NASA's Lunar Reconnaissance Orbiter (LRO) Teacher Kit

Teacher Implementation Support

1. What's in this kit?
2. Why teach about the Moon and the LRO spacecraft?
3. What are the connections to other curriculum and standards taught?
4. Are there ways to adapt the lessons/activities in this curriculum?
5. What are the different ways to implement this curriculum?
6. How can students be assessed while using this curriculum?
7. What additional resources or extension activities are available for students related to the content of this curriculum?
8. What additional support is available for teaching lunar concepts and content?

1. What's in this kit?

Curriculum

NASA Education and Outreach (E/PO) professionals who work for the Lunar Reconnaissance Orbiter spacecraft developed these lessons, activities and resources.

The LRO E/PO team is comprised of educators from diverse institutions including: Goddard Space Flight Center, Adler Planetarium and Astronomy Museum, Denver Museum of Nature and Science, John's Hopkins University's Applied Physics Laboratory, University of New Hampshire, Arizona State University, and University of California, Los Angeles.

Each of these lessons has successfully gone through the NASA Education Product Review. This process assesses them for scientific accuracy, developmentally appropriate resources and effective instructional strategies.

Lunar Exploration Timeline
Lesson plan included

Mapping the Surface of the Moon
Curriculum guide included

Lunar Image Analysis
Student activity guide included

Question Moon
Lesson plan included

Exploring the Moon through Image Analysis
Lesson plan included

Making a 3D Model of the Moon's Surface
Lesson plan included

Making a Model
Lesson plan included

Planning a Mission to the Lunar South Pole
Lesson plan included

Lunar Image Processing with GIMP
Activity guide included

Lunar Laser Altimetry:
Studying the Topography of the Moon
Lesson plan included

Learning about Light
Lesson plan included

Using Radar to Search the Darkness
Student and Teacher guide included with lesson plan

CRaTER
Lesson plan included

How to Detect Cosmic Rays
Lesson plan included

How Cosmic Rays Affect Humans
Lesson plan included

The Discovery and Nature of Cosmic Rays
Lesson plan included

Seeing in the Dark
Lesson plan included

Various non-consumable materials for activities in the kit.

- Play-Doh
- Image sets
- Ping-pong balls

Related LRO resources and enrichment materials

- Posters, lithographs, images, CD's etc.

2. Why teach about the Moon and the LRO spacecraft?

Connections to National Science Education Standards and Benchmarks for Science Literacy (AAAS)

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Abilities necessary to do scientific inquiry

- Identify questions that can be answered through scientific investigations.
- Use appropriate tools and techniques to gather, analyze and interpret data
- Develop descriptions, explanations, predictions and models using evidence
- Think critically and logically to make the relationships between evidence and explanations
- Communicate scientific procedures and explanations

Content Standard B: Physical Science

- The Sun is a major source of energy for changes on the Earth's surface. The Sun loses energy by emitting light. A tiny fraction of that light reaches the Earth, transferring energy from the Sun to the Earth. 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

- The Earth processes we see today, including erosion, movement of lithospheric composition, are similar to those that occurred in the past.

Content Standard E: Understanding about science and technology

- Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.
- Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

Content Standard F: Science and Technology in Society

- Science and technology have advanced through contributions of many different people, in different cultures, at different times in history.

Content Standard G: History and Nature of Science

- In historical perspective, science has been practiced by different individuals in different cultures.

ADVANCEMENT FOR SCIENCE LITERACY BENCHMARKS

1B/1: Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.

1C/M1: Important contributions to the advancement of science, mathematics, and technology have been made by different kinds of people, in different cultures, at different times.

3A/M2: Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.

4A/H3: Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and X-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle data and complicated computations to interpret them; space probes send back data and materials from remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed.

11B/M3: Different models can be used to represent the same thing. What model to use depends on its purpose.

12E/H4: Insist that the key assumptions and reasoning in any argument—whether one's own or that of others—be made explicit; analyze the arguments for flawed assumptions, flawed reasoning, or both; and be critical of the claims if any flaws in the argument are found.

12A/H1: Exhibit traits such as curiosity, honesty, openness, and skepticism when making investigations, and value those traits in others.

4F/M5: Human eyes respond to only a narrow range of wavelengths of electromagnetic waves— visible light. Differences in wavelength within that range are perceived as differences of color.

M4: Understand oral, written, or visual presentation that incorporate circle charts, bar and line graphs, two-data tables, diagrams, and symbols.

21ST CENTURY SKILLS

Learning and Innovation Skills

- Creativity and Innovation
- Critical Thinking and Problem Solving
- Collaboration

Information, Media and Technology Literacy

- Information and Communication Technology (ICT) Literacy
- Flexibility and Adaptability

Life and Career Skills

- Social and Cross-Cultural Skills

Provides Access to Authentic Resources and Learning Experiences to Meaningfully Engage Students in Science

AUTHENTIC EXPERIENCES, LEARNING AND RESOURCES

- Authentic experiences are rendered authentic through the expertise and authority of the people designing and facilitating them. For example, participating in a task that would be done by real people such as the scientists that work for NASA and the LRO spacecraft.
- Authentic learning is achieved in environments where students are presented with problem-solving activities that incorporate authentic, real-life questions and issues in a format that encourages interaction with authentic resources, collaborative effort, dialogue with informed expert sources, and generalization to broader ideas and application. In this curriculum, students have access to real scientific data straight from the spacecraft. This means the students and scientists are both looking at the same data at the same time, which is exciting for students!

THE IMPACT OF AUTHENTICITY:

- Authentic resources and experiences can have a real impact on students that expand even beyond the classroom. Although some of the impacts are related to growth of knowledge, others are more affective in nature and just as significant. Some of the exciting ways in which authentic programs impact students include:
- Building knowledge that is lasting and meaningful to foster lifelong learning and citizenship.
- Encouraging students to extend and deepen their own knowledge about, interest in, and personal connections to the subject matter at hand.
- Inspiring and empowering students to sustain active participation in certain communities of practice.
- Building confidence in students as legitimate contributors to society.

Opportunity to Connect Students with Current Science in a Professional Field and Teach the True Nature of Science

ENCOURAGE AN INTEREST IN SCIENTIFIC FIELDS:

Part of our mission as educators is to prepare students to be successful in the real world. By introducing and exposing students to professional communities of practice and using examples of real scientific studies being done currently, teachers can present their students with a real world environment where what they learn in the classroom is being put to use outside of school.

TEACHING THE NATURE OF SCIENCE:

Teaching the nature of science moves beyond the simplistic scientific method and seeks to portray science more authentically as a creative, social process of understanding the natural world. This process is modeled in these activities by implementing more inquiry –based instructional methods.

- The simplified, linear scientific method implies that scientific studies follow an unvarying, linear recipe.
  But in reality, in their work, scientists engage in many different activities in many different sequences. Scientific investigations often involve repeating the same steps many times to account for new information and ideas.

- The simplified, linear scientific method implies that science is done by individual scientists working through these steps in isolation.
  But in reality, science depends on interactions within the scientific community. Different people may carry out different parts of the process of science at different times.

- The simplified, linear scientific method implies that science has little room for creativity.
  But in reality, the process of science is exciting, dynamic, and unpredictable. Science relies on creative people thinking outside the box!

When students read about how the real LRO scientists do their work, they are provided evidence that real science works in ways they discussed earlier when solving problems and conducting investigations. By scaffolding students from their own investigation to learning about the investigations of the actual LRO science team, students can deepen their understanding of the Nature of Science and start to see science as a highly creative, dynamic, social and human endeavor.

3. What are the connections to other subject curriculum and standards taught?

Earth Science/Geology

- Comparing and Contrasting the lunar surface with the Earth's surface
- Understanding geological processes that can change the surfaces of both the Earth and the Moon.
- Identifying landforms on the Moon similar to how we study the topography of the Earth.
- Finding locations on maps, interpreting information displayed on maps, and using maps to navigate.

Mathematics

- Estimation of distances and actual sizes from scale drawings, models or maps
- Accurately taking measurement of objects and using those measurements to compare objects
- Use graphs, tables and formulas to interpret and communicate information

Physics

- Applying an understanding of the electromagnetic spectrum: Human eyes only respond to a narrow wavelength of electromagnetic waves – visible light. The other wavelengths of light can be used to detect what is invisible to our eyes.
- Light can be absorbed, redirected, bounced back or allowed to pass through.

Technology/Engineering

- Progress in science and invention depends heavily on what else is happening in society, and history often depends on scientific and technological developments
- Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.
- Engineers use knowledge of science and technology, together with strategies of design, to solve practical problems.
- New technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research.

English Language Arts

- Determine a central idea of a text and how it is conveyed through particular details; provide a summary of the text distinct from personal opinions or judgments.
- Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
- Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

History/Social Studies

- History often involves scientific and technological developments.
- The human ability to influence the course of history comes from its capacity for generating knowledge and developing new technologies
- Important contributions to the advancement of science, mathematics, and technology have been made by different kinds of people, in different cultures, at different times.

4. What are the different ways to teach this curriculum?

Implement Individual Curriculum Component

If time and resources are limited, a single piece of this curriculum can stand-alone. Each lesson or activity was designed to be a complete experience in itself, related to a particular LRO instrument. Note the duration, materials and learning objectives of each lesson to choose the appropriate lesson for your classroom environment and the best fit with your other required curriculum.

Complete Components of Curriculum with Extensions

If time and resources allow, the extension activities sections provide more in depth activities and interactions with the LRO mission and data.

Choose a Topic Strand to Follow Part of Curriculum

Many of these lessons are connected by their content focus and learning goals. They can be taught in sequence, one building upon another to strengthen and reinforce learning goals, as well as increase student engagement and confidence.

There are three main strands:

1. **Lunar Exploration** – These are most appropriate for students who need an introduction to how we explore the Moon, especially in science classes. However, social studies classes can use these as well.
2. **Mapping the Moon** – These lessons are best for taking students who are familiar with the Moon one step further. These lessons involve more in-depth exploration of data and student inquiry. They include many connections to Earth Science and Geology.
3. **Tools of Investigation** – These lessons are more high-level lessons that challenge students to not just explore data but also understand the technology that is used to analyze and collect that data. They include many connections to technology, engineering and physics.

Please note: There are some lessons or activities that overlap between strands because they work well in both. See the full strands on the next few pages.

Strand #1: Lunar Exploration

Introduction: Humans first observed the Moon with their eyes. The development of telescopes enabled us to learn even more about the Moon. Over time, we developed spacecraft that allowed us to learn even more about the Moon and even took people to the moon. As we continue to improve upon our technology and methods of exploration, we continue to develop a more sophisticated understanding of this familiar celestial object.

Teacher Notes: This strand provides students with more background information on lunar science. These lessons focus more on general knowledge about the Moon and provide an overview of lunar exploration both past and present. This strand is good for students who need to understand the process of science and make connections to how spacecraft technology can help us explore.

SUGGESTED ACTIVITIES:

Lunar Exploration Timeline
Lesson plan included

Mapping the Surface of the Moon
Curriculum Guide included (sequence of eight activities)

Making a 3D Model of the Surface of the Moon
Lesson plan included

Making a Model
Lesson plan included

Lunar Image Analysis
Student activity guide included

Question Moon
Lesson plan included

RECOMMENDED RESOURCES:

Lunar Educational Materials for Grades 6-8:
http://lunar.gsfc.nasa.gov/educational-6-8.html

LROC Images and Information:
http://www.lroc.sese.asu.edu

Lunar and Planetary Institute's My Moon:
http://www.lpi.usra.edu/mymoon/

Strand #2: Mapping the Moon

Introduction: In order to better understand and explore the Moon and other rocky planetary bodies, scientists utilize sophisticated technology and methods for investigating features and mapping resources. The LRO spacecraft has seven individual scientific instruments. Many of these instruments help us study specific points of interest and make maps of them on the Moon. These include: high-resolution images of the surface, topographical data, mineralogical composition, possible locations of water ice, levels of atmospheric radiation in particular regions and more.

Teacher Notes: These activities focus on data from specific instruments on the LRO spacecraft and how scientists use that data to create maps of the Moon. Students will learn how technology is fundamental in our ability to map far away places. In the resources section you will find information about the instruments on LRO that are working to map the valuable resources on the Moon. Therefore these lessons can easily tie into other curriculum on geography, cartography, as well as geology and Earth science.

SUGGESTED ACTIVITIES:

Mapping the Surface of the Moon
Curriculum Guide included

Exploring the Moon through Image Analysis
Lesson plan included

Planning a Mission to the Lunar South Pole
Lesson plan included

Making a 3D Model of the Moon's Surface
Lesson plan included

Making a Model
Lesson plan included

RECOMMENDED RESOURCES:

LROC Images and Information:
http://www.lroc.sese.asu.edu

Diviner Videos/Simulations: DVD/Flash Drive included

LAMP Videos/Simulations

Zooniverse's MoonZoo:
www.moonzoo.org

Strand #3: Tools of Investigation

Introduction: In order to understand and explore rocky planetary bodies like our Moon, scientists have developed sophisticated technology and methods to investigate the features and characteristics of those foreign places. The LRO spacecraft has several scientific instruments that help us study specific points of interest about the Moon. These instruments provide us with detailed images of the surface, maps of lunar mineralogy, assist with the detection of water ice, and much more. Technology also plays an essential role in the way scientific data from the Moon is collected, processed and analyzed.

Teacher Notes: These activities allow students to learn the science behind the instruments that are studying the Moon on the LRO spacecraft and how scientists then use that information to inform their understanding. These lessons, by their nature, are interdisciplinary. Students will use math, physics, and technology skills that inform the overall science of LRO.

SUGGESTED ACTIVITIES:

Lunar Image Processing with GIMP
Activity guide included

Lunar Laser Altimetry: Studying the Topography of the Moon
Lesson plan included

Learning about Light
Lesson plan Included

Planning a Mission to the Lunar South Pole
Lesson plan included

Using Radar to Search the Darkness
Student and Teacher guide included with lesson plan

CRaTER
Lesson plan included

How to Detect Cosmic Rays
Lesson plan include

How Cosmic Rays Affect Humans
Lesson plan included

The Discovery and Nature of Cosmic Rays
Lesson plan included

RECOMMENDED RESOURCES:

Scientific Instrument Specific Resources: Available off the LRO site:
http://lro.gsfc.nasa.gov/index.html

See extension suggestions for student image tools in this guide

5. How else can these lessons be used?

This kit can be used for Out-of-School time programming.

AFTER SCHOOL CLUB

If there is little time during the school day for these types of activities they can be modified for an after school environment. It is recommended that students stick to the more hands-on inquiry related lessons in this type of setting.

SCIENCE FAIR

If you have students who would like to use current space science as a topic for their science fair project, introducing them to some of the more in-depth analysis lessons may be a nice introduction to that type of investigation.

SUMMER PROGRAM

This curriculum could lend itself to an in depth summer inquiry experience related to current lunar science. It is recommended that this curriculum be implemented interspersed with some of the other engaging extension activities to really connect students with the current science and the spacecraft technology.

6. How can students be assessed while using the curriculum in this kit?

Assessment tools are embedded into certain lessons.

- Alternative Assessments
- Rubric Scoring
- Observation
- And More…

Alternative Assessments can be applied throughout the curriculum:

Alternative assessments can be any type of assessment that is not a test. In alternative assessments, participants create a response to a question or task. They can include written or oral short answer questions, essays, performance assessments, oral presentations, demonstrations, exhibitions, and portfolios.

7. What additional resources or extension activities are available for students related to the content of this curriculum?

LRO Scientific Instrument Resources

LROC Images and Information:
http://www.lroc.sese.asu.edu

Diviner Videos/Simulations:
http://www.diviner.ucla.edu

LAMP Videos/Simulations:
http://www.boulder.swri.edu/lamp/index.html

LOLA Resources:
http://lunar.gsfc.nasa.gov/lola

CRaTER Resources:
http://crater.sr.unh.edu

LEND Resources:
http://lro.gsfc.nasa.gov/lend.html

Mini–RF Resources:
http://lro.gsfc.nasa.gov/mini-rf.html

Interactive Lunar Maps

LROC Quick Map:
http://target.lroc.asu.edu/da/qmap.html

Google Moon:
http://www.google.com/earth/explore/showcase/moon.html

Student Imaging Tools

LROC Targeting Tool:
http://target.lroc.asu.edu/output/lroc/lroc_page.html

GRAIL Mission MoonKam Project:
https://moonkam.ucsd.edu

Moon Related Citizen Science

Zooniverse's Moon Zoo:
www.moonzoo.org

CosmoQuest's Moon Mappers

Other NASA Lunar Mission Resources

GRAIL:
http://solarsystem.nasa.gov/grail/home.cfm

LADEE:
http://www.nasa.gov/mission_pages/LADEE/main

ARTEMIS:
http://www.nasa.gov/mission_pages/artemis/index.html

Special Public Science Events

International Observe the Moon Night:
www.observethemoonnight.org

8. What additional support is available for teaching lunar concepts and content?

Online Communities:

ZooTeach:

http://teach.zooniverse.org

Professional Development Opportunities:

www.smdeponews.org