MarsBots

A Mars and Robotics Learning Module for Grades 3-4 with activities in Science, Mathematics, Technology, and Language Arts

National Aeronautics and Space Administration (NASA)
Phoenix Mars Scout Mission, The University of Arizona and NASA
NASA’s Science, Engineering, Mathematics, and Aerospace Academy (SEMAA)

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The Phoenix Mars Mission Education and Public Outreach Program
NASA’s Science, Engineering, Mathematics, and Aerospace Academy

Master Teachers:
Mary Lara
Katy Wilkins

Developers:
Andrew Shaner
Lisa Tidwell
Doug Lombardi
Peter Smith

Editors:
Lisa Tidwell
Connie Garcia

Images:
All Images are courtesy of NASA unless otherwise noted.
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Overview
This is a Mars robotics learning module for grades 3 and 4, with extensions for younger students. The module expands the robotics strand of the Mars Public Engagement Program. The objective is for students to experience the hands-on, minds-on activities in the module allowing them to investigate the Martian environment and robotic technologies of space exploration, fostering inspiration to study science, mathematics, and language arts further. The Phoenix Mars Mission Education and Public Outreach (E/PO) program teamed up with NASA’s Science, Engineering, Mathematics and Aerospace Academy (SEMAA) program to develop the MarsBots learning module.

The learning module contains 16 standards-based lessons. These lessons are designed to progress logically from learning about Mars and why scientists and engineers want to explore Mars with robots (lessons 1 through 8) to the fundamental principles of robotics and how these principles are applied to design, construct, and test robotic explorers (lessons 9 through 16).

The MarsBots learning module is integrated to support fundamental concepts and skills in science, mathematics, and language arts. As a unit, the lessons in the module cover 3-4 weeks of classroom time. Lessons may also be used separately as stand-alone activities. The time it will take to complete each lesson is estimated.

MarsBots is designed to be adaptable for no-technology or low-technology school environments. Some of the activities have background resource materials that are freely available over the Internet. For those schools that do not have Internet access, these resources are available on CD-ROM, which may be requested by contacting:

Doug Lombardi
Phoenix Mars Mission
Education and Public Outreach Manager
1415 N. 6th Avenue
Tucson, Arizona 85705
520-626-8973 (voice)
520-626-1973 (fax)

For schools without computers, background resource materials not requiring computers (e.g., books) have been listed with the applicable MarsBots activities. For additional low-technology resources or for more information please contact Doug Lombardi at the above contact information.

A background section along with “italicized teacher notes” throughout the module will give the necessary background information to present the lessons. Typical student questions are anticipated and answered throughout MarsBots. The PowerPoint presentations used in individual lessons include a script with the information needed for the presentations.
Since ancient times, humans have been particularly fond of Mars. But why? All the planets in our Solar System are unique in their own way so why are we so fascinated with Mars? Most students are also very fascinated by the red planet. Ancient peoples were drawn to Mars by its red color, knowing the planet only as a bright point of light in the sky. The word “Mars” comes from the ancient Romans who named the planet after their god of war. The ancient Greeks called it Ares and other ancient cultures had different names for the red planet, as well as, their own unique stories about Mars. For more information on the history of early interest in Mars visit: http://mars.jpl.nasa.gov/mep/history/.

Today, humans are still drawn to Mars, but not just by its red color. We look at Mars, not as a god, but as a sister planet to Earth. Mars and Earth are similar in many ways, yet extremely different in others. But how do we know? How do we know what the similarities and differences are? The answer lies in robotic spacecraft. Since the 1960s, we have sent flyby, orbiter, and lander spacecraft to the red planet in order to study it in better detail. Each spacecraft has or had its own purpose and each contributes or contributed to our current understanding of Mars.
Mars is a cold, dry, dusty world with no liquid water on its surface – no rivers, lakes, or oceans. Global dust storms and whirlwinds, called dust devils, are frequent on the red planet. Surface winds have been recorded at up to 40 meters per second (80 miles per hour). While Mars is only 1/6th the volume of Earth, at present it has the same dry surface area as our ocean-covered planet. However, evidence from robotic spacecraft suggests Mars was very different in the past from the cold dry planet we see today.

Extensive spacecraft exploration of Mars has revealed geologic features that lead us to believe liquid water once flowed on the surface of the red planet. Channels connect high and low areas convincing most scientists that water eroded these channels long ago. Gullies, another geologic feature, provide evidence of past liquid water. Scientists are actively debating the formation of these gullies. One idea suggests that liquid water, flowing underneath a protective layer of snow, may form Martian gullies similar to those on Earth. Some gullies are so recent that they are likely to still be active periodically. However, no evidence exists of liquid water currently flowing on the surface, but evidence of past liquid water on the surface continues to build. Liquid water is important because all known life forms require it to survive.

Although scientists do not believe liquid water currently exists on the Martian surface, they know water exists in the form of ice. Both the north and south polar caps are made of frozen water. The polar caps expand and recede with the Martian seasons just like Earth’s polar caps. Mars has seasons like Earth because its rotational axis is tilted (approximately 25° compared to Earth’s 23.5°) with respect to the plane of its orbit. Since Mars’s year is roughly twice the length of Earth’s year, its seasons are also about twice as long. There are a lot of similarities between Earth and Mars and our understanding of Mars might give us insights into
our home, Earth. The exploration and discoveries on Mars continue with scientists on Earth, robots like the Phoenix Mars Lander, and maybe someday, humans on Mars.

Robots

A robot is a mechanical device which performs automated tasks either according to direct human supervision, a pre-defined program, or a set of general guidelines using artificial intelligence techniques. These tasks either replace or enhance human work, such as in manufacturing, construction or manipulation of heavy or hazardous materials or working in harsh environments like that of space.

Robots are made up of many components including simple machines. Simple machines affect our everyday life and make performing tasks easier. There are six types of simple machines: 1) lever, 2) pulley, 3) inclined plane, 4) screw, 5) wheel and axle, and 6) wedge. For more information on simple machines visit: http://www.grc.nasa.gov/WWW/K-12/Summer_Training/KaeAvenueES/Resource_Chart.html.

Machines made of two or more simple machines are called complex machines. Robots are complex machines made of several simple machines, sensors, power supplies, and electrical actuators. Sensors detect the conditions in the environment around the robot and inform the robot on what actions to take. The simple machines components within a robot allow the robot to perform specified actions. The power supply gives the robot the needed power to operate.

Robots are used on Earth everyday to help make tasks safer and easier. Engineers are designing robots to help commercial farmers harvest crops. Autonomous robots are being used by rescue workers to investigate hazardous areas such as collapsed buildings or harmful chemical environments. Law enforcement officers use robots to investigate and/or disarm bombs. Manufacturers use robots to perform repetitive assembly tasks. More information on robots can be found at: http://prime.jsc.nasa.gov/ROV/types.html. And information on agricultural robotics can be found at: www.peerlessequipment.com.

Throughout the history of space exploration robots have been used to gather information for scientists to study the unique and harsh space environment. In 1964, NASA sent the first robotic missions to Mars, Mariner 3 & 4. These spacecraft took the first up close pictures of Mars changing scientific understanding of the red planet forever. As technology improved so did the robotic Mars missions. The first images returned from Mars were grainy and lacked details. Forty years later, the cameras and scientific instruments sent to Mars are extremely sophisticated and precise giving scientists more
information to uncover the mysteries of Mars. Scientists believe that unlocking the secrets of Mars, using robotic exploration, will help us better understand our own planet, Earth.

**History of Mars Exploration**

Before humans began their robotic exploration of Mars, scientists on Earth used telescopes to observe Mars. Galileo is credited as being the first to observe Mars through a telescope in 1609. A year later in 1610 he wrote a friend saying, “I dare not affirm that I was able to observe the phases of Mars; nevertheless, if I am not mistaken, I believe that I have seen that it is not perfectly round.”

Christiaan Huygens observed Mars with improved telescopes and in 1659 produced a sketch of Mars showing what is believed to be Syrtis Major. Huygens also attempted to determine the length of one day by measuring the rotational period of Mars. He calculated a value of 24 hours, which is very close to the 24 hours and 39 minutes we now know to be Mars’ rotational period. Giovanni Cassini is credited as being the first to observe a polar cap on Mars. The southern polar cap appears on a sketch Cassini made of Mars in 1672.

Over 100 years later, the Earth based exploration of the red planet continued with William Herschel and his 1775 paper on Mars. The paper concluded that because of the planet’s obliquity, or tilt, Mars has season like Earth. In the same paper, he claimed the polar caps were thin layers of ice and snow that changed with the seasons.

In 1877, Giovanni Schiaparelli sketched what he called “canali” (channels) on Mars. Though Schiaparelli never claimed his “canali” to be artificial, he never denied it either. Percival Lowell, an American astronomer, believed that the “canali,” which he translated to “canals” were evidence of intelligent life on Mars. From his observatory in Flagstaff, AZ he made 917 sketches of Mars mapping 437 “canals,” (http://www.lowell.edu/). Lowell insisted until the day he died in 1916 that intelligent beings inhabited Mars. Lowell’s work had two effects; it generated enormous public interest in Mars and it gave planetary science a bad reputation among American astronomers during the first half of the 20th century.
Robotic Missions to Mars

Prior to the first spacecraft exploration of Mars, what was known about Mars was speculation based on drawings made late at night looking through telescopes. By the mid-1900’s most scientists believed that Mars possessed liquid water and vegetation. Observations with telescopes showed dark regions on Mars changing shape, color and size with the seasons which was interpreted as the growth and death of plant life. The first spacecraft to fly near Mars shattered that idea.

Mariner Missions

In 1965, Mariner 4 revealed a Mars that looked similar to the Earth’s Moon. Though the pictures were blurred, the Martian surface was shown to be littered with craters. The Mariner 6 and 7 flybys in 1969 showed much the same thing, but with clearer images. Mariner 4, 6, and 7, however, concentrated on the southern hemisphere of Mars. Mariner 9, the first orbiter, imaged the entire planet and showed a much more geologically diverse Mars than its predecessors.

Global mapping of Mars by Mariner 9 led to the discovery of both Olympus Mons, the largest known volcano in the Solar System, and Valles Marineris, a canyon that dwarfs the Earth’s Grand Canyon by comparison. It is approximately the length of the continental United States. Mariner 9 revealed the global dichotomy of Mars – the older, heavily cratered southern highlands and the younger northern lowlands with volcanoes and volcanic plains. Mariner 9 also discovered many channels appearing to be ancient river beds. While the Mariner program was very successful, it was not without its failures. Mariner 3 never made it to Mars after its shroud failed to jettison and Mariner 8 failed during launch. For more information and images from the Mariner missions visit: http://nssdc.gsfc.nasa.gov/planetary/mars/mariner.html.

Viking Missions

The Viking missions, which followed the Mariner program, were composed of two orbiter-landers. Viking 1 reached Martian orbit on June 19, 1976 with the hope of landing on the surface on July 4. The original landing site was an area where a large channel empties onto a large plain. This was thought to be the best area where liquid water and near-surface ice could be found. However, this landing site was abandoned when Viking arrived because images of the site found that it was too dangerous. Rocks and small craters that could have been hazardous to the lander were observed scattered across the landscape. An alternative landing site was found and the Viking 1 Lander touched down on Mars on July 20, coincidentally on the seventh anniversary of the first Moon landing.
Viking 2 touched down on the opposite side of Mars on September 3, 1976. Besides taking photographs and collecting other science data on the Martian surface, the two landers conducted three biology experiments designed to look for possible signs of life. These experiments discovered unexpected and enigmatic chemical activity in the Martian soil, but provided no clear evidence for the presence of living microorganisms in the soil near the landing sites. To learn more about the Viking missions visit: http://mars.jpl.nasa.gov/missions/past/viking.html.

Russian Missions
While the United States was working on the successful Mariner and Viking programs Russia had a failure-plagued Mars program of its own. Of the fifteen Russian spacecraft bound for Mars between 1960 and 1988 only four spacecraft (Mars 3, Mars 5, Mars 6, and Mars 7) returned any data. And none of the missions met their mission objectives. For more information on Russia’s Mars efforts visit: http://www.russianspaceweb.com/spacecraft_planetary_mars.html.

Mars Observer
Seventeen years after the Viking missions, the United States attempted to return to Mars with the 1992 Mars Observer. Contact with the spacecraft was lost on August 21, 1993, three days before it was scheduled to reach Mars. An investigation concluded the most probable cause of the mishap was a fuel line rupture during fuel tank pressurization which would have caused the spacecraft to spin uncontrollably. To learn more about the Mars Observer visit: http://nssdc.gsfc.nasa.gov/nmc/tmp/1992-063A.html.

Mars Global Surveyor
The United States’ next attempt to reach Mars had a much different fate. Mars Global Surveyor became the first successful mission to the red planet in two decades when it launched November 7, 1996, and entered orbit on September 12, 1997. After an unplanned year and a half spent trimming its orbit from a looping ellipse to a circular track around the planet, the spacecraft began its prime mapping mission in March 1999. It observed the planet from a low-altitude, nearly polar orbit (circling the planet from the north to south poles) over the course of one complete Martian year, the equivalent of nearly two Earth years. Mars Global Surveyor completed its primary mission on January 31, 2001, and is now in an extended mission phase. The mission has studied the entire Martian surface, atmosphere, and interior, and has returned more data about the red planet than all the previous Mars missions combined.

Among key science findings, Global Surveyor has taken pictures of gullies and debris flow features that suggest there may possibly be current sources of liquid water, similar to an aquifer, at or near the surface.
of the planet. Magnetometer readings show that the planet's magnetic field is not globally generated in the planet's core, like Earth, but is localized in particular areas of the crust. New temperature data and close-up images of the Martian moon Phobos show its surface is composed of powdery material at least 1 meter (3 feet) thick, caused by millions of years of meteoroid impacts. Data from the spacecraft's laser altimeter have given scientists their first 3-D views of Mars' north polar ice cap. More Mars Global Surveyor information can be found at: http://mars.jpl.nasa.gov/missions/present/globalsurveyor.html.

Mars Pathfinder

In addition to the launch of the highly successful Mars Global Surveyor, 1996 marked the successful launch of the Mars Pathfinder. On July 4, 1997, Mars Pathfinder, a spacecraft composed of a lander and a rover, landed on the Martian surface. The lander portion of the Pathfinder mission was formally named the “Carl Sagan Memorial Station” after the American astronomer and popular science interpreter. The rover portion of Pathfinder was named Sojourner after American civil rights crusader Sojourner Truth. Both robots outlived their design lives — the lander by nearly three times, and the rover by 12 times.

Mars Pathfinder used an innovative method of directly entering the Martian atmosphere, assisted by a parachute to slow its descent through the thin Martian atmosphere and a giant system of airbags to cushion the impact. The landing site, an ancient flood plain in Mars' northern hemisphere at the mouth of the huge canyon called Ares Vallis, chosen because scientists believed it to be a relatively safe surface to land on and one which contained a scientifically interesting variety of rocks. The expectation was that rocks had been transported by floods from the entire drainage basin of Ares Vallis.

Throughout its life, Mars Pathfinder returned more than 16,500 images from the lander and 550 images from the rover, as well as more than 15 chemical analyses of rocks and soil and extensive data on winds and other weather factors. Findings from the investigations carried out by scientific instruments on both the lander and the rover suggest that Mars was warm and wet at one time in its past, with water existing in its liquid state and an atmosphere much thicker than at present. More information can be found at: http://mars.jpl.nasa.gov/missions/past/pathfinder.html.

Mars Climate Orbiter

On December 11, 1998, the Mars Climate Orbiter began its journey to Mars. The Mars Climate Orbiter was designed to function as an interplanetary weather satellite and a communications station for the Mars Polar Lander. The orbiter carried two science instruments: a replica of an atmospheric sounder the Mars Observer spacecraft lost in 1993, and a new, lightweight color imager combining wide- and medium-angle cameras. Sadly, the spacecraft was lost on arrival to Mars on September 23, 1999. Engineers concluded that the spacecraft entered the planet’s atmosphere too low and probably burned up. More information can be found at: http://mars.jpl.nasa.gov/missions/past/climorb.html.
**Mars Polar Lander**

Less than a month after the Mars Climate Orbiter launched, the Mars Polar Lander lifted-off on its own journey to the red planet. Mars Polar Lander was an ambitious mission to set a spacecraft down on the frigid terrain near the edge of Mars’ south polar cap and dig for water-ice with a robotic arm. Piggybacking on the lander were two small probes called Deep Space 2 designed to impact the Martian surface to test new technologies. Mars Polar Lander and Deep Space 2 were lost at arrival December 3, 1999. An investigation concluded the most probable cause of the failure was a premature shutdown of the engines used to land the spacecraft. More information on the Mars Polar Lander can be found at: [http://mars.jpl.nasa.gov/missions/past/polarlander.html](http://mars.jpl.nasa.gov/missions/past/polarlander.html).

**Mars Odyssey**

2001 Mars Odyssey is an orbiting spacecraft designed to determine the composition of the planet’s surface, to detect water and shallow buried ice, and to study the radiation environment. Mars Odyssey carries three main science instruments to reach these goals: The Gamma Ray Spectrometer, the Thermal Emission Imaging System, and the Mars Radiation Environment Experiment. The spacecraft was launched on April 7, 2001, arrived at Mars on October 24, 2001 and began its science mapping on February 18, 2002 after months of slowly getting into the correct orbit around Mars.

The surface of Mars has long been thought to consist of a mixture of rock, soil and icy material. However, the exact composition of these materials is largely unknown. At the time of this publication, Odyssey is collecting data that are used to identify the minerals present in the soils and rocks on the surface and to study small-scale geologic processes and landing site characteristics. By measuring the amount of hydrogen in the upper meter of soil across the whole planet, the spacecraft is helping researchers understand how much water may be available for future human exploration, as well as give us clues about the planet’s climate history. The orbiter is also collecting data on the radiation environment to help assess potential risks to any future human explorers, and can act as a communications relay for future Mars landers. More information can be found at: [http://mars.jpl.nasa.gov/missions/present/odyssey.html](http://mars.jpl.nasa.gov/missions/present/odyssey.html).
Mars Express

Mars Express, launched in June 2003, is an international effort, which will explore the atmosphere and surface of Mars from polar orbit. NASA is participating in the mission planned by the European Space Agency and the Italian Space Agency. The spacecraft carries a science payload with several European instruments rebuilt after they were lost on the ill-fated Russian Mars '96 mission, as well as a communications relay to support the communication needs of future Mars lander missions. The mission’s main objective is to search for sub-surface water from orbit and deliver a lander to the Martian surface. The lander was named Beagle 2 after the ship in which Charles Darwin set sail to explore uncharted areas of the Earth in 1831. After coming to rest on the surface, Beagle 2 was to perform exobiology and geochemistry research; however, no contact was made with the lander after it was to have reached the Martian surface.

Seven scientific instruments onboard the orbiting spacecraft are studying the Martian atmosphere, the planet’s structure and its geology. In early 2004, the Mars Express science team confirmed that the spacecraft had detected evidence of water-ice all throughout the southern polar cap. Mars Express has also returned many interesting images of Vallis Marineris, and other Martian geologic features. More information and images can be found at: http://mars.jpl.nasa.gov/missions/present/express.html.

Mars Exploration Rovers

In the summer of 2003, two powerful Mars rovers began their voyage to the red planet. They arrived on opposite sides of Mars in January 2004 to roam across the surface and search for clues to the history of water on Mars. The robotic explorers, Spirit and Opportunity, can travel more than 100 meters (about 109 yards) in a Martian day, more than the Mars Pathfinder traveled throughout its entire mission. The rovers arrived on Mars within weeks of each other for a three to five month mission. Due to the vast success of the rovers, the mission has been greatly extended and at the time of this publication the rovers are still roaming the Martian surface after celebrating their one-year Martian anniversary (687 days).

Each rover carries a sophisticated set of instruments that allow it to search for evidence of liquid water that may have been present in the planet’s past. The identical geologist rovers are searching for and characterizing a wide range of rocks and soils. This information will unlock clues to help scientists understand past water (in liquid or ice form) activity on Mars. The landing sites were selected because they appeared to have been affected by liquid water in the past. Gusev Crater, where Spirit landed, is a possible former lakebed in a giant impact crater. Meridiani Planum, the landing site of Opportunity, has mineral deposits (hematite) that suggests Mars had a wet past. The rovers have found several minerals believed to have formed in
the presence of liquid water. More information about the Mars Exploration Rovers can be found at: http://marsrovers.jpl.nasa.gov/overview/.

**Mars Reconnaissance Orbiter**

NASA's Mars Reconnaissance Orbiter (MRO) was launched on August 12, 2005 and will arrive at Mars in March 2006. After several months of aerobraking, a process used to slow the spacecraft down and get it into the desired orbit, the orbiter will begin science operations in November 2006. The robotic orbiter will send extreme close-up images of the Martian terrain, carry a sounder (a type of instrument that measures changes in atmospheric temperature or composition with height) and a radar experiment to find subsurface water. MRO’s goals include looking for safe and scientifically worthy landing sites for future exploration.

Equipped with the most powerful camera ever flown on a planetary exploration mission, the spacecraft will image details of the Martian terrain with extraordinary clarity. While past cameras on Martian orbiters could identify objects no smaller than a large room, the camera on MRO will be able to spot something as small as a breakfast table. This will provide astoundingly detailed views of the geology and structure of Mars and help future landers and rovers find safe landing sites. More information can be found at: http://mars.jpl.nasa.gov/missions/present/2005.html.

**Phoenix Mars Lander**

The Phoenix Mars Mission is the first chosen for NASA's Scout program, a competition to provide smaller, lower-cost spacecraft. Named for the mythological bird, Phoenix uses a spacecraft that was intended for use by 2001’s Mars Surveyor lander prior to its cancellation. It also carries improved variations of instruments that flew on the lost Mars Polar Lander. Phoenix will land in the arctic plains of Mars between 65° and 72°-north latitude, approximately where northern Canada is on Earth. Phoenix will study the history of water on Mars and determine whether the Martian arctic soil can support life.

As a stationary lander, the robotic spacecraft will use a 2 meter (6.5 feet) long arm to be the first to dig into the Martian soil and touch water-ice. Soil and water-ice samples will be delivered to a sophisticated suite of science instruments for analysis. During the course of the three-month mission, Phoenix will take images of the landing site’s geology, seek to update our understanding of Martian atmospheric processes, and analyze soil and ice samples to determine the composition and characteristics of the arctic terrain. For more information on the Phoenix mission, visit: http://phoenix.lpl.arizona.edu.
Scheduled for launch in December of 2009, the Mars Science Laboratory will collect Martian soil samples and rock cores and analyze them on the Martian surface for organic compounds and environmental conditions that could have supported microbial life now or in the past. Mars Science Laboratory is intended to be the first planetary mission to use precision landing techniques, making the landing zone three to five times smaller than previous Mars surface missions. The rover will be twice as long (at approximately 3 meters or 10 feet) and three times as heavy (at approximately 520 kilograms or 1150 pounds) as the Mars Exploration Rovers.

Like the twin rovers, Mars Science Laboratory will have six wheels and cameras mounted on a mast. Unlike the twin rovers, it will carry a laser for vaporizing a thin layer from the surface of a rock and analyzing the elemental composition of the underlying materials. It will then be able to collect and crush rock and soil samples and distribute them to on-board test chambers for chemical analysis. Its design includes a suite of scientific instruments for identifying organic compounds such as proteins, amino acids, and other acids and bases that attach themselves to carbon backbones and are essential to life as we know it. It could also identify features such as atmospheric gases that may be associated with biological activity. More information can be found at: http://mars.jpl.nasa.gov/missions/future/msl.html

For more information about all robotic Mars missions visit: http://mars.jpl.nasa.gov/missions/.
### National Science Education Content Standards: K-4

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### Principles and Standards for School Mathematics: K-4

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### NCTE/IRA Standards for English Language Arts

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Lesson 1: My Place in Space

Purpose: To deepen student understanding about their place in space, starting with their bedroom and extending out to the Milky Way.

Standards

NCTE/IRA Standards for English Language Arts
Standard 1 - Students read a wide range of print and non-print texts...to build an understanding of themselves [and] acquire new information.
Standard 5 - Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.
Standard 12 - Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Science Education Standards
Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.
Science and Technology – Content Standard E
Abilities to distinguish between natural objects and objects made by humans - Some objects occur in nature while others are designed and made by people.

Overview

Your students probably know their address well enough that they can write it down without hesitating. But what about their global and universal addresses? Just like their home addresses, your students can write to describe their place in the universe. Pictures taken by robotic spacecraft and telescopes are helping us better understand our place in the universe. In this activity, students will learn the difference between natural and artificial satellites and use images taken by robotic spacecraft and telescopes to gain an understanding of their place in space.

Understandings

1. Our knowledge and understanding of our Earth and Solar System changes and/or expands as new discoveries are made.
2. Robots gather different information (data) depending on their design and use.
3. Combining the information (data) gathered by a variety of robots gives us a broader and more in-depth understanding of our Earth and Solar System.

Materials

3. Black construction paper 12” x 18", cut in half lengthwise, 2 strips per student
4. Copies of drawing and image sheets for each student (templates included)
5. Glue or glue sticks
6. Pencils
7. Markers, crayons, colored pencils, etc...
8. Ribbon, string or yarn, 27” lengths one per student
9. Index cards, 1 per student

Supplemental Materials

1. A Spacecraft Tour of the Solar System—Slide Show by the Lunar and Planetary Institute
http://www.lpi.usra.edu/publications/slidesets/ss_tour/ss_tour_index.shtml
**Time**
Two 20-minute sessions to read and discuss books
Five 30-minute sessions to cover the 5-step writing process listed below:
1. Pre-Writing Process
2. Drafting
3. Revising
4. Edit
5. Publishing (Final Draft)

**Directions**

1. Read and discuss the two books. *In the discussion, you may wish to ask your students what satellites are. There are two types of satellites, natural and artificial. Natural satellites, like the Moon (satellite of the Earth) and the Earth (satellite of the Sun), occur naturally and are not built by humans. Artificial satellites are built and placed in their locations by humans.*

2. Have students write a friendly letter to a friend or relative, explaining where they live. Follow the 5-step writing process. *You may wish to create your universal address as a class first. Include the following: room number, building, street, town, county, state, country, continent, planet, Solar System, Orion arm of Milky Way galaxy, galaxy, and universe. The students may wish to write their letter with their room and home address.*

3. Show the students the drawing and image sheets. *While showing the students the drawing and image sheets, you may wish to discuss how each drawing made by the students will help describe their place in space.*

Also, *discuss how the images of the U.S. and North America were not taken by humans, but by robotic spacecraft placed into orbit around the Earth and how the galaxy and universe images were taken by robotic telescopes.*

4. Have the students color a map of their room, on the “My Space” block, a picture of their house on the “My House” block, and a picture of themselves on the “Me” block. Have the students design a book cover with the words “My Place in Space by child’s name” on the index card.

5. Have students cut out all of the images and illustrations. *You may wish to find local images of your town/city and state. NASA has satellite images of your city/town and state at http://worldwind.arc.nasa.gov/bluemarble/. The Earth image was taken by the Apollo 17 astronauts. There are no true images of the Solar System, of course, because we cannot send spacecraft out far enough to take such a picture. The galaxy image used in this lesson is the Andromeda galaxy. It was chosen because, like the Solar System, we cannot take a picture of our own galaxy and the Andromeda galaxy is very similar to our own Milky Way galaxy. The picture of the “universe” is the Ultra-Deep Field image taken by the Hubble Space Telescope. This picture shows a tiny fraction of the entire universe, but helps represent the hierarchical structure of the large-scale universe – the universe contains galaxies and galaxy clusters.*
6. Accordion book construction can be done before hand or with the students depending on teacher preference. Fold each construction paper strip in fourths accordion style. Then glue the last panel of the first strip to the first panel of the second strip.

7. Have the students paste all the images to the panels of accordion book. Images should go sequentially from the smallest scale, me, to the largest scale, the Hubble Ultra Deep Field.

8. Punch hole in the right side of cover and thread ribbon, string or yarn through to secure book closed.

Lesson 2: KWL-Mars

Purpose: To probe students’ prior knowledge about Mars, what students wish to learn about Mars, and chart new understandings during the course of the module.

Standards

NCTE/IRA Standards for English Language Arts

Standard 5 - Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 7 - Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

Standard 12 - Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Science Education Standards

Science as Inquiry – Content Standard A

1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.

Overview

Your students have many ideas about Mars and robotic exploration of Mars. Some will be correct others will be incorrect. In this lesson you will review what your students know and what they would like to know. This is an exercise to help present the MarsBots lessons using the knowledge your students bring to the classroom and the knowledge they wish to gain. Revisiting the KWL chart throughout the MarsBots learning module will assess what the students have learned.

Understandings

1. Our knowledge and understanding of our Earth and Solar System changes and/or expands as new discoveries are made.

Materials

1. 3 large sheets of butcher or chart paper
2. Sticky notes (3” x 3”) 4 per student
3. Markers

Time

Initial lesson 45 to 60 minutes
Daily revisit and revision 20 to 30 minutes

Directions

1. Create a large KWL chart for the entire class. Label chart #1 “What I Know About Mars,” #2 “What I Want to Know About Mars,” #3 “What I Have Learned About Mars.” Explain that the charts will be revised as new knowledge and understandings are acquired.

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<thead>
<tr>
<th>What I Know About Mars</th>
<th>What I Want to Know About Mars</th>
<th>What I Have Learned About Mars</th>
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</table>

2. Hand out sticky notes. Ask students to write two things they know about Mars and two things that they want to know about Mars on separate sticky notes.

3. Have each student place the sticky notes with what they know on chart #1 and what they want to know on chart #2.

4. As a class, read each sticky. This is not the time to discuss or debate statements. Discuss what the class wrote down as what they know or want to know. Explain to the class that the sticky notes will move over to chart #3 as they learn about Mars through their activities.
5. Each day before beginning a new MarsBots lesson, revisit charts. Discuss new knowledge, new understandings, and possible misunderstandings. Move sticky notes as needed.
Lesson 3: Play Dough Planets

This lesson is adapted from “3-D Model of the Earth and Moon,” an activity in *The Universe at Your Fingertips*, by the Astronomical Society of the Pacific (http://www.astrosociety.org/education/astro/astropubs/universe.html)

**Purpose:** To demonstrate the size (volume) differences between Earth, Earth’s Moon, and Mars through a hands-on activity.

**Standards**

National Science Education Standards

Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.

Physical Science – Content Standard B
Properties of objects and materials: objects have many observable properties such as size.

**Principles and Standards for School Mathematics**

**Geometry**
1. Analyze characteristics and properties of three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.
2. Use visualization, spatial reasoning, and geometric modeling to solve problems.

**Measurement**
Understand measurable attributes of objects and the units, systems, and processes of measurement.

**Connections**
Recognize and apply mathematics in contexts outside of mathematics.

**Overview**

The size of and distance to Mars is important in planning robotic missions to the red planet. So, how big is Mars anyway? How far away is the planet? The size question is commonly answered in one of two ways. First the answer can come in terms of its diameter, 6,794 km (4,222 miles). Second is in terms of its volume, which is the way to answer the question more accurately. While Mars is roughly one-half the diameter of the Earth’s 12,756 km (7,926 miles) diameter, it is one-sixth the volume of Earth. This means you could fill the Earth with six planets the size of Mars. In this lesson, students will investigate the differences in volume between the Earth, the Moon, and Mars. Students will also estimate the distance between the Earth and the Moon and the Earth and Mars using the scale of the play dough planets’ sizes.

**Understandings**

1. Our knowledge and understanding of our Earth and Solar System changes and/or expands as new discoveries are made.

**Materials**

1. Play dough (see recipe)

**Play Dough Recipe**

1 C flour
½ C salt
1 T oil
2 t cream of tarter
Food coloring
1 C water

Mix ingredients (it is helpful to mix the food coloring with the water before adding to other ingredients) and cook over medium to medium-low heat. Stir constantly until it forms a ball and all “mushy” spots are out. Knead slightly. Store in air-tight container.

**Supplemental Materials**

1. Poster – Earth and Mars: As Different as They Are Alike (JPL 400-935 03/01/01 EW-2001-02-009-JPL)*
2. Mars/Earth Comparison Web Site at JPL (http://mars.jpl.nasa.gov/facts/)

* Can be ordered from the NASA online catalog CORE (http://catalog.core.nasa.gov/) or receive a free teacher copy from http://marsprogram.jpl.nasa.gov/classroom/earthMarsForm.html
Time
One to two hours depending on size of groups and length of discussion.

Directions
1. Have students work in small groups. Instruct them to make a play dough ball about the size of a marble. Explain that this ball is the Moon.

2. Ask children how many “Moons” it would take to make a ball the size of the Mars. After volunteers to share their ideas, tell students that it would take 8 of the Moon-sized balls to make Mars.

3. Have students make and combine 8 of the Moon-size balls to make one “Mars” ball.

4. Ask the students how many “Moons” it would take to make a ball the size of Earth. After several students share their ideas, tell the students it would take 50 Moon-sized balls to make up Earth.

5. The students now have a Moon and a Mars, instruct groups to make combine 50 Moon-size balls, to make “Earth.”

6. Discuss the size differences of the Earth, Mars and the Moon. Don’t let the students mash their “planets” together if you plan on doing the extension.

Extension
Materials
1. Meter tapes, 1 per group
2. String or yarn, approximately 4 yards per group

Time
Fifteen to 20 minutes

Directions
1. After making a “Moon” and “Earth” ask students to estimate how far their Moon should be from their Earth. Have students use meter tapes to measure their estimated distance. Discuss the students’ estimates.

2. Instruct students that the Moon is approximately 9.5 times the distance around the Earth’s equator from the Earth. Have students use string or yarn to wrap around their earth 9.5 times and place the Moon at the proper scale distance.

3. Discuss the accuracy of their estimates.

4. Ask students to estimate the distance from the Earth to Mars. The distance between the Earth and Mars ranges from approximately 72 million km (45 million miles) to 370 million km (230 million miles) or 1800 to 9200 wraps of the yarn around the play dough Earth. The difference is dependent on where Earth and Mars are in their orbits around the Sun. For more information on the distance between the Earth and
Mars visit

http://athena.cornell.edu/kids/tommy_t

5. Discuss the students’ estimates.
Lesson 4: History of Mars Exploration

Purpose: To engage students in the wonder of the science and engineering of space exploration.

Standards

NCTE/IRA Standards for English Language Arts

Standard 5: Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 7: Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

Standard 8: Students use a variety of technological and informational resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12: Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Science Education Standards

Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.

Earth and Space Science – Content Standard D
Objects in the sky: The Sun, Moon, [planets] and stars all have properties, locations, and movements that can be observed and described.

Science and Technology – Content Standard E
1. Understanding about science and technology – scientists and engineers often work together in teams.
2. Understanding about science and technology – tools help scientists make better observations.
3. Abilities to distinguish between natural objects and objects made by humans – some objects occur in nature; others have been designed and made by people to solve human problems.

Overview

Robotic spacecraft have been sent to study Mars up close since Mariner 4 in 1965. Through their successes, and failures, we have greatly expanded our knowledge of Mars (see background materials). In this activity, students will research a past, present, or future mission to Mars and share their findings with the class. The class will then create an overall Mars exploration timeline.

Understandings

1. Robotics are made up of simple machines and sensors.
2. Our knowledge and understanding of our Earth and Solar System changes and/or expands as new discoveries are made.
3. Robots gather different information (data) depending on their design and use.
4. Combining the information (data) gathered by a variety of robots gives us a broader and more in-depth understanding of our Earth and Solar System.

Materials

1. History of Mars Exploration slide show*


10. Other Mars research materials

11. Poster board

12. Crayons, marking pens, colored pencils

Supplemental Materials

1. http://phoenix.lpl.arizona.edu/

*Slide show can be downloaded from the MarsBots Material section of the Phoenix Mission Website in both Microsoft PowerPoint (PPT) or Adobe Acrobat (PDF) format (http://phoenix.lpl.arizona.edu). ***note: the specific address will be available as we make final preparations on the learning module.

Directions

1. Introduce students to Mars robotic exploration using the History of Mars Exploration PowerPoint. Use the script for additional assistance in discussing Mars exploration.

2. Divide the class into groups.

3. Assign each group different missions to Mars past, present and future. (Mariner 4, 6, 7, & 9; Viking 1 & 2; Mars Observer; Mars Pathfinder; Mars Climate Orbiter; Mars Polar Lander/Deep Space 2; Mars Global Surveyor; Mars Odyssey; Mars Express; 2003 Mars Exploration Rovers; Mars Reconnaissance Orbiter; Phoenix Mars Lander, Mars Science Laboratory)

4. Explain to the groups that they are to research the missions and answer the following questions:
   a. When did/will the spacecraft launch and how long was it/will it be operational?
   b. Was the mission a success (did the spacecraft make it to Mars)? Why or why not?
   c. Which type of robot (flyby, orbiter, lander, or rover) is the spacecraft?
   d. Why do you (the group) think this type of robot was/will be used for this mission?
   e. What did the robot discover about Mars? For future missions, what is the purpose of the robot?

5. Along with answering the questions, each group should also find an image of the spacecraft and at least two (2) images of Mars taken by the spacecraft.

6. As each group finishes their research, their pictures and information will be added to a class “History of Mars Exploration Timeline”. Each mission should get its own poster board.
7. Each group will then present their findings to the rest of the class.

3. Crayons/markers/colored pencils

**Supplemental Materials**

1. *All We Did Was Fly to the Moon* by the astronauts, as told by Dick Lattimer, ISBN 0-9611228-0-3

*Slide show can be downloaded from the MarsBots Material section of the Phoenix Mission Website in both Microsoft PowerPoint (PPT) and Adobe Acrobat (PDF) format ([http://phoenix.lpl.arizona.edu](http://phoenix.lpl.arizona.edu)). ***note: we will make the specific address available as we make final preparations on the learning module.*

**Time**

Forty-five to 60 minutes

**Directions**

1. Discuss the story behind the Mars mission patches. *The stories are included with the patch images and in the script of the PowerPoint.*

2. Working in groups, have students design a mission patch for the Phoenix mission or another Mars mission. *You may wish to have students design their own mission and mission patch.*

3. Have groups present their design to the class, telling the story behind their design.

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**For Younger Students**

For younger students you will want to view the resources and decide the best method to disseminate the information on the exploration of Mars and our Solar System. Several sources have been included. As a class create a timeline of the exploration of Mars. Have students draw pictures of each mission. Display timeline in classroom to refer to later during this unit. Make the pictures of the mission easy to remove and have the students assemble the timeline as a game.

**Extension**

**Materials**

1. Mission Patch PowerPoint* or Mission Patch sheets (included)
2. Paper
The Mars Global Surveyor (MGS) patch was designed by Dr. David Seal at the Jet Propulsion Laboratory in Pasadena, CA. Depicted in the foreground is the Global Surveyor orbiter and Mars. The blue streak behind MGS represents the path the spacecraft took to Mars from Earth (the blue ball). Venus and Mercury are shown as yellow and brown balls and the Sun is shown as a yellow star. David added a little personal touch by drawing the two constellations in the background in the shape of his initials. After seeing his design on stickers and T-shirts, David began to feel a little uneasy about his initials on the design. “I had occasional discomfort that this would be ‘found out’ and I would get in some sort of trouble.” Of course, David never got in trouble.

Mission Goals:
1) Image the Martian surface
2) Map the Martian topography
The Pathfinder patch was also designed by David Seal and has some of the same elements seen in the Mars Global Surveyor patch. A landscape of the Martian surface is in the foreground with both the Pathfinder lander (right) and the Sojourner rover (left) operating on the surface. Pathfinder’s flight path is shown as a red streak starting at the Earth, once again a blue ball, and ending at Mars. The Sun is shown as a yellow star in the center of the design. The shape of this patch is an oval because David wanted to give the landscape a more accurate 2-D appearance. The constellations in this patch, however, are not David’s initials. “I did not repeat the trick with the Pathfinder patch...for some reason the initials looked a lot more obvious.”

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<th>Mission Goals:</th>
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<td>1) Demonstrate the use of a parachute and airbag to deliver a science payload to Mars</td>
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<td>2) Demonstrate the mobility and usefulness of a microrover on the surface of Mars</td>
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<td>3) Study the geology and surface morphology of Mars</td>
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<td>4) Study the geochemistry and petrology of soils and rocks</td>
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<td>5) Study the magnetic and mechanical properties of the soil as well as the magnetic properties of the dust</td>
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<tr>
<td>6) Study the atmosphere as well as rotational and orbital dynamics of Mars</td>
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The Mars Odyssey patch was designed by Corby Waste. Corby has also produced much of the artwork of NASA spacecraft. For the Odyssey patch, Corby decided to create a "science logo." In all the artwork Corby was doing for the Odyssey mission, the spacecraft was just seen hovering over Mars. He wanted to create a logo depicting the Odyssey instruments “in action.” On the right side of Mars, the Thermal Imaging System (THEMIS) instrument is taking infrared data. On the left, the Gamma Ray Spectrometer (GRS) is taking gamma ray data. The shape of the logo was “invented” by Corby. “It was something I just like...not round, not square, it was something new.” Within the border of the logo are all the institutions involved with the Odyssey mission: Arizona State University, the Jet Propulsion Laboratory, Johnson Space Center, NASA, Lockheed Martin and The University of Arizona.

To view Corby’s spacecraft artwork, visit: http://www.fourth-millennium.net/mission-artwork/mission-index.html

Mission Goals:
1) Determine the composition of the Martian surface
2) Detect water and shallow buried ice
3) Study the radiation environment
Phoenix Mars Scout Mission
Launching August 2007

The Phoenix Mars Scout Mission logo was designed by Isabelle Tremblay. Isabelle is an engineer with the Canadian Space Agency, one of the Phoenix mission’s engineering partners. The logo depicts Mars in the background with the northern polar cap visible on the upper right of Mars. This symbolizes the destination of the Phoenix lander – the northern arctic plains. In front of Mars is a blending of a blue water droplet, representing NASA’s “follow the water” theme for Mars exploration, and the phoenix bird. According to ancient mythologies, the phoenix bursts into flames upon its death and a new bird rises from the ashes. Similar to the phoenix bird, the Phoenix Mission “raises from the ashes” a spacecraft and instruments from two previous unsuccessful attempts to explore Mars: the Mars Polar Lander and the Mars Surveyor 2001 Lander. Circling the interior design are the names of all the partners involved with the Phoenix mission.

Mission Goals:

1) Study the History of Water in All its Phases
2) Search for Evidence of Habitable Zones and Assess the Biological Potential of the Ice-Soil Boundary
Lesson 5: Space Survey

Purpose: To demonstrate public opinion about space exploration and the use of robotics in space exploration.

Standards

NCTE/IRA Standards for English Language Arts
Standard 7—Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

National Science Education Standards
Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.
Science in Personal and Social Perspectives – Content Standard F
Science and technology in local challenges – new ideas and invention often affect other people; sometimes the effects are good and sometimes they are bad.

Principles and Standards for School Mathematics
Data Analysis and Probability
Formulate questions that can be addressed with data, and collect, organize, and display relevant data to answer them.

Overview
We have gained a great deal of knowledge from decades of robotic exploration and currently, robotic exploration is paving the way for human exploration of Mars. The knowledge gained from the process of developing missions to space and the information sent back from these missions has been invaluable to humans. However, many people believe that the money spent on these space missions should have been spent for Earthly needs like curing illnesses and fighting world hunger. This lesson will introduce your students to different opinions about space exploration and give them an opportunity to strengthen their data analysis skills.

Understandings
1. Robots gather different information (data) depending on their design and use.
2. Combining the information (data) gathered by a variety of robots gives us a broader and more in-depth understanding of our Earth and Solar System.
3. Our knowledge and understanding of our Earth and Solar System changes and/or expands as new discoveries are made.

Materials
1. Copies of “Space Survey” enough for each child to interview 4-5 adults.
2. Butcher paper

Supplemental Materials
1. NASA’s Vision for Space Exploration Web Site (http://www.nasa.gov/missions/solar_system/explore_main.html)

Time
Thirty minutes class time to introduce activity
Data collection time at teacher discretion
Forty-five minutes for data compilation and analysis

Directions
1. Discuss with the class that people all have different views and ideas. Share with them what a survey is and how it can be useful.
2. Decide as a group how many people each student will be surveying.
3. As a group, decide what the last two questions should be on the survey.
4. Set a date for all surveys to be returned and tallied.
5. Once surveys have been collected help show the students how to tally the results. *This can be done on a class chart or broken up in some other manner.* *Students can work in groups.*

6. Students create a graph or pie chart to show survey results.

**For Younger Students**
For younger students you may want to just survey them and work through the process of posting the results. The students could then come up with two questions of their own or use the ones provided to survey their parents. Then work them through the process of tallying the results and creating a graph or pie chart.

**Extension**
Create survey for other topics in your school.
## Space Survey

What do you, your family, friends and neighbors think about space? Should our government spend a lot of money and get to Mars as quickly as we can? Or are there more important things to spend money on in our country? Find out by taking a survey.

First you will want to find someone to survey. Then ask the person each of the questions below (write in two other questions of your own or ones that your classmates have chosen) and use tally marks under “Yes” or “No”. Record the next person’s answers in the same places. When you have finished, add up your tallies to get your results. Share your findings with your class.

<table>
<thead>
<tr>
<th>QUESTIONS</th>
<th>YES</th>
<th>NO</th>
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</thead>
<tbody>
<tr>
<td>1. Was sending a human to the Moon a good thing?</td>
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<tr>
<td>2. Should NASA build a base on the Moon before going to Mars?</td>
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<tr>
<td>3. Do you think NASA should send astronauts to Mars?</td>
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Lesson 6: Mars Match Game
This lesson is adapted from MarsQuest Online’s “Earth or Mars?” produced by the Space Science Institute (http://www.marsquestonline.org/tour/welcome/earthormars/index.html).

Purpose: To deepen student understanding of Mars, Mars exploration and the similarities and differences between the Earth and Mars.

Standards
NCTE/IRA Standards for English Language Arts
Standard 5: Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

National Science Education Standards
Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.
Physical Science – Content Standard B
Properties of objects and materials- objects have many observable properties such as size, and color.
Earth and Space Science – Content Standard D
Properties of Earth materials- Earth materials are solid rocks and soils, water, and the gases of the atmosphere.

Principles and Standards for School Mathematics
Measurement
1. Understand measurable attributes of objects and the units, systems, and processes of measurement.
2. Apply appropriate techniques and tools to determine measurements.

Connections
Recognize and apply mathematics in contexts outside of mathematics.

Overview
Of all the planets in the Solar System, Mars is the most like Earth. Though it currently has no liquid water flowing on the surface, there is evidence that suggests Mars was once warmer and wetter like the Earth. Geologic features revealed by orbiting robotic spacecraft, and secrets uncovered in Martian rocks by robotic rovers on the ground show that long ago Mars and Earth could have looked very much alike.

In this activity, students will compare physical properties of Earth to those of Mars. Students will also become planetary scientists as they investigate images of features on Mars and try to find similar features in images of the Earth.

Understandings
1. Our knowledge and understanding of our Earth and Solar System changes and/or expands as new discoveries are made.
2. Robots gather different information (data) depending on their design and use.
3. Combining the information (data) gathered by a variety of robots gives us a broader and more in-depth understanding of our Earth and Solar System.

Materials
1. Earth vs Mars slide show*
2. Earth/Mars game cards (included)
3. Earth/Mars comparison worksheet (included)
4. Mars Match Game Answer Key, Script (included)

*Slide show can be downloaded from the MarsBots Material section of the Phoenix Mission Website in both Microsoft PowerPoint (PPT) or Adobe Acrobat (PDF) format (http://phoenix.lpl.arizona.edu). **note: we will make the specific address available as we make final preparations on the learning module.

Time
Ten to 30 minutes for PowerPoint depending on length of class discussion
Thirty to 45 minutes for activity and discussion

Directions
1. Show students the Earth vs. Mars slide show discussing the various differences between Earth and Mars. Use the script provided in the notes section of the PowerPoint to assist you with the
discussion. (Select “notes page” print option to print a copy of the PowerPoint presentation notes)

2. After discussing differences, hand out the Earth/Mars comparison images. Each image from Mars has a matching image of Earth. Students are to look at each image from Mars and identify the image from Earth that most resembles the image from Mars. Have students work in pairs for this activity.

3. Hand out the Earth/Mars Comparison worksheets to help guide students as they make their choices.

4. Talk about how scientists compare features found on the Earth, known to be formed by liquid water, with features on Mars. While some features seen on Mars could be explained by other processes (e.g. lava flows) others were almost certainly formed by water a long time ago. See the Mars section of the background information at the front of the MarsBots learning module.

5. Discuss how robotic spacecraft have given us these images of Mars that allow us to see these similarities and differences.
Earth/Mars Comparison game cards

Print pages 37-48 double sided.
Cyclones are large storms on Earth.

Rivers can change the direction they flow.
This crater is almost 1 mile across.

The island in this river did not erode as much as the land around it.

This island is up to 18 miles across and 1 mile deep.

Small streams come together to make one big river.
Rivers end in lakes or oceans and form deltas.

The Grand Canyon is 280 miles long.

The island of Lanai (Hawaii) is a shield volcano.

Both the north and south polar caps of Earth are locked in the southern cap.

Most of Earth's fresh water is made of frozen water.
Gullies form on the slopes of hills where there is liquid water.
# Earth/Mars Comparison Worksheet

Use this worksheet to record your observations of the Earth and Mars images. Identify which Mars and Earth images you are comparing by writing the letter of the image on the appropriate line. Next, describe in words both the Earth and Mars image. Using your descriptions of each image, explain why you think the Mars image is a good comparison to the Earth image.

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<thead>
<tr>
<th>Mars Image ____</th>
<th>Earth Image ____</th>
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</table>
Mars Match Game Answer Key, Script

M-01, E-05 - Tributaries

This feature seen on Mars resembles a series of **tributaries** – small streams or rivers that combine to form larger streams and/or rivers. On Earth, smaller rivers or streams combine into larger and larger rivers. Eventually all these rivers become one single river and empty into a larger body of water such as a lake or an ocean.

M-02, E-10 – River Delta

This feature on Mars resembles a **river delta**. River deltas on Earth form where rivers empty into lakes or oceans. Deltas form as sand and other particles are dropped by the river into the lake or ocean. Over time, the sand and particles build up, eventually blocking the flow of the river. The river then re-directs its flow into the lake or ocean and the process starts over again. This image from Mars is considered strong evidence that liquid water once flowed on the surface of Mars for extended periods of time.

M-03, E-01 – Meandering River

This feature on Mars can be seen in Mars image 03. It is a close-up focusing on what looks like a **meandering river** that changed its direction of flow. The feature can be seen just to the left of center in Mars image 02. On the Earth, rivers redirect themselves over time as seen in the Earth image 01 of the Amazon River. The light blue is the current path of the river - the darker blue next to it shows the path the river took in the past. The same pattern can be seen in the Mars image 03 where the earlier path the water took is cut by the later path.

M-04, E-11 – Gullies

Gullies, like those in Mars image 04, are typically found in mid-latitude regions of Mars. They can be seen in the sides of hills and the walls of craters. Gullies seen on the Earth are typically formed by flowing water, although they may also be formed by landslides. One of the most debated topics in Mars science is whether or not gullies on Mars were formed by liquid water or landslides.

M-05, E-09 – Polar Ice Caps

Like the Earth, Mars has polar ice caps. Mars image 05 shows the northern polar ice cap with its distinct spiral shape. Like the Earth’s ice caps, Mars’ north and south ice cap are made of frozen water. However, during their respective winters, both the north and south ice cap are covered by a layer of carbon dioxide ice, or dry ice.

M-06, E-03 - Canyons

Mars image 06 shows a perspective of Coprates Chasma. Coprates Chasma is part of the Valles Marineris canyon system. Valles Marineris is as deep as 10 km (6 miles) and as wide as 600 km (372 miles)! In comparison, the Grand Canyon has an average depth of 1.6 km (1 mile) and a maximum width of 29 km (18 miles).
**M-07, E-08 - Canyons**

The Mars 07 image shows a view of Valles Marineris as seen from orbit around Mars. Valles Marineris stretches over 4000 km (~2500 miles) across the surface of Mars. If you were to put Valles Marineris on the Earth it would stretch across the entire United States! The Grand Canyon in comparison is just 446 km (277 miles) in length.

**M-08, E-07 - Volcanoes**

Mars has volcanoes like the Earth. Olympus Mons is a type of volcano called a shield volcano. The Hawaiian Islands and the Galapagos Islands are examples of shield volcanoes on the Earth. Most people think of volcanoes as steep, explosive mountains like Mt. St. Helens in Washington. Shield volcanoes, however, are broad, dome-shaped volcanoes that erupt rather quietly. Instead of erupting violently like an explosion, lava oozes out of vent located at and near the top of the volcano then flows down the slopes. Olympus Mons is the largest known volcano in the Solar System. The base of the volcano is as big as the state of Arizona and the top of the volcano is over 26 km (16 miles) high!

**M-09, E-06 - Craters**

Craters are formed when asteroids or comets slam into another body leaving a large hole in the ground. Craters can be seen scattered on Mars, particularly in the southern hemisphere, and on the Moon, Mercury, and the moons of the outer planets. There are craters on the Earth too, but not as many as we see on other planets like Mars. Why? *Ask the class why they think we don’t see many craters on the Earth.* The Earth has been hit just as many times as the Moon, Mars, and Mercury. The difference is that Earth has weather that has eroded away many craters. Meteor crater in Arizona is the best preserved crater on Earth. This crater is small compared to craters on other bodies in the Solar System. It is only 1.2 km (0.75 miles) across. Gusev crater on Mars, for example, is 150 km (93 miles) wide.

**M-10, E-02 – Storms**

Cyclonic storms exist on both Earth and Mars. Examples of cyclonic storms on the Earth are hurricanes and tornadoes. Cyclonic storms on Mars are not hurricanes or tornadoes but very large dust storms which can engulf the entire planet.

**M-11, E-04 – Streamlined Islands**

The Mars 11 image shows an area where streamlined islands are believed to have been carved by a catastrophic flood. Water flowed from the upper right of the image to the lower left. These same types of features are seen on the Earth like in the Earth 04 image from the Amazon River.
Lesson 7: Touchdown Mars!

Purpose: To facilitate and engage students’ imagination about the processes and skills needed to explore our Solar System.

Standards

NCTE/IRA Standards for English Language Arts

Standard 1 - Students read a wide range of print and non-print texts...to build and understanding of themselves [and] acquire new information.

Standard 5 - Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 12 - Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Science Education Standards

Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.

Science and Technology – Content Standard E
1. Understanding about science and technology – scientists and engineers often work together in teams.
2. Understanding about science and technology – tools help scientists make better observations.

Overview

Robotic exploration is important to our understanding of Mars and the Solar System. It is through knowledge gained from robotic exploration that we will be able to someday send humans to the red planet. This lesson will give students an opportunity to learn basic information about Mars and space exploration and give them an opportunity to practice their writing skills.

Understandings

1. Simple machines affect our everyday lives.
2. Simple machines make tasks easier.
3. Our knowledge and understanding of our Earth and Solar System changes and/or expands as new discoveries are made.

Materials

2. Paper, pencils, crayons, & colored pencils

Time

Thirty to 60 minutes to read and discuss book
Thirty to 60 minutes to construct book

Directions

1. Read and discuss the book.
2. As a class discuss how to create an ABC book on Mars based on the students’ current level of Mars knowledge. You may wish to re-visit the PowerPoint presentation from Lesson 4: History of Mars Exploration.
3. Have students work individually or in pairs to create their own Mars ABC book following the example of Touchdown Mars!
You can have the students display their books in the school library or share their books with younger students.

For Younger Students

For younger students you may want to create a class ABC book.
Lesson 8: Blind Mice

This lesson is adapted from "Strange New Planet," an activity in The Mars Activity Book, by the Mars Education Program at Arizona State University (http://marsed.asu.edu/pages/pdfs/MSIP-MarsActivities.pdf)

Purpose: To expand student understanding that combining information gathered by a variety of robots gives us a more comprehensive understanding of our Solar System.

Standards

**NCTE/IRA Standards for English Language Arts**

**Standard 1** - Students read a wide range of print and non-print texts...to build and understanding of themselves [and] acquire new information.

**Standard 5** - Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

**Standard 12** - Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

**National Science Education Standards**

**Science as Inquiry – Content Standard A**

1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.

**Physical Science – Content Standard B**

1. Properties of objects and materials- objects have many observable properties such as size, shape, and color.
2. Position and motion of objects- the position of an object can be described by locating it relative to another object or the background.

**Science and Technology – Content Standard E**

1. Understanding about science and technology – scientists and engineers often work together in teams.
2. Understanding about science and technology – tools help scientists make better observations.
3. Abilities to distinguish between natural objects and objects made by humans – some objects occur in nature; others have been designed and made by people to solve human problems.

Overview

Our knowledge of Mars increases with every robotic spacecraft we send to investigate the red planet. Early ground-based telescopic observations by Cassini, Schiaparelli, Lowell and others showed dark regions on Mars (that until 1965 were believed to be vegetation) and polar caps, changing in size with the seasons. Ground-based telescopic observations also gave early estimates of the rotational period of Mars. Some observations led to the speculation (and strong belief by some) that intelligent life existed on Mars. However, the past 40 years of exploring Mars with robotic spacecraft flying by, orbiting and landing on Mars has shown us a cold, dry, desert world with no sign of liquid water, vegetation, or intelligent life. Advances in technology have allowed us to build better robotic spacecraft that have helped us gain a better understanding of Mars and the Solar System. In this activity, students will gain an understanding of how knowledge of planets and their characteristics increases with the use of better technology.

Part One of the lesson will address how man uses previous knowledge to understand and interpret new situations. Often our understandings must be altered to accommodate new observations and findings. Part Two of this lesson will help the students understand that observations from far away (ground-based telescopes) can provide information about the entire planet, but with little detail. Flyby and orbiter observations provide information about the planet as a whole but still leave many unanswered questions. Landers give us greater detail but only of the selected landing site.

Understandings

1. Robots gather different information (data) depending on their design and use.
2. Combining the information (data) gathered by a variety of robots gives us a broader and more in-depth understanding of our Earth and Solar System.
3. Our knowledge and understanding of our Earth and Solar System changes and/or expands as new discoveries are made.

Materials
2. Viewers (one per pair of students): paper towel tubes with 3 x 3 inch blue cellophane squares attached to the end with rubber bands
3. One or more “planet(s)” formed out of different colors of play dough (see recipe in Lesson 3: Play dough Planets). Create land formations (volcanoes, riverbeds, and craters) and add decorations (glitter, pipe cleaners, beads, stickers, etc.) to simulate geologic and inhabitant features.
4. A small towel to cover each of the “planets”

Time
Preparation time for forming “planets” and making Viewers: 45 minutes
Part One: 20-30 minutes
Part Two: 45-60 minutes

Directions
Part One
1. Read Seven Blind Mice to the students.

2. Discuss what each mouse thought and why the combined opinion was more accurate.

3. Extend the discussion to our exploration of other worlds and the concept of combining a variety of information (data) to achieve a better idea of what the planet is like. Discuss how the ancient Greeks could only observe Mars as a point of light that moved across the sky. It was not until Galileo first observed Mars through a telescope that humans began to see Mars as more than a point of light.

Part Two
1. Background information: Over 4,000 years ago civilizations were observing Mars with only their eyes. At first people believed that Mars was just a red star. Then after observing that the star moved they started calling it a planet, which is Greek for wanderer. The invention of the telescope in the 1600s gave astronomers a better view of Mars as a planet. However, ground-based observations were restricted by the incredible distance separating Earth and Mars and the effect of viewing through the Earth’s atmosphere. Many people believed that there was a detailed canal system and some strongly believed these canals proved the existence of intelligent life on the red planet. Space-based telescopes, such as, the Hubble Space Telescope gives researchers better views from Earth-orbit by being outside of the Earth’s atmosphere but there is still an incredible distance of at least 55 million kilometers (35 million miles) between the two planets. In 1964, NASA launched a robot, Mariner 4 to fly by Mars giving scientists their first up-close look at the red planet. Mariner 9 was the first spacecraft to orbit Mars sending back many pictures. By now scientists realized that Mars was a cold, dry, desert world.
Viking 1 was the first robot to land on another planet successfully. In 1975, Viking touched down on the Martian surface giving scientists even more information. Current robotic missions to Mars are continually improving our knowledge and understanding of Mars, helping give us a better picture of the “elephant” of Mars.

2. Discuss with the students what type of information we receive from ground-based telescope observations, orbiting telescope observations, flybys, orbiters and landers and how all types of robotic spacecraft have given us more knowledge and a better understanding of Mars and the rest of our Solar System. You can tie this back to the Seven Blind Mice book.

3. Pair up students into observing teams. Explain to students that they are Scientists who are observing a newly discovered planet in our Solar System.

4. **Role Play** Teacher: “Your observing team has written a proposal and has been approved for observing time at a ground-based telescope. Your team will be recording its findings in preparation for future exploration funding proposals.”

5. Have the students simulate ground-based telescopic observations. Arrange students in pairs on opposite side of room from the planet and distribute one “viewer” to each pair. One student will be the Observer and the other will be the recording Scientist. **Discuss with the students how the Earth’s atmosphere affects such observations.** The Earth’s atmosphere is a layer of gases that surrounds the Earth which regulates temperatures and blocks the Earth from harmful radiation, which is good for protecting life on Earth. However, the atmosphere blurs images and makes it difficult to study objects in space.

6. Have all the students turn their backs to the “planet.” Uncover the planet and have the Observer turn around and view the planet through their viewer for 15 seconds. Cover the planet and have the Observer describe their observations to the Scientist. The Scientist records the observations. Students may choose to record observations with words and/or pictures.

7. Students reverse roles and repeat step 6.

8. Discuss observations. What knowledge was gained about the planet?

9. **Role Play** Teacher: “Congratulations! Because of your fine ground-based observations your team has been approved for time on a space-based telescope.”

10. Have students resume original roles, repeat steps 6 & 7 without cellophane. This is a simulation of observations made from a space-based telescope such
as Hubble Space Telescope. Have scientists record the observations.

11. Discuss observations. Was any additional knowledge gained about the planet? Can you compare and contrast the ground-based and space-based observations? **Review with the students the effect of the atmosphere in telescopic observations.**

12. **Role Play** Teacher: “Fantastic work! Your team’s initial observations provided new knowledge about this unknown planet and have generated the quest for additional knowledge. NASA has agreed to fund a flyby!”

13. Have students resume original roles. Have Observers line up and prepare for a planetary flyby. Scientists should turn their backs to the covered planet. Explain to the Observers that they will be following each other as they pass by the new planet. They will be observing the new planet through their viewing tubes. This simulates the view of the spacecraft’s camera. After all Observers have “flown by” the planet, cover and have them relay to the Scientists what they observed for the Scientist to record.


15. Discuss findings. Did you gain any additional knowledge from this flyby? Would this information have been gained through a telescope observation? Did your flyby observation cause you to wonder more about this new planet? How could additional knowledge be gained about this planet?

16. **Role Play** Teacher: “Outstanding teamwork! Once again NASA has agreed to fund an additional mission. Your team will be orbiting the new planet.”

17. Students resume original roles. Have Observers line up and prepare for a planetary orbit. Scientists will turn their backs to the covered planet. Explain to the Observers that they will be following each other as they circle the new planet. They will continue to view the planet through the viewing tubes. Once they complete one orbit they are to return to the Scientist and relay their findings for the Scientist to record.

18. Students reverse roles and repeat step 17.

19. Discuss findings. Did you gain any new knowledge? Did this observation generate any new questions? How did the flyby and orbital observations differ?

20. **Role Play** Teacher: “Newsflash! We interrupt this activity for a NASA update. NASA has selected your team to send a lander to this new planet. Your team must select a landing location based on your previous observations. Keep in mind that if your lander crashes the mission is lost.”
21. Students resume original roles. Have Observers line up and prepare to land on the planet. Give teams time to select their landing site. Scientists will turn their backs to the covered planet. Observers will need to approach the covered planet one at a time, indicate their chosen landing site and view it through the viewer. Only uncover that portion of the planet and allow ten seconds for viewing. Return to the Scientist and relay findings for the Scientist to record.

22. Students reverse roles and repeat step 21.

23. Discuss findings. Did you gain additional knowledge about the planet? What are the advantages/disadvantages of a lander?

24. Lead the students in a discussion giving pros and cons of each of these forms of observation/exploration. Help the students understand the importance of using a variety of observation/exploration methods to gain a broader and more in-depth understanding of our Earth and Solar System.

**Extension**

Create more than one planet for this lesson.

After steps 8, 11, 15, and 19, teams could write a proposal to fund further exploration of the new planet.

Students could write a persuasive article in favor of funding future NASA missions.
Lesson 9: KWL-Robotics

Purpose: To probe students’ prior knowledge about robotics, what students wish to learn about robotics, and chart new understandings during the course of the module.

Standards

- NCTE/IRA Standards for English Language Arts
  - Standard 1: Students read a wide range of print and non-print texts...to build and understanding of themselves (and) acquire new information.
  - Standard 5: Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.
  - Standard 12: Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

- National Science Education Standards
  - Science as Inquiry – Content Standard A
    - 1. Abilities necessary to do scientific inquiry.
    - 2. Understanding about scientific inquiry.

Overview

Your students have many ideas about robotic exploration. Some will be correct others will be incorrect. In this lesson you will review what your students know and what they would like to know. This is an exercise to help present the MarsBots lessons using the knowledge your students bring to the classroom and the knowledge they wish to gain. Revisiting the KWL chart throughout the MarsBots learning module will assess what the students have learned.

Understandings

1. Robots are made up of simple machines.
2. Robots gather different information (data) depending on their design and use.

Materials

1. 3 large sheets of butcher or chart paper
2. Sticky notes (3” x 3”) 4 per student
3. Markers

Time

Initial lesson 45 to 60 minutes
Daily revisit and revision 20 to 30 minutes

Directions

1. Create a large KWL chart for the entire class. Label chart #1 “What I Know About Robots,” #2 “What I Want to Know About Robots,” #3 “What I Have Learned About Robots.” Explain that the charts will be revised as knowledge and understandings are acquired.

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<th>What I Want to Know About Robots</th>
<th>What I Have Learned About Robots</th>
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2. Hand out sticky notes. Ask each student to write down two things they know about and two things that they want to know about robots on separate sticky notes.

3. Have each student place the sticky notes with what they know on chart #1 and what they want to know on chart #2.

4. As a class, read each sticky. This is not the time to discuss or debate statements. Discuss what the class wrote down as what they know or want to know. Explain to the class that the sticky notes will move over to chart #3 as they learn about robots through their activities.
5. Each day before beginning a new MarsBots lesson, revisit charts. *Discuss new knowledge, new understandings, and possible misunderstandings. Move sticky notes as needed.*
Lesson 10: Simple Machines

Purpose: To expand student understanding that simple machines affect our everyday lives and make tasks easier.

Standards

NCTE/IRA Standards for English Language Arts

Standard 7- Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

Standard 8- Students use a variety of technological and informational resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12- Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Science Education Standards

Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.

Physical Science – Content Standard B
1. Position and motion of an object – an object’s motion can be described by tracing and measuring its position over time.
2. Position and motion of an object – the position and motion of objects can be changed by pushing or pulling.

Science and Technology – Content Standard E
Understanding about science and technology – people have always had problems and invented tools and techniques (ways of doing something) to solve problems.

Principles and Standards for School Mathematics

Representation
Create and use representations to organize, record, and communicate ideas.

Overview

Although robots are complex, the core of their operations lie in simple machines. There are six types of simple machines: 1) lever, 2) pulley, 3) inclined plane, 4) screw, 5) wheel and axle, and 6) wedge. Machines made of two or more simple machines are called complex machines.

A Rube Goldberg Machine is a type of complex machine. These machines are made up of several simple machines and simplify performing a task. However, Rube Goldberg Machines illustrate how we sometimes put much more effort into accomplishing a simple task than is necessary (visit http://www.rube-goldberg.com/html/gallery.htm for more information on Rube Goldberg Machines).

Robots are even more complex because they combine machines and electronic sensors. Sensors detect the conditions in the environment around the robot and inform the robot on what actions to take. The simple machines components within a robot allow the robot to perform the actions. In this lesson, students will gain an understanding of simple machines and how they may be used in our everyday lives. Students will also have an opportunity to design a Rube Goldberg Machine of their own.

Understandings

1. Simple machines make tasks easier.
2. Simple machines affect our everyday lives.
3. Robots are made up of simple machines.

Materials

2. Paper
3. Pencils, pens, crayons, and/or markers

Time

Fifteen minutes for explanations
Forty-five minutes for activities

Directions

1. Discuss with the class the six types of simple machines: lever, pulley, wheel and axle, wedge, screw, and inclined
planes. Discuss with the class how each type may be used in everyday life.

2. Have the class walk around the classroom asking them to identify simple machines they encounter in the classroom. Have the students create a chart on which they record the object and what type of simple machine it is.

<table>
<thead>
<tr>
<th>Lever</th>
<th>Pulley</th>
<th>Wheel &amp; Axle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wedge</td>
<td>Screw</td>
<td>Inclined Plane</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


4. Have the students design their own Rube Goldberg Machine that will help them perform an everyday task. Students should draw their Rube Goldberg device on a sheet of paper. The drawing should include an explanation of what the device is trying to accomplish and how the device will operate. If possible, students should include a list of materials that would be used to create the device.

Extension
Have students build their Rube Goldberg Machine either in class or at home and share it with the class. If this extension is done in class you will need to provide materials or have the students bring building materials from home.
Lesson 11: Program It!

This lesson is adapted from the “Write It, Do It” event, which is part of Science Olympiad.
(http://www.scioly.org/eventpages/writeitdoit.html)

Purpose: To introduce students to the fundamental communication skills necessary for successful robotic programming.

Standards

NCTE/IRA Standards for English Language Arts

Standard 4- Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a wide variety of audiences and for different purposes.

Standard 5- Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 12- Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Science Education Standards

Science as Inquiry – Content Standard A

1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.

Science and Technology – Content Standard E

Abilities of technological design – student abilities should include oral, written, and pictorial communication of the design process.

Overview

Though it is still difficult, scientists and engineers have learned how to operate a robotic spacecraft on the surface of Mars from Earth. Unfortunately, due to the vast distance between the Earth and Mars spacecraft cannot be operated in real-time like a remote controlled car on Earth. It takes commands approximately 10 to 15 minutes to travel from Earth to Mars and another 10 to 15 minutes to get responses from the spacecraft back to Earth. Mission planners must write a sequence of specific commands on Earth to send to the spacecraft on Mars. Mission planners must be very careful and very specific about what they want the spacecraft to do if they are to be successful. Future plans for sending humans to Mars include sending robots first to construct the habitats where humans will live and work. In this activity, students will experience what it is like to give specific commands to construct something with their partners.

Understandings

1. Robots gather different information (data) depending on their design and use.

Materials

1. Two (2) sets per pair of students of Lego’s, pattern blocks, or anything that can be used to build. Both sets for a group should have identical building materials.

2. Divider to hide work from partner.

Time

Ten minutes for explanations
Ten minutes for each student in the teams
Five minutes for discussion

Directions

1. Pair students together and hand out building materials.

2. Discuss with the students how NASA is planning to use robots to construct the places where humans will live and work when they eventually arrive on Mars. Discuss that humans will have to command the robots on Mars from Earth.

3. Tell students that one student is the Engineer on Earth designing something using the materials given to them, which will be built on Mars by their partner robot. The other student will act as the Robot on Mars to reconstruct what the first student built, using only
commands given to them from the Engineer.

4. The divider should be placed between students to hide the constructed object from view.

5. Once the Engineer has built the object, the Robot must build the same object without looking at the original, using only commands from the Engineer. The Engineer, however, cannot assist the Robot by any means other than confirming the correct placement of a piece. The Engineer may not touch the Robots object or tell them something is wrong.

6. Once the object is finished being rebuilt, have the students switch jobs.

7. Discuss the difficulties of building something using only the commands of the Engineer on Earth.
Lesson 12: The Phoenix Mission: Uncovering Martian Water

Purpose: To increase student knowledge about the Phoenix Mars Lander’s science mission to use robotic technology to uncover water on Mars.

Standards

NCTE/IRA Standards for English Language Arts

Standard 12- Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Science Education Standards

Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.

Physical Science – Content Standard B
1. Properties of objects and materials – objects have many observable properties, such as size, that can be measured using tools.
2. Properties of objects and materials – materials can exist in different states—solid, liquid, and gas. Some common materials, such as water, can be changed from one state to another by heating and cooling.

Earth and Space Science – Content Standard D
1. Properties of Earth materials – soils have properties of color and texture, and capacity to retain water.

Overview

What is in the Martian arctic soil? That is what Phoenix is going to investigate. Using a robotic arm and a suite of instruments, the Phoenix Lander will dig down to (1) study the history of water in all its phases and (2) search for evidence of a habitable zone and evaluate the biological potential of the ice-soil boundary. Like other robots sent to study Mars, the Phoenix lander is designed to perform certain tasks unique to the mission. In this activity, students will be introduced to the mission and conduct some simple experiments to learn about the important properties of water and water-ice.

Understandings

1. Water is a special compound, which is essential to life on Earth and may be the key to discovering life beyond Earth.
2. Robots gather different information (data) depending on their design and use.
3. Combining the information (data) gathered by a variety of robots gives us a broader and more in-depth understanding of our Earth and Solar System.

Materials

2. Hand lens or magnifying glass (1 per student)
3. Paper plates (1 per student)
4. Copies of the Soil and Icicle Observations sheets (included)
5. Two different types of soil samples labeled Sample A and Sample B, Sand or small grain gravel are good types of soil samples that can be analyzed with small hand lenses. Pick one type of soil for Sample A and another type of soil for Sample B. Soil samples can be dug up from the local school yard or surrounding area. Try to avoid getting large amounts of biological material (i.e., leaves and roots) in the soil samples.
6. Soil/Water icicles (1 per group), Make the Soil/Water Icicles at least one day prior to the lesson by saturating the soil samples with water in small clear plastic cups and freezing the mixtures. Mark each tray of icicles Sample A or Sample B but do not label the cups. The students will be determining which soil sample is in their group’s icicle.

7. Icicle scraping tools: wooden craft or popsicle sticks, metal paperclip or other small metal object, plastic comb or paperclip, and any other readily available materials to scrap the icicles (1 of each per group)

*Videos can be downloaded from the MarsBots Material section of the Phoenix Mission Website (http://phoenix.lpl.arizona.edu) ***note: we will make the specific address available as we make final preparations on the learning module.

Directions

Part One: Dry Soil Observations

1. Watch the two 1-minute NASA KSNN™ segments and discuss the Phoenix Mission with the students. The Phoenix Mars Lander is designed to measure volatiles (especially water) and organic molecules in the arctic plains of Mars, where the Mars Odyssey orbiter has discovered evidence of ice-rich soil very near the surface (see background section). More information about the mission can be obtained at http://phoenix.lpl.arizona.edu.

2. Distribute a paper plate to each student. Instruct the students to divide the paper plate into halves, marking one half "A" and one half "B."

3. For this experiment, students will be using a hand lens to make observations. Distribute the hand lenses and have the students practice using a hand lens. If hand lenses are limited the students can form the groups and share a single lens within their group.

4. Give each student a small scoop (approx. 1 teaspoon) of both Sample A and Sample B. Have the students individually observe the small soil samples they receive using their hand lens. Allow the students to use all their senses in observing: sight, touch, and smell (for safety purposes students should waft when smelling and not smell the sample directly. Also, under no circumstances should the students taste the soil.) Consider using terms such as

Time

Ten to fifteen minutes to prepare the soil/water icicles
Ten minutes to watch the video clips and discuss the Phoenix Mission
Fifty minutes to make the observations and conduct experiment
Fifteen to twenty minutes for discussion
grainy, gritty, smooth, rough, wet, dry, musty, and so on.

5. Have students record their observations in the data chart. When recording their observations have the students consider the following questions. How do the soils compare? How do the textures compare? Which particles are larger? How do the colors compare?

6. Discuss the students’ findings and relate their observations to Phoenix. The Phoenix Lander will use a very sophisticated suite of scientific instruments to examine the Martian arctic soil. A microscope will be examining the texture of the soil to try and understand the history of the arctic soils. By examining the grain size and texture, scientists can determine if the soils were ever affected by liquid water. Today, there is no liquid water on Mars and liquid water is necessary for life, as we know it. Understanding the history of the soil will help determine if the Martian arctic environment could have supported life in the past (see the background information).

Part Two: Icy Soil Observations

7. Discuss with the class how there is no liquid water on Mars but there is water in the form of ice in the planet’s polar regions. Reemphasize that Phoenix is looking for evidence of past liquid water by examining both the dry soil on top of the Martian surface and the icy soil below the surface.

8. Divide students into observation groups (3-4 students per group) and give each group one icicle sample. Do not let them know if it is made with Sample A or Sample B soil. At this point have the students remove the dry soil samples from their work stations (they will use their observation sheets for this section) but keep them available for the students to refer back to throughout the remainder of the lesson.

9. Have the students examine the icicle and record their observations in the data chart. Students can peel away the wax paper cup so they can observe the sample from all angles. Students should consider the following questions as they record their observations. Does the icicle contain Sample A or Sample B soil? How can you tell? (Textures, grain size, color...)

10. Discuss the difference between dry soil and icy soil. Which is easier to get small samples of soil from to analyze? How could you get small amounts of the icy soil into science instruments? Explain that Phoenix needs to dig into the very hard icy-soil and bring small amounts of the icy soil to the lander deck for analysis by the science instruments.

11. Distribute the icicle scraping tools and have each group make a single motion scrape across the icicle surface with each tool. Have the students record their observations. Size of savings. Soil removal. Which tool worked best to remove icy soil samples? Why?
12. Then have each group make five quick scraping motions across the surface to simulate a motorized brush. Now which tool worked best to remove icy-soil samples? Which method is better at scraping the hard ice samples: a single scooping motion or a “motorized” tool? Which would use more energy?

13. Discuss what the Phoenix engineers had to think about when designing a tool to dig into the hard icy-soils of Mars’ northern arctic plains. Talk about the different materials (metal, plastic, wood) and methods used to scrape at the ice (dig, scoop, drill) and get enough of a sample that can go to the lander deck instruments for analysis.
Soil and Icicle Observations

The Phoenix Mars Lander will use a robotic arm to dig into the icy-soils of the Martian arctic to study the soil and water history. Life, as we know it, requires liquid water. However, today there is no liquid water on Mars. Understanding if the Martian arctic ever had liquid water will help determine if it ever had an environment that could have supported life.

Phoenix will study the grain size, texture, color and chemical make-up of the icy-soil. In this exercise, you will get two soil samples to examine and compare. Then you will get a mystery icicle sample, similar to what Phoenix expects to find on Mars. Use the tools provided to examine the mystery sample and determine what type of soil is in your icicle and what type of tool is best for examining the sample.

<table>
<thead>
<tr>
<th>Traits</th>
<th>Sample A</th>
<th>Sample B</th>
<th>Icicle Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle Size</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smell</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compare Samples A and B. How are they similar? Different?

Was the soil A or B? How do you know?

<table>
<thead>
<tr>
<th>Wooden tool</th>
<th>Metal tool</th>
<th>Plastic tool</th>
<th>Other tool</th>
</tr>
</thead>
</table>

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Lesson 13: Phoenix’s Robotic Arm

Purpose: To simulate remote operation of robotics in order to deepen student understanding of programming and communications in space exploration.

Standards

NCTE/IRA Standards for English Language Arts

Standard 4 - Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a wide variety of audiences and for different purposes.

Standard 12 - Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Science Education Standards

Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.

Science and Technology – Content Standard E
1. Abilities of technological design – student abilities should include oral, written, and pictorial communication of the design process.
2. Understanding about science and technology – tools help scientists make better observations, measurements, and equipment for investigations.

Overview

Of all the instruments onboard the Phoenix lander, the robotic arm is the most critical to the success of the mission. The robotic arm makes it possible to analyze soil and ice samples by bringing them to the lander deck where the scientific instruments are located. Because of the vast distance between the Earth and Mars, spacecraft cannot be operated in real-time. It takes commands approximately 10 to 15 minutes to travel between Earth and Mars. Mission planners must write a sequence of concise and specific commands on Earth to send to the lander on Mars. Mission planners must be very careful and very specific about what they want the robotic arm to do if they are to be successful. In this activity, students will simulate sending commands to operate a robotic arm to complete a task. Similar to the Program It! activity, students will again have to be specific in their commands, but will only be allowed to use one word commands.

Understandings

1. Robots are made up of simple machines.
2. Robots gather different information (data) depending on their design and use.
3. Combining the information (data) gathered by a variety of robots gives us a broader and more in-depth understanding of our Earth and Solar System.

Materials

1. Blindfolds, 1 per pair of students
2. Various objects such as a paper cup, a ruler, a book, chalk, a block

Time

Approximately 45 minutes

Directions

1. Discuss the Phoenix’s robotic arm and its importance to the mission. More information on the Phoenix Mars Mission can be found on the internet at http://phoenix.lpl.arizona.edu.
2. Pair up students into teams of an Engineer and a Robotic arm.
3. Blindfold the student portraying the Phoenix Robotic arm.
4. Arrange objects in front of the Robotic arm.

5. On the chalkboard, write a task, such as “Pick up the block and place it on the book.”

6. The second student is the Engineer. The Engineer is not allowed to touch the objects, but rather must follow the directions using the Robotic arm.

7. The Engineer gives a verbal direction to the Robotic arm to locate the object and manipulate it as instructed. The Engineer is allowed to use only one-word commands, such as “forward,” “up,” “close.”

8. Count the number of commands it takes to complete the task.

9. Students reverse rolls and repeat activity.

**Extension**

If desired, pairs may compete with each other to complete the task with the fewest number of directions.
Lesson 14: Lander Design

This lesson is adapted from “Edible Mars Spacecraft,” by Amalia Plummer and Tricia Dieck, College of Education, Arizona State University, which was adapted from Jean Settle’s “Edible Rockets” and “Edible Space Stations” activities: Jean Settle, Aerospace Education Consultant, 16487 Hollister Crossing Dr., St. Louis, MO 63011.

Purpose: To allow students to apply the understanding they have gained about landers and robotic components through a hands-on experience.

Standards

NCTE/IRA Standards for English Language Arts

Standard 1 - Students read a wide range of print and non-print texts...to build and understanding of themselves [and] acquire new information.

Standard 5 - Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 12 - Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Science Education Standards

Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.

Science and Technology – Content Standard E
1. Ability of technological design – students should develop the abilities to identify a simple problem, propose a solution, implement a proposed solution, evaluate a product or design, and communicate a problem, design, and solution.
2. Understanding about science and technology – scientists and engineers often work in teams with different individuals doing different things that contribute to the results.

Overview

A robot is a mechanical device which performs automated tasks, either according to direct human supervision, a pre-defined program or, a set of general guidelines, using artificial intelligence techniques. These tasks either replace or enhance human work, such as in manufacturing, construction or manipulation of heavy or hazardous materials. Every spacecraft ever sent to Mars has been a robot. Each of these robots has had tasks and was built to specifically perform these tasks.

Results from the Mars Exploration Rovers robotic arms and cameras have shown that, long ago, Mars was soaked with liquid water. The rovers found evidence for this as they roved across the surface studying rocks along the way. The 2007 Phoenix lander, however, will be stationary and will dig down into the soil instead of roving along the surface. The rovers showed us liquid water once flowed on Mars, while Phoenix will analyze the soil to study the biological potential of the soil. Phoenix must dig down because any possible biology would have to be under the surface where it is protected from solar radiation, which easily penetrates the thin atmosphere of Mars.

In this activity students will design and build a prototype robot. This activity can be done in small groups or individually. You may decide to have the students work in small groups for the initial design process and then allow each student to begin again from the drawing stage and take it through to the final creation of their prototype robot.

Understandings

1. Simple machines make tasks easier.
2. Simple machines affect our everyday lives.
3. Robots are made up of simple machines.
4. Robots gather different information (data) depending on their design and use.
5. Combining the information (data) gathered by a variety of robots gives us a broader and more in-depth understanding of our Earth and Solar System.
Materials

1. Pictures of landers (included)
2. Science and Technology Subject Area Classroom Module: Let’s Talk Robotics; 15 min NASA*
3. Butcher paper or large tablet paper
4. Materials that students can use to make their robot i.e.: foil, cardboard boxes, wooden sticks, shoe boxes, cardboard tubes, lids, plastic containers, etc...
5. Optional: toy robot

* Can be ordered from the NASA online catalog CORE (http://catalog.core.nasa.gov/) or contact the JPL Education Resource Center (http://education.jpl.nasa.gov/erc.html or 909-397-4420) for a free teacher copy

Supplemental Materials

1. Drive a rover the way NASA does at:
   http://www.marsquestonline.org/
2. Mars Exploration Rovers: Challenges of Getting to Mars; JPL
   (http://marsrovers.jpl.nasa.gov/gallery/video/)
3. Mars Exploration Rovers; JPL
   (http://marsrovers.jpl.nasa.gov/gallery/video/animation.html)

Time
Two 60-minute sessions

Directions

1. Review what simple machines are and how they help us in our daily lives with the students. Let the students share examples. You can review the material in the background section at the beginning of the MarsBots learning module or in Lesson10: Simple Machines for more information on simple machines.

2. Lead the students in a discussion about robots and landers that have been used in exploration (Pathfinder, Vikings I and II, the Mars Exploration Rovers, Phoenix, and the Mars Science Lab) and how they are all actually robots, controlled by the scientists here on Earth millions of miles away. See the information about robots in the Background section of the MarsBots Learning Module. Robotic exploration is important because we are able to send robots into very harsh environments where humans are not able to go. Robotic planetary missions include scientific instruments to conduct experiments to determine surface and atmospheric compositions. The Phoenix lander will conduct several experiments to determine if the building blocks for life are present in the Martian artic and study the history of water on Mars. Have the students tell a revealing story about how our understanding of another planet is limited by using information (data) from just one source.

3. This activity can be done in small groups or individually. You may decide to have the students work in small groups for the initial design process and then allow each student to begin again from the drawing stage and take it through to the final creation of their prototype robot.
4. Ask the students to brainstorm examples of robots. Record the student’s responses on the board or a large piece of paper. If you anticipate difficulties (with brainstorming ideas), gather materials that are part of this unit to use as a lead in for this lesson. This may mean the students view portions of videos that you have already used.

5. Tell the students that they are now going to create a drawing of a robotic lander that must have a power source and be able to do the following tasks:
   - Conduct a scientific experiment
   - Receive and send messages to scientists back on Earth
   - Take pictures (panoramic)
   - Test something – students must decide what their robot is testing

   The students must label the parts of their robot on their drawing as well as any other detail that they feel should be noted.

6. Each group (or student if not working cooperatively) will then present their drawing to the class. Display each group’s illustration.

7. The students will now begin the process of building their prototype lander. Provide materials for the students to build their lander. Display final projects alongside the drawings.

Extensions

Landers could be constructed using edible materials (graham crackers, cookies, candies, icing, pretzels etc...)

Students could write a newspaper article describing their lander and purpose.
Lander Images

Viking Lander

Mars Exploration Rover
Mars Pathfinder- Sojourner Rover

Phoenix Mars Lander
Lesson 15: Egg Drop Lander
This lesson is adapted from “Mars Pathfinder: Egg Drop and Landing” an activity in The Mars Activity Book, by the Mars Education Program at Arizona State University (http://marsed.asu.edu/pages/pdfs/MSIP-MarsActivities.pdf)

Purpose: To provide collaborative opportunity to design and test a lander and practice writing skills.

Standards
NCTE/IRA Standards for English Language Arts
Standard 5- Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.
Standard 12- Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Science Education Standards
Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.
Science and Technology – Content Standard E
1. Ability of technological design – students should develop the abilities to identify a simple problem, propose a solution, implement a proposed solution, evaluate a product or design, and communicate a problem, design, and solution.
2. Understanding about science and technology – scientists and engineers often work in teams with different individuals doing different things that contribute to the results.

Overview
The only thing more unnerving than the launch of a spacecraft to Mars is entry, descent, and landing (EDL) onto the Martian surface. Those “six minutes of terror” make even the most seasoned EDL engineer a nervous wreck. After Phoenix plunges into the atmosphere at 16,000 mph, it has six minutes to slow down to 7.9 ft/s (0.09 mph) in order to make a safe, soft landing on the surface of Mars, all controlled automatically through the robotic sensors aboard the spacecraft. Borrowing from the classical egg drop, in this activity, students will design and build a descent and landing system for an egg. The students will also practice their writing skills by writing a letter or article about the success or failure of their spacecraft design.

Understandings
1. Simple machines make tasks easier.
2. Simple machines affect our everyday lives.
3. Robots are made up of simple machines.

Materials
1. Plastic zipper storage bags to hold lander building materials
2. Paper clips
3. Drinking straws (any size)
4. Popsicle or craft sticks
5. String
6. Masking tape
7. Rubber bands
8. Pipe cleaners
9. Paper
10. Bubble wrap
11. Styrofoam (peanuts, cups, packing materials etc…)
12. Scissors
13. Ruler
14. Eggs
15. Small zipper storage bags to hold egg

Supplemental Materials
2. Phoenix Mars Lander Entry Descent and Landing Animation*

* Can be found in the MarsBots Material section of http://phoenix.lpl.arizona.edu

Time
Sixty to 90 minutes for building and dropping the “landers”
Directions

1. Students may work with a partner or in small cooperative groups. Ask the students to imagine that they are a space engineer with the task of designing a lander that will safely get its cargo (an egg) onto a planet’s surface after being launched from an orbiting spacecraft. What will it need to land safely?

2. Have each group or individual create a blueprint of what their lander will look like. Show the students what materials they will be given. You may decide to give each engineer a specific set of materials (so that all will receive the same amount of items) or allow the students to bring items to place in a community pile. If you are allowing the students unlimited materials you may want to also ask for a supply list along with the blueprint.

3. Once their design has been approved have the students build their lander. Place the lander cargo (egg) in a plastic zipper storage bag to avoid splattered egg everywhere in the landing zone.

4. Locate a safe place to have the students drop their lander. Have each group or individual drop their lander one at a time. They should all be dropped from the same height. Be sure the landing area is clear of students and objects.

5. Have the students respond to the following questions in writing. How successful was your design? How would you change or improve a future design? This could be in the format of an article, or news bulletin.

6. Discuss the different lander designs and as a class discuss what design seemed to work best and why.
Lesson 16: Careers in Space

Purpose: To help students understand the variety of careers in space exploration.

Standards

NCTE/IRA Standards for English Language Arts

Standard 1 - Students read a wide range of print and non-print texts...to build and understanding of themselves (and) acquire new information.

Standard 5 - Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 12 - Students use spoken, written, and visual information to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Science Education Standards

Science as Inquiry – Content Standard A
1. Abilities necessary to do scientific inquiry.
2. Understanding about scientific inquiry.

History and Nature of Science - Content Standard G
Science as a human endeavor – many people choose science as a career and devote their entire lives to studying it.

Overview

The space environment is an ideal place for some industries to produce better products. A future space industry will be the production of solar energy. In space there is no atmosphere to block the Sun’s radiation. Solar cells will collect Sun power and send it to Earth as microwaves. Receiving stations will convert the microwaves to electricity. Mining is another important future space industry. Asteroids are rich sources of metals, including gold and platinum. These materials would be mined and brought back to Earth. These future jobs will use robotics to help humans work in the harsh environment of space.

Understandings

1. Our knowledge and understanding of our Earth and Solar System changes and/or expands as new discoveries are made.

Materials

1. Want ads from local newspaper
2. Website: http://www.planetary.org/html/mmp/
3. Paper and pencil
4. Dictionaries
5. Construction paper for Ads

Time

Forty-five to 60 minutes

Directions

1. Have students examine the want ads and discuss the types of jobs advertised. Discuss the need for a variety of professions and the contributions made by different professions.

2. Brainstorm ideas for careers in the future. If settlements are developed on the Moon or on Mars, what services will be needed? How will these needs be met?

3. Have pairs of students design want ads for a paper of the future. Don’t neglect the travel industry (future humans may visit the Moon or Mars on vacation!)
Extensions

Have your students interview adults in different careers to learn the educational requirements and contributions each career makes to society.

Have the students write a personal narrative about their future career aspirations.