals, NASA is planning robotic missions to study the Moon for possible landing sites, examining the Moon’s natural resources, and preparing technology suitable for future human landings.

As we study the Moon today, we are preparing for tomorrow’s exploration. Your students may be among the next generation of astronauts and space explorers; we welcome them to join in these activities as today’s scientists examining the Moon.

The Chandrayaan Mission and the Moon Mineralogy Mapper Instrument

The Indian Space Research Organisation will launch its first mission to the Moon in 2008, with an instrument provided by NASA to map the mineral composition of the lunar surface.

The Moon Mineralogy Mapper (M^3) is a state-of-the-art imaging spectrometer which will examine lunar mineralogy at high spatial and spectral resolution. It will map the entire lunar surface from an altitude of 100 kilometers (62 miles) at 140 meter spatial sampling and 40 nanometer spectral sampling, with selected targets mapped at 70 meter spatial and 10 nanometer spectral resolution. M3 will be launched aboard India's Chandrayaan-1 spacecraft in March, 2008. The mapping mission will last two years.

This information will be important both for science and human exploration. A detailed characterization of lunar surface mineralogy can dramatically improve our understanding of the Moon's origin and geologic evolution, as well as the early development of the Earth. A detailed map of lunar resources will also be needed by future astronauts who may live and work on the Moon.

M^3 will be one of 11 instruments onboard the spacecraft, of which six will be Indian, two will be American, and three will be from other countries.

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M3 Activities Correlated with National Science Education Standards

Description of Standard	*Activity to which Standard Applies*							
	Activity 1A	Activity 1B	Activity 1C	Activity 1D	Activity 2A	Activity 2B	Activity 3A	Activity 3B
Content Standard A: Science as Inquiry								
Abilities to do Inquiry: Develop descriptions, explanations, predictions, and models using evidence					■			■
Abilities to do Inquiry: Use appropriate tools and techniques to gather, analyze, and interpret data.	■	■	■	■		■		
Abilities to do Inquiry: Communicate scientific procedures and explanations	■	■				■		■
Abilities to do Inquiry: Recognize and analyze alternative explanations and predictions	■	■				■		■
Mathematics is important in all aspects of scientific inquiry.			■	■		■		
Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.		■	■	■	■	■		■
Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.	■					■		■
Asking questions and querying other scientists' explanations is part of scientific inquiry. Scientists evaluate explanations by examining and comparing evidence, identifying faulty reasoning, and suggesting alternative explanations for observations.	■	■				■		■
Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data..				■				■
Content Standard B: Physical Science								
Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object--emitted by or scattered from it--must enter the eye.	■	■	■	■	■	■		
The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.		■	■		■			
Content Standard D: Earth and Space Science								
Land forms are the result of a combination of constructive and destructive forces..								■

The earth is the third planet from the sun in a system that includes the moon…					■			■

CONTENT STANDARD E: Science & Technology

Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena.

Assessing Current Understanding

What do your students know about white light and the frequencies of light? What do they know about the Moon and current robotic space missions?

You may wish to spend some time during the activities or before beginning the activities discovering your students' current knowledge and understanding of the concepts to be presented so that you can ensure you will meet your learning objectives.

There are many common misconceptions about light and the electromagnetic spectrum documented for middle school to college students. These include:

- An object is seen whenever light shines on it, with no recognition that light must move from the object to the observer's eye.
- An object can be seen in the dark, with absolutely no light, as long as the observer's eyes have had time to adapt.
- We see by looking (visual ray idea) not by light being reflected to our eyes.
- Light is reflected away from shiny surfaces, but light is not reflected from other surfaces.
- Different forms of light include "natural", "electric", "ultraviolet", and "radioactive".
- When light passes through a prism or a filter, color is added to the light.
- Color is a property of an object, not affected by the illuminating light.

There are also misconceptions regarding NASA's exploration of the Solar System. Some students may believe that humans have never been to the Moon, while others may believe that astronauts have visited many of the planets in the Solar System. Students may not be aware of past or ongoing scientific robotic missions to our Moon and other planets.

Assessment Activities 1 and 2 will help you determine your students' current understanding of light and of our exploration of the Solar System.

Assessment Activity 1: The Little Bit of Light

In this 10 minute activity, students complete a story about light. The teacher will then examine their stories for key concepts and (mis)preconceptions regarding how we see and the role of light in seeing.

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Anticipated class time: 10 minutes

Objectives:

- The teacher will be able to use the results of this activity to better understand his or her student's preconceptions of sight.

Key Concepts:

- Light travels or moves until it is reflected or absorbed by an object.
- Light can be reflected, or "bounce" off of any object (not just mirrors).
- In order for a person to see something, light must be reflected off of that object and into his or her eye(s).

Materials

For each student:

- One copies of the Story of the Little Bit of Light
- Pen or pencil
- Colored pencils

The Activity:

1. Hand out copies of the *Story of the Little Bit of Light* to your students. Let them know that this science writing activity is for you and that their work will not receive a grade—this is not a test.

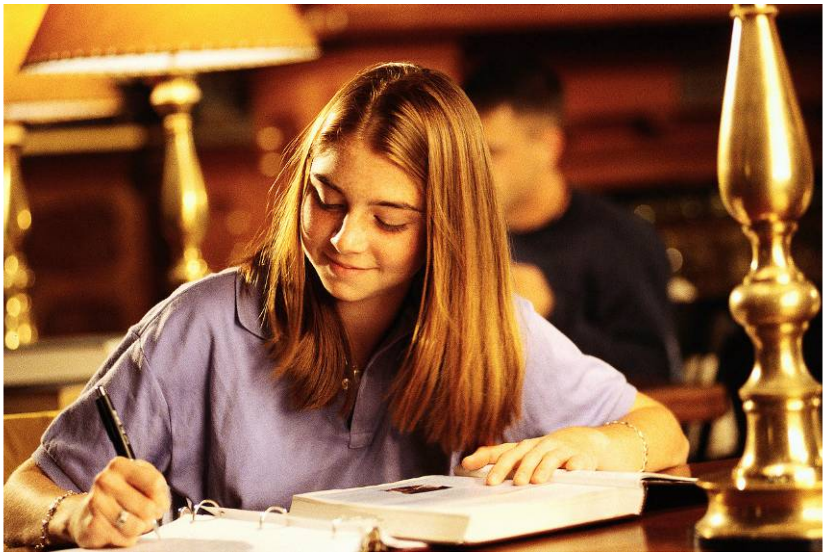
2. Let the students know they have 10 minutes to write the rest of the story. Their assignment is to write what happens to the light –*what does it do?, where does it go?, so that the student in the photo can see the book*. Remind the students that this is a science writing exercise; you would like a scientific story about the light, not a fictional story.

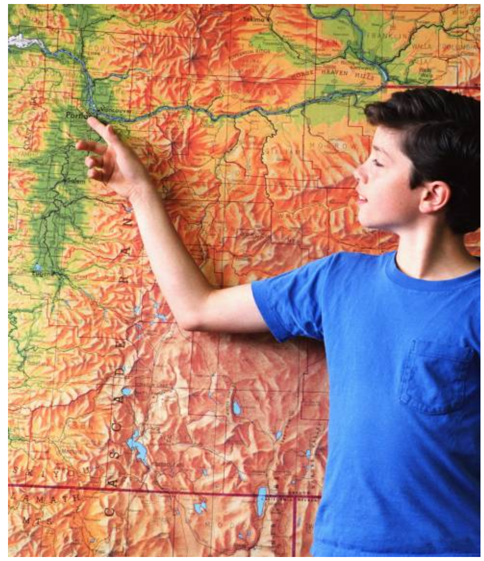
3. At the end of 10 minutes, collect the students' work. Outside of class, examine the stories for indications that the students understand that light keeps moving (instead of stopping), that the light reflects or hits objects, and that it does travel to the child's eyes in order for him or her to see.

4. Keep your students' preconceptions in mind while conducting the activities in these modules and address them throughout the activities. If there is substantial confusion as to how we see, consider discussion and activities about sight and seeing before conducting the activities in the modules.

5. Re-apply the assessment after the students complete further exploration of light, the electromagnetic spectrum, and how we see, to assess if there has been an increase in their understanding of these concepts.

The Story of a Bit of Light





Finish the science story, using one of the two pictures above,
ending with a student seeing the object(s):

I am a little bit of light. I was formed inside a light bulb inside a lamp in a dark room with no windows. I moved through the glass of the bulb and then I

Assessment Activity 2:
The Electromagnetic Spectrum

In this 15 minute activity, students write a description or draw a spectrum that includes the different types of light or radiation, and then compare two of the types of light, to allow the teacher to assess their understanding of the electromagnetic spectrum.

Objectives:

- The teacher will be able to use the results of this activity to better understand his or her student's preconceptions or misconceptions about the spectrum.

Key Concepts:

- White light can be broken down into different colors.
- There are different types of visible light, ranging from blue to red, and types of light that we cannot see (radio waves, infrared, ultraviolet, x-rays, and gamma rays).
- Different types of light have different frequencies, which correspond to different amounts of energy and different wavelengths.

Materials

For each student:

- a sheets of paper
- Pens or pencils
- Colored markers, pencils or crayons

The Activity:

1. Hand out blank sheets of paper and (if desired) markers or crayons to your students. Let them know that this activity is for you and that their work will not receive a grade—this is not a test.

2. Let the students know they have 10 minutes. Their assignment has two tasks:
   a) Write about or to draw and label the electromagnetic spectrum.
   b) Write down a comparison of two of the different types of light that make up the spectrum.

3. Collect the students' work. Outside of class, examine the stories for indications that a spectrum is made of light, and that it has been divided into different colors. Look for other concepts in both tasks relevant to your students' experiences and your grade level's standards—such as frequency, wavelength, energy, and types of light that are not visible.

4. Keep your students' preconceptions in mind while conducting the activities in these modules. If you have questions whether students' understood something, you will want to bring it up for discussion.

5. You can re-apply the assessment at the close of the ALTA activities to see if there has been an increase in understanding.