

INVESTIGATING THE MOON

Ages:
Grades 9-12

Duration:
3 hours total

Materials:

Per group of students

- At least 1 computer with internet access for each small groups of students (2-3 students per group)
- Writing instrument and ability to record and share small group and class results—e.g. blackboard(s) and chalk, poster-sized paper, or computer for powerpoints for each small group of students
- Projector hooked up to computer with internet, to allow the teacher to display different website images for the class

OVERVIEW —

Students explore the Moon through a series of mini-research projects that are progressively open-ended in this “backwards-faded scaffolded” research activity. In the first project, the instructor provides students with a question, a mechanism for doing the research, and shows them how to answer the question. In the second project, the instructor provides the students with a question and a mechanism for doing the research, but invites the students to answer the question themselves. In the third project, the instructor provides a question, but not a mechanism for doing the research or an answer. In the last project, the students develop their own questions and collect their own data to determine an answer. Each of these projects uses the database available at http://webgis2.wr.usgs.gov/Lunar_Global_GIS/.

OBJECTIVE —

The students will:

- describe and analyze visual lunar data
- share their findings
- compare and contrast the Moon’s near side and far side
- develop research questions
- apply the process of scientific research

BEFORE YOU START:

- Students should already be familiar with the Moon’s scale relative to the Earth, and with the Moon’s rotation (they should understand that the Moon keeps the same side facing the Earth).
- Students should already be familiar with how craters form.
- Test the ability of your computers to open the USGS application browser, and become familiar with it yourself. (Help is available at http://webgis2.wr.usgs.gov/Lunar_Global_GIS/Help/Default.htm.)

ACTIVITY —

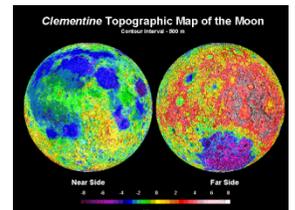
Introduction

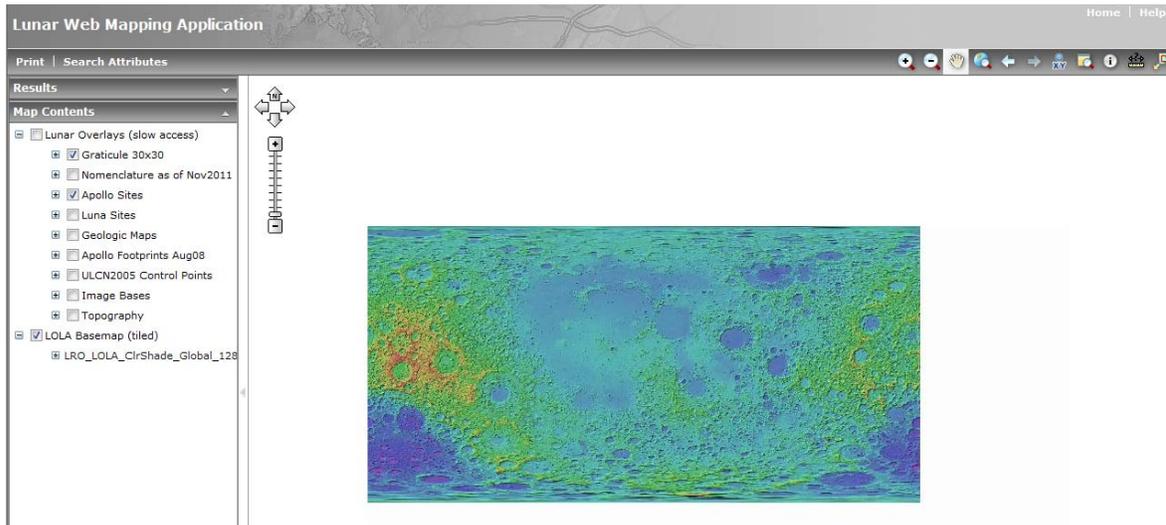
Let the students know that they will be studying a variety of data sets in the form of maps of the Moon, and using these data sets to investigate the Moon’s geology. At first, the instructor will ask them specific research questions, show them how to do the research to help answer those questions, and guide them through the best ways share their results. By the end of this project, the students will ask their own questions, determine out the research they need to do to answer those questions, and share their results with the rest of the class (either in a poster or a presentation).

Step 1

Help the students become familiar with a basic map of the Moon’s surface and features.

- Invite the students to examine this image of the Moon:
http://www.lpi.usra.edu/lunar/missions/clementine/images/img1_lg.gif
 - *What type of map is this?* Topographic
 - *What do the different colors represent?*
Elevation: purple and blue areas are very low, while orange and red regions are high.
 - *Are there any differences between the near side and the far side?* The near side has more deep areas and the far side has more highlands (and a large deep area).
 - *Does this create any questions? Do you have other questions? How can we learn more?* We need more data!



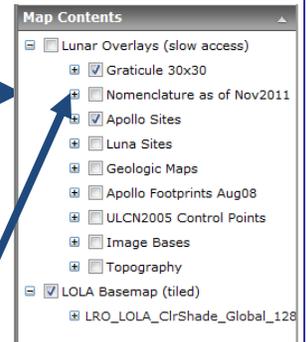


Step 2: Help the students become familiar with the application they can use to investigate further.

- Ask participants to go to http://webgis2.wr.usgs.gov/Lunar_Global_GIS/ (and write the website where the students can see it), and use a projector to display the website where the entire class can see it as well.
 - If it refuses to open, close it and try again, or cut and paste the website into the browser and try again.

- Discuss the website:

- *There is a map on the website. What is this a map of?* The Moon
- *What do you see in the left tool bar under Map Contents??* Different data options—ask your students to wait a little longer before they explore these options
- *How can you move around in the map, or look closer?* Use your mouse and scroll



- Getting oriented, using the Apollo Landing sites:

- Turn on a location grid by clicking the square in the left menu bar titled “Graticule 30x30.” Grid lines should appear.
- Tell the students that the latitudinal lines are 30 degrees apart, and that the line running horizontally through the middle of the map is the Moon’s equator (0 degrees latitude). *What is the latitude near the top of the map?* (90 degrees) *At the bottom of the map?* (-90 degrees)
- Take a look at the locations of the Apollo landing sites. *Where, roughly, did the astronauts land?* (Closer to the equator than the poles, all close together.)
- Zero degrees longitude—located in the middle of the map—is a line running down the center of the Moon’s face (the near side of the Moon) from its North pole to its South pole. The other vertical lines are all 30 degrees apart, ranging from -180 degrees on the left to +180 degrees on the right. *Are all of the Apollo sites on the side of the Moon facing the Earth, or are some on the far side of the Moon?* They are all on the side facing us, between -90 to +90 degrees longitude (the range we can see from Earth).

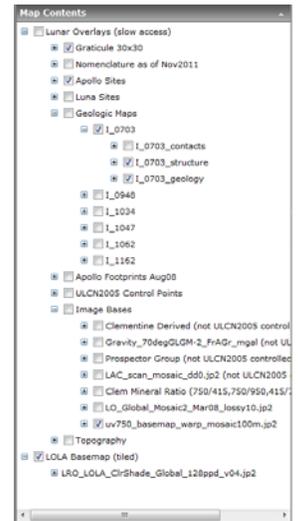
- Describe what type of data this map is displaying:

- Click on the + sign next to “LOLA Basemap.” Notice that “LRO_LOLA_ClrShade_Global...” appears. Turn off and on the check mark next to LOLA Basemap to see what happens. *The map disappears and reappears.*
- To find the key to any data set, click on the + sign next to the set. Click on the + sign next to “LRO_LOLA_ClrShade...”
- *What do the colors on this map signify?* This map is a topographic map; the colors represent elevation, like the first picture we saw; blues indicate areas with lower elevations and reds indicate higher elevations. (LOLA is a laser altimeter aboard the Lunar Reconnaissance Orbiter.)

- Invite the students to examine other functions of the application:

-  The globe tool at the top right can be used to return to the original map resolution, if you have zoomed in or out.
-  The small ruler at the top right can be used to measure the distance between two points.

- Lower on the left under Map Contents, students may want to check out various options. By clicking the + beside each dataset, students can open its key or see what additional data is contained within that larger dataset. The top folder needs to be checked in order to exhibit a checked dataset within. [For example, clicking on the + beside “Geologic Maps” reveals that one of the boxes is checked within the datasets, but because “Geologic Maps” has not been selected, this data does not appear on the map. Now select “Geologic Maps” (a check appears in the box beside it). A geologic map of a region of the Moon now appears on top of the topography. Each of the other datasets in this section contains information about the geology of a different region of the Moon. Invite the students to click on the + beside “I_0703” and within it select only the “structure” information. The black lines that appear show the outlines of impact basins in this region.]
- Within Map Contents in the Image Bases folder, students can explore a variety of lunar maps, such as gravity maps, a map of the Moon in ultraviolet (uv), and (within the “Clementine Derived” folder) maps of the weight percent of titanium (“Wt%-TiO₂”) and iron (“Wt%-FeO”).



Step 3: First Research Question: The instructor provides students with a question, a mechanism for doing the research, and shows them how to answer the question — *Which side of the Moon has the most craters, the near side or the far side?*

- Record the question where all students can see it, and invite the students to share their ideas on how to use this site to gather the data needed to answer this question.
- Suggest that they bring up the grid (“Graticule”), which divides the map into smaller sections. Have students count the number of craters visible (or just visually compare numbers of craters) in an equal number of sections on the near side (the center of the map) and the far side (the edges of the map). When counting or comparing crater numbers, make sure students zoom in on each section so that the section fills the screen. Each group of students should count the craters in one gridded section from the Moon’s near side and one gridded section from the Moon’s far side. They will share their results with the rest of the class.
- Invite each group of students to record their results where the others can see them. One suggested format to do this is by listing the crater counts on a blackboard or poster paper in two columns: near side and far side.
- After students have compared counts, invite them to discuss their results. Record the following questions and answers for all to see:
 - *What are the groups’ results? Which side of the Moon has more craters?* The far side
 - *What are potential sources of error in our data (our crater counts)?* Miscounts, difficulty with identifying craters, uneven distribution of data selection—too many students selecting the same areas and leaving other areas unsampled, trying to identify craters near the top and bottom of the map where the data is less clear
 - *How can we improve our data and results?* We could collect more data, particularly at higher resolution, to see if the same observation holds true of small and large craters.
 - *What new questions do our results create?* Students may wonder why there are more craters on the far side. Let them know that areas with more craters, particularly more large craters, are older (this is true of planets and moons throughout the solar system). Many of the craters on the near side of the Moon have been covered with volcanic lava flows, so much of the crust on the near side is relatively younger than the ancient crust on the far side.

Step 4: Second Research Question: The instructor provides the students with a question and a mechanism for doing the research, but invites the students to answer the question themselves — *Which side of the Moon has more iron in its crust—the near side or the far side? Or are they equal?*

- Record the question where all students can see it.
- Inside the “Image Bases” folder on the left, inside the “Clementine Derived” folder, there is a dataset containing information about the abundance of iron on the Moon (Wt%-FeO). Ask students to select this folder (making sure that both “Image Bases” and “Clementine Derived” are also selected). They will want to turn off most other folders to see the data clearly. Clicking on the “legend” file in “Clementine Derived” will add a legend. (Note: disregard the top two legends and the checkmark within; the color legend for Wt%-FeO is the only important one for this map.)

- Invite the students to share their ideas on how to use this site to gather data to answer the question. They may decide to use the same method that they did in the previous question to answer it.
- Invite each group of students to record their results where the others can see them—perhaps by listing their results in two columns: near side and far side.
- After students have compared their data, invite them to lead the discussion of their results, and to record the discussion for everyone to see.
- Students may suspect that the iron on the near side is associated with the younger material.

Step 5: Third Research Question: The instructor asks a question; students decide how to determine the answer—*What is the relationship between the location and abundance of iron on the Moon's surface and the elevation?*

- Record the question where all students can see it.
- Invite the students to share their ideas on how to use this site to gather the data to answer the question.
- Invite each group of students to record their results where the others can see them.
- After students have compared their data, invite them to lead and record the discussion of their results.
 - It may occur to some students that the iron is in lower elevations because it pooled in those deep basins.

Step 6: Fourth Research Question: Students select a question and decide how to determine the answer.

- Ask the groups to select a question about the Moon which they can answer with the data and functions in the Lunar Web Mapping Application. (Students who have difficulty can be prompted to look at the other data sets; they may want to examine a data set for differences between the Moon's near side and far side, or compare two data sets to determine if there is a relationship. Richer data sets are within the Geologic Maps section and the Image Bases section of the Map Contents toolbar. They may want to use the ruler to compare features sizes between one region and another.)
- Ask each team to record their question, the data sets they plan to use to answer their question, the data they collect, and their results, and their group's discussion of the results. Let them know that they will be sharing this information at the end of the project with the class, either in a 5 minute presentation (using PowerPoint or a similar program), or on a poster. Share how much time they have (at least one class period is recommended.)

Step 7: Concluding Discussion.

- After all of the student teams have shared their projects, invite them to share what they have learned about the Moon. Has their research led to other questions? If so, what other questions do they have? Would they like to find out more? Ask students how they could find out more.
- Invite the students to describe the possible goals of this project. Have they learned more about how research can be done? Was it easier to pick a research question after doing research on other questions? Do they now have a better understanding of the Moon? Will the information help them as they hear about results from lunar missions in the future? Has this changed their understanding of the process of science?

BACKGROUND —

More information on Backwards Faded Scaffolding activities is available at

http://caperteam.com/Documents/jge_nov2008_slater_408.pdf

Information about the Lunar Geology:

Early Stages: A Magma Ocean — As the rocky materials orbiting Earth accreted, the Moon grew larger and hotter. Heat from accretion caused the outer surface, and perhaps more, of the Moon to melt, forming 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: low-density, aluminum-rich, plagioclase feldspar. This rock forms the "lunar highlands," the brighter, light-colored, 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 50–100 million years, low-density minerals such as plagioclase floated to the top, while denser minerals such as pyroxene and olivine sank. The oldest rocks collected by Apollo astronauts are 4.5 billion years old, which is thought to indicate when the Moon's crust solidified.

As the outer layers solidified, the interior of the Moon also differentiated. The heavier iron separated from the less-dense rock in the mantle and sank, forming a small core surrounded by the rocky mantle and crust.

Big Impacts, Big Basins — Our early solar system was a messy place! An abundance of material remained in space and debris of all sizes constantly pummeled the Moon and all other planetary bodies. The impactors left their mark; huge impact basins such as Imbrium, Crisium, and Serenitatis, hundreds of miles 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 melt breccias — rocks made of angular, broken fragments, finer matrix between the fragments, and melted rock. These rocks, collected by Apollo astronauts, provide scientists with the timing of basin formation, ranging from 3.8 to 4.0 billion years ago. By 3.8 billion years ago, the period of intense bombardment came to a close; impact events became less frequent and were generally smaller. Impacts still occur today.

Basin Filling — Although cooling, the Moon was still hot, heated by radioactive decay of unstable isotopes of elements, such as uranium and thorium, and the processes of accretion and differentiation. Isolated pockets of hot mantle material slowly rose to the surface, melting at lower pressures. This magma poured out through cracks in the lunar surface — fissures — many of which were created by the earlier impacts. The magma flooded across the lowest regions on the lunar surface to fill the impact basins. It crystallized quickly, forming basalt, a dark, fine-grained, volcanic rock. The composition of the basalt varies because the magma formed in different places in the lunar interior. Some basalts have more titanium, others are more enriched in other elements such as potassium and aluminum. The large, smooth, dark regions we see on the Moon are the basaltic "lunar maria." "Maria" is Latin for "seas," as these areas looked like seas to early astronomers. They are smooth because they are less cratered than the lunar highlands. The smaller number of craters in the maria suggests that these regions have not been impacted as much and therefore are younger. Mare basalts have been radiometrically dated to be between 3.0 and 3.8 billion years old.

Imagine standing on the Moon at this time. Hot basalt lava flowed from long fissures, filling regions of low elevation. Fountains of lava sporadically erupted along the fissures, spewing molten rock high above the lunar surface. Chilled magma droplets fell back as beads of colored volcanic glass, later sampled by Apollo astronauts. Flowing lava cut channels into the landscape. In a few locations, small volcanic domes built up on the surface of the maria. Gradually, as the Moon's interior cooled, volcanism ceased.

Recent History — For the last one billion years, our Moon has been geologically inactive except for small meteoroids pummeling its surface, breaking the rocks and gradually adding to the layer of fine lunar dust — regolith — that covers the surface. In some places the regolith may be thicker than 50 feet (15 meters). The Moon has no atmosphere, flowing water, or life to erode or disturb its surface features.

Other than impactors, only a few spacecraft, and the footsteps of 12 humans, have reshaped its landscape. The data returned by orbiting spacecraft and 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 our planet's early history of formation, differentiation, and asteroid bombardment. New missions will help scientists piece together details of the history and evolution of the Moon (and Earth) and will help us better understand lunar processes and the distribution of resources in preparation for humans to live and work on the Moon.

National Science Education Standards

Gr 5-8

Earth and Space Science - Content Standard D

Structure of the Earth System

- Land forms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and deposition of sediment, while destructive forces include weathering and erosion.

Earth's History

- The earth processes we see today, including erosion, movement of lithospheric plates, and changes in atmospheric composition, are similar to those that occurred in the past. earth history is also influenced by occasional catastrophes, such as the impact of an asteroid or comet.

Grades 9-12

Science as Inquiry - Content Standard A

Abilities Necessary to Do Scientific Inquiry

IDENTIFY QUESTIONS AND CONCEPTS THAT GUIDE SCIENTIFIC INVESTIGATIONS. Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and conceptual understanding of scientific investigations.

USE TECHNOLOGY AND MATHEMATICS TO IMPROVE INVESTIGATIONS AND COMMUNICATIONS. A variety of technologies, such as hand tools, measuring instruments, and calculators, should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data is also a part of this standard. Mathematics plays an essential role in all aspects of an inquiry. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results.

COMMUNICATE AND DEFEND A SCIENTIFIC ARGUMENT. Students in school science programs should develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments.

Earth and Space Science - Content Standard D

The Origin and Evolution of the Earth System

- The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early earth was very different from the planet we live on today.
- Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations.