National Aeronautics and
Space Administration

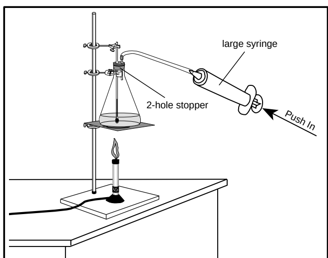
Educational Product	
Educators	Grades 9–12

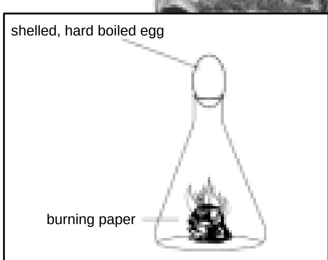
EG-1999-06-121-HQ

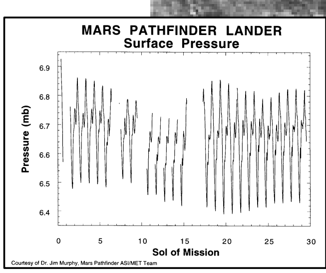
Mars Exploration

Is There Water on Mars?

An Educator's Guide With Activities for Physical and Earth and Space Science







Is There Water on Mars?—An Educator's Guide With Activities for Physical and Earth and Space Science is available in electronic format through NASA Spacelink—one of the Agency's electronic resources specifically developed for use by the educational community.

This guide and other NASA educational products may be accessed at the following address: *http://spacelink.nasa.gov/products*

Is There Water on Mars?

An Educator's Guide With Activities for Physical and Earth and Space Science

NASA Aeronautics and Space Administration
Office of Human Resources and Education
Education
Washington, DC

Prepared by TERC, Inc.
2067 Massachusetts Avenue
Cambridge, Massachusetts 02140

EG-1999-12-121-HQ

Mars Exploration Education and Public Outreach Program

These modules were prepared by the TERC Center for Earth and Space Science Education with assistance from personnel of NASA's Mars Exploration Education and Public Outreach Program. This Program is managed for NASA by the Jet Propulsion Laboratory, a division of the California Institute of Technology.

These materials were developed for JPL's Mars Exploration Education and Public Outreach Program, which is part of NASA's Mars Exploration Program. The work is funded by NASA's Jet Propulsion Laboratory (JPL), which has overall responsibility for the Mars Exploration Program.

The curriculum materials were developed through a subcontract to the Center for Earth and Space Science Education (CESSE) at TERC, Inc., a nonprofit educational research and development company. The materials have been reviewed by NASA scientists and field-tested by scores of teachers.

Government Sponsorship is acknowledged under contract NASA7-1260.

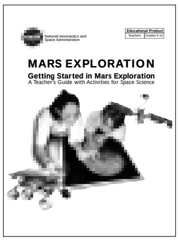
Welcome to the Mars Education Program

Between 1997 and 2007, NASA plans to send 10 spacecraft to investigate Mars. To take advantage of this historic set of explorations, NASA's Mars Exploration Program has created a series of curriculum modules to connect students to the excitement and learning potential of these missions. The Mars Exploration Program will help you:

- Engage your students in hands-on, inquiry-based learning
- Involve students in questions central to current Mars exploration
- Teach engineering concepts and physical, life, and Earth and space science in a relevant way
- Provide a context for learning about both Mars and Earth
- Address student misconceptions
- Prepare students for using live data and images from Mars

The module series was developed and field tested by a team of educators and scientists to make sure that it is both scientifically accurate and educationally powerful. Each module contains a set of activities that relate to an over-arching theme. The activities are sequenced so students can progress from introductory experiences to more advanced investigations and deeper understandings. The educator handbook and correlated student materials enable you and your students to do the activities regardless of your previous knowledge about Mars and planetary exploration.

Modules Available in the Mars Exploration Series

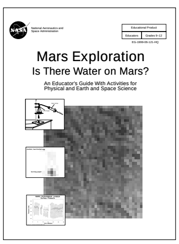


Getting Started in Mars Exploration

Grades 4–10, 2 Weeks

How can students study Mars and Mars exploration in the classroom?

This comprehensive introduction to studying Mars in the classroom develops students' understanding of Mars, the solar system, and planetary exploration. The module introduces many of the intriguing riddles posed by Mars and provides teachers a variety of ways to integrate the study of Mars into their classrooms.

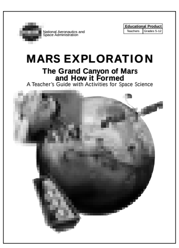


Is There Water on Mars?

Grades 9–12, 3 Weeks

Can water exist on Mars today?

By experimenting with water as it changes state and investigating some effects of air pressure, students not only learn core ideas in physical science but can deduce the water situation on Mars by applying those concepts. They use evidence from their work as well as data and images from NASA's missions to Mars to take a position on whether there was ever water on Mars.

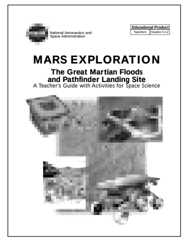


The Grand Canyon of Mars and How It Formed

Grades 6–12, 3 Weeks

What can a colossal fracture tell us about Mars?

Students investigate the formation of Mars' 3,000-mile-long rift valley. After investigating how a planet's surface can be altered and analyzing data and images from NASA's missions to Mars, students develop hypotheses to explain the rift valley's formation and amass evidence to support their ideas.



The Great Martian Floods and Pathfinder Landing Site

Grades 6–12, 3 Weeks

Is the landing site in a floodplain, and why would that be good news?

Students learn how sediment, landforms, and drainage patterns provide clues about a planet's geologic history. They use evidence from their work and data and images from NASA's missions to Mars to understand the advantages of landing at the end of a flood channel.

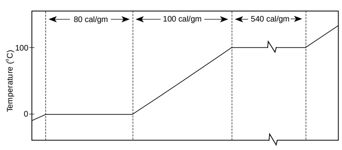
An Overview of What the Modules Provide

- Hands-on, inquiry-based activities written by educators, reviewed by NASA scientists, and field-tested by students
- Engaging physical and Earth science activities that use experiments, models, analogs, and image and data interpretation to investigate questions central to Mars research
- Practical applications of the National Science Standards
- Educator's guides with background information, procedures, teaching strategies, student sheets, assessment recommendations, and a resource list

Table of Contents

Module Overview

Is there liquid water on Mars? By experimenting with water as it changes state and investigating some effects of air pressure, students not only learn core ideas in physical science but can deduce the water situation on Mars by applying those concepts.

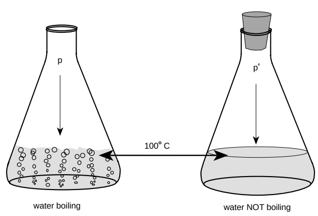


Calories added to 1 gram of water

In Activities 1 and 2, students discover the existence of two temperature plateaus as water changes state. Students have to make sense of these plateaus and come to grips with what changes of state mean at the molecular level. Once students understand the process of boiling and melting, they are ready to examine another factor that significantly impacts the existence of liquid water and atmospheric pressure.

Key Concepts in Activities 1 and 2

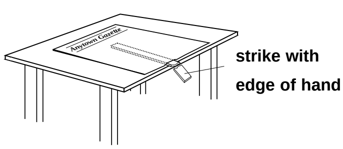
- Water can only be heated to its boiling temperature.
- The temperature of ice water can rise only after all the ice has melted.
- Temperature measures the average vibrational energy of a particle or group of particles.
- As the water in Activity 1 boiled and the ice in Activity 2 melted, the particles used the energy from the heat source to gain the extra kinetic energy required to change state. As a result, the temperature during these transitions never changed.



In Activity 3, students increase the boiling temperature of water by increasing the pressure in the container. In this activity, students not only develop an understanding of pressure's role in water's boiling temperature but also of its role in maintaining liquid water.

Key Concept in Activity 3

- Water boils when its vapor pressure equals atmospheric pressure. As a result, water's boiling temperature is pressure, rather than temperature, dependent.

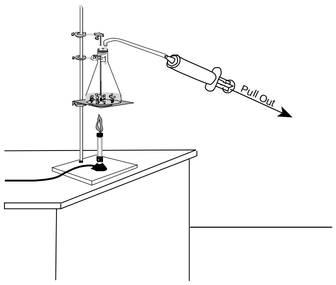


In Activity 4, students perform several activities showing that Earth's atmosphere exerts considerable force at the surface. Many students are unaware that they are subject to considerable atmospheric pressure and have little appreciation for how important this pressure is in their world. By acknowledging air pressure and understanding its role in maintaining water, students can consider questions such as: Why doesn't water on Earth boil away? Could water exist on planets such as Mars?

Key Concepts in Activity 4

- Air has mass and volume.
- Air pressure is a function of the height and density of the atmosphere in conjunction with a planet's gravitational pull.
- The particles in high-pressure air are packed more densely than those in low-pressure air.

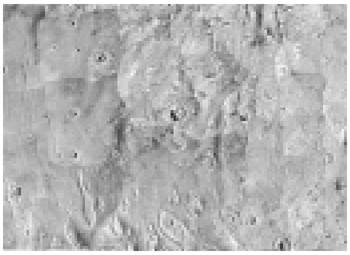
- Air flows from areas of high pressure to areas of low pressure to equalize the pressures.
- When the volume of a given mass of gas increases, its pressure decreases, provided that the temperature remains constant (Boyle's Law).



In Activity 5, students build on ideas introduced earlier and discuss ways to reduce the boiling temperature of water. Students find that water can boil well below its typical boiling temperature by reducing the pressure above the surface of the liquid. They learn about phase change diagrams and use one to better understand their previous work with pressure and changes of state.

Key Concepts in Activity 5

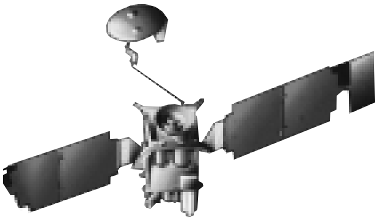
- Water boils when its vapor pressure equals atmospheric pressure. As a result, water's boiling temperature is pressure, rather than temperature, dependent.



In Activity 6, students analyze temperature and pressure graphs from the first 30 days of the Pathfinder mission and realize that liquid water could not have existed under these conditions. Next, students look at a number of images of Mars. By interpreting the landforms and comparing a river-cut valley on Mars with Earth's Grand Canyon, they identify water as the agent that shaped the surface. They hypothesize about how water could have flowed across the Martian surface, even though current conditions make it virtually impossible for liquid water to exist.

Key Concepts in Activity 6

- Current climatic conditions make the existence of liquid water virtually impossible.
- Features on the Martian surface provide strong evidence for past flows of large amounts of water.



In Activity 7, students generate questions based on their module experiences, and they pinpoint specific information they would like to obtain. They then read about the objectives and instrument payloads of the upcoming missions and see how these missions may provide data that can help them answer their questions. Finally, students create a calendar for the missions and consider how they will access the information returned by the missions.

Key Concepts in Activity 7

- Each Mars mission has specific objectives and the instruments it needs to achieve them.
- Space missions arise out of questions people have about Mars, and students can generate questions worthy of future study.
- Every mission has a specific timetable, and students can follow the progress of each mission in a number of ways.

An Overview of the Pedagogical Approach Used in This Module

Mathematics and science distinguish themselves from other disciplines in that they have certain absolutes and fixed principles. Science further distinguishes itself in that most students arrive at school with their own ideas and explanations of many of these absolutes. Unfortunately, many of their ideas are at odds with current scientific understanding. The discrepancy between naive and expert understandings gives science teachers an unusual and exciting opportunity—to help students move from incomplete or incorrect explanations to ideas consistent with current understanding.

A considerable and growing body of research shows that one of the best ways to change students' thinking is to first make them aware of their preconceptions and then provide experiences that probe or challenge those preconceptions. Say that students conduct an experiment that produces an unexpected result. If their preconceived ideas cannot explain the observations, the students should be encouraged to construct new explanations. If these explanations are superior to the ones they previously held, the students are likely to change their ideas. If a student's new explanation is better than his or her old one but is still incomplete or incorrect, the educator can provide another experience and repeat the cycle until the student's understanding is consistent with current scientific understanding.

> *The well established methods of inquiry are not only desirable but also are absolutely necessary for students to construct ideas, test them, and, if necessary, reject them and begin again in their search for ideas that more accurately reflect the real world.*
>
> "Pathways to the Science Standards—High School Edition," National Science Teachers Association, 1997, p. 3

To help educators identify students' preconceptions, each activity begins with a preassessment question. These questions help students become aware of their own ideas, take a position on a particular question, and have a personal stake in the activity. To avoid any embarrassment associated with feeling ignorant or uninformed, the students hand their answers in to the educator rather than state their ideas in a group or class discussion. At the end of each activity, the students are asked to respond to the preassessment question again and compare how they answered it before and after the activity. As the educator, you can use this comparison as:

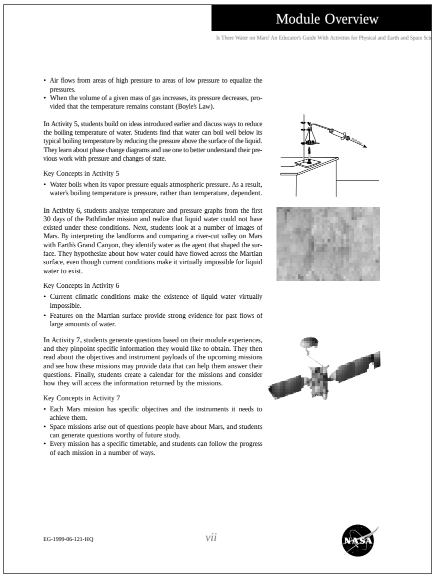
- An assessment of student understanding
- An assessment of the effectiveness of the learning experience
- An indication of whether additional experiences are necessary to develop concept mastery
- A way to structure your class discussion of the experimental observations
- A way to document how students develop an understanding of a concept

The activities early in the module are more proscribed than those later in the module. Progressing from structured to more open-ended investigations lays an indispensable foundation for the inquiry-based learning later in the module. This "guided" approach helps students become increasingly independent investigators by:

- Assuring the mastery of a core set of concepts
- Developing skills required in scientific inquiry
- Providing students a common set of experiences to refer to as they investigate their own questions

Furthermore, the module promotes inquiry-based learning by providing students opportunities to design experiments, develop procedures, or pursue their own ideas. By the end of the module, the students will have developed the skills and understanding they need to investigate their own questions.

How Do I Get Started?



Module Overview

Is There Water on Mars? An Educator's Guide With Activities for Physical and Earth and Space Sci

- Air flows from areas of high pressure to areas of low pressure to equalize the pressures.
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In Activity 5, students build on ideas introduced earlier and discuss ways to reduce the boiling temperature of water. Students find that water can boil well below its typical boiling temperature by reducing the pressure above the surface of the liquid. They learn about phase change diagrams and use one to better understand their previous work with pressure and changes of state.

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Activity 1—At a Glance

Is There Water on Mars? An Educator's Guide With Activities for Physical and Earth and Space Sci

How Hot Can You Make Water?

Purpose

To have students graph the temperature of water as it reaches a boil and discover the existence of the transition plateau

Overview

Students become aware of their preconceptions by considering how hot they could heat water. They then test their preconceived ideas by heating water and measuring its temperature. At some point near 100 degrees Celsius, students find that the water temperature no longer rises. They graph the data and try to make sense of the temperature plateau.

Key Concepts

- Water can only be heated to its boiling temperature.
- The slope of a graph line in this activity shows the rate of temperature change.

Context for This Activity

Mars has such low atmospheric pressure that any water at the surface would boil away. In this activity, students investigate the process of boiling and what is involved when water changes from a liquid to a gas under everyday conditions. In Activities 3 and 5, they will take a closer look at pressure's role in maintaining liquid water.

Skills

- *Predicting* the outcome of an experiment
- *Writing* a procedure to test a prediction
- *Controlling* variables
- *Conducting* an experiment
- *Collecting, recording,* and *graphing* data
- *Drawing* conclusions
- *Communicating* explanations to others

Common Misconceptions

- Water can be heated indefinitely to very high temperatures.
- The heat source controls boiling.
- Reaching temperature plateau means that something is malfunctioning

Materials

Heat source, beaker or flask, water supply, thermometer, ring stand or tripod, ring clamps, thermometer clamp, stirring rod, wire gauze (burners only), graph paper, goggles, appropriate safety equipment (see pages 5 and 19).

Preparation

- Plan how to present the initial problem and the best way to develop a procedure.
- Set out the necessary equipment for each group. Attach thermometers to ring stands.
- Discuss safety procedures related to heat sources, thermometers, glassware, and hot water.

Time: 2 class periods

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Finding Out What Is In a Module

To understand how the activities in the module examine a question or topic, read the overview of the science concepts starting on page vi. Each activity and its key concepts are succinctly described.

Finding Out What Is In an Activity

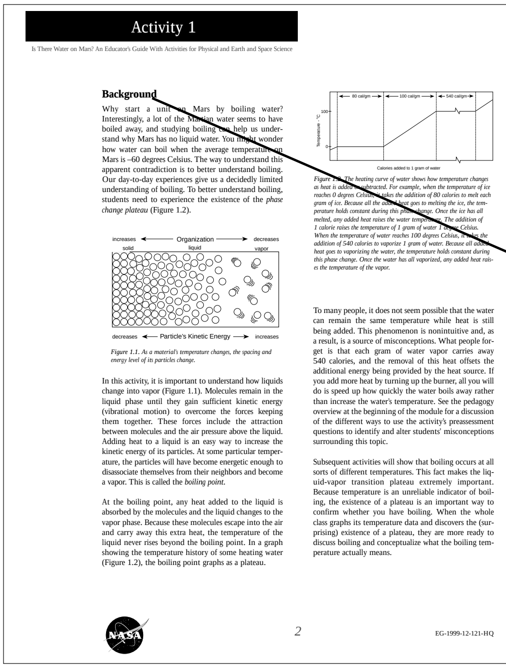
To understand each activity in greater detail (including material and time requirements), read the shaded "At a Glance" page at the beginning of each activity.

Materials

The "At a Glance" pages list the materials used in an activity. The activities use readily available materials.

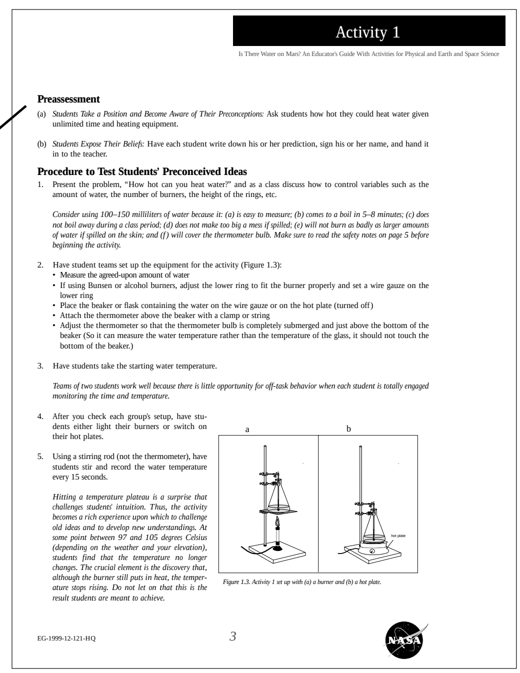
How Is This Module Organized?

This module is written as an educator guide. This approach makes it possible to give it a conceptual and pedagogical structure while still providing educators the flexibility to tailor the activities to the needs of their classes. The educator guide prepares educators to conduct classes around core questions, and it outlines investigations that explore those questions.



Background

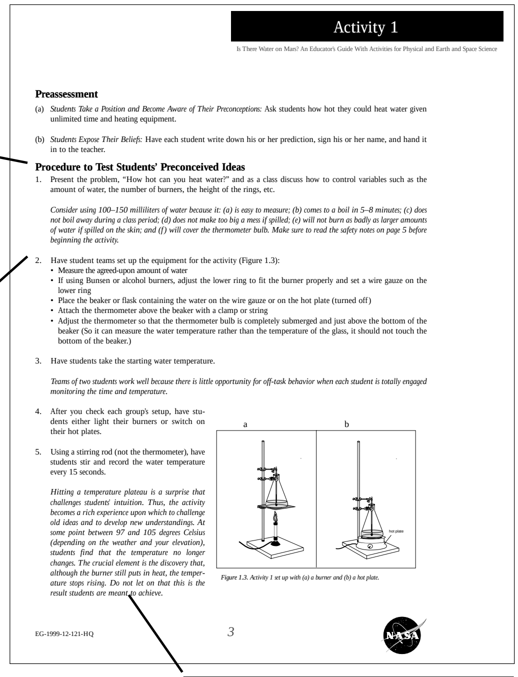
Thorough, easy-to-understand background information enables you to understand the key concepts in an activity.



Learning Activities

Clear, detailed activity procedures (with reproducible student sheets, when required) facilitate planning and classroom implementation.

How Is This Module Organized?



Activity 1

Is There Water on Mars? An Educator's Guide With Activities for Physical and Earth and Space Science

Preassessment

(a) *Students Take a Position and Become Aware of Their Preconceptions:* Ask students how hot they could heat water given unlimited time and heating equipment.

(b) *Students Expose Their Beliefs:* Have each student write down his or her prediction, sign his or her name, and hand it in to the teacher.

Procedure to Test Students' Preconceived Ideas

1. Present the problem, "How hot can you heat water?" and as a class discuss how to control variables such as the amount of water, the number of burners, the height of the rings, etc.

   Consider using 100–150 milliliters of water because it: (a) is easy to measure; (b) comes to a boil in 5–8 minutes; (c) does not boil away during a class period; (d) does not make too big a mess if spilled; (e) will not burn as badly as larger amounts of water if spilled on the skin; and (f) will cover the thermometer bulb. Make sure to read the safety notes on page 5 before beginning the activity.

2. Have student teams set up the equipment for the activity (Figure 1.3):
   - Measure the agreed-upon amount of water
   - If using Bunsen or alcohol burners, adjust the lower ring to fit the burner properly and set a wire gauze on the lower ring
   - Place the beaker or flask containing the water on the wire gauze or on the hot plate (turned off)
   - Attach the thermometer above the beaker with a clamp or string
   - Adjust the thermometer so that the thermometer bulb is completely submerged and just above the bottom of the beaker (So it can measure the water temperature rather than the temperature of the glass, it should not touch the bottom of the beaker.)

3. Have students take the starting water temperature.

   Teams of two students work well because there is little opportunity for off-task behavior when each student is totally engaged monitoring the time and temperature.

4. After you check each group's setup, have students either light their burners or switch on their hot plates.

5. Using a stirring rod (not the thermometer), have students stir and record the water temperature every 15 seconds.

   Hitting a temperature plateau is a surprise that challenges students' intuition. Thus, the activity becomes a rich experience upon which to challenge old ideas and to develop new understandings. At some point between 97 and 105 degrees Celsius (depending on the weather and your elevation), students find that the temperature no longer changes. The crucial element is the discovery that, although the burner still puts in heat, the temperature stops rising. Do not let on that this is the result students are meant to achieve.

a b hot plate

Figure 1.3. Activity 1 set up with (a) a burner and (b) a hot plate.

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Teaching Pointers

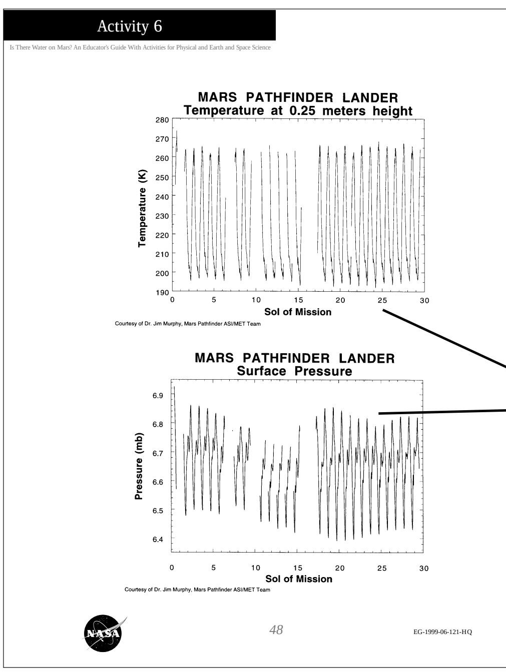
To assist you in conducting hands-on, inquiry-based activities, you will find pointers, classroom management strategies, discussion suggestions, extensions, and answers to the questions presented throughout the module.

Assessment Suggestions

This module outlines several options for assessing students, including preassessment question sets, case studies, and suggestions for alternate ways of exhibiting student understanding.

Technology and Internet Recommendations

Computers and the Web can give students access to a rich set of support materials. The module lists pertinent Web sites, CD–ROM's, and videos and how to get actual Martian data and images. However, this module does not require the use of any classroom technology.



Activity 6

Is There Water on Mars? An Educator's Guide With Activities for Physical and Earth and Space Science

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Case Study

Each activity in this module provides some of the information needed to answer the question: Is there water on Mars? In Activity 6, students take a position on this question and apply and integrate the module's concepts. This synthesis can be used as an assessment.

Which Science Standards Are Supported in This Module?

	Activity 1: How Hot Can You Make Water?	Activity 2: How Fast Does Water Warm as Ice Melts?	Activity 3: How Can We Increase the Height of the Transition Plateau?	Activity 4: Do Fish Believe in Water? Do Students Believe in Air?	Activity 5: Testing Your Hypothesis by Boiling Water Below Its Temperature	Activity 6: Is There Water on Mars?	Activity 7: Where Would You Search for Water on Mars?
Unifying Concepts and Processes							
• Systems, Order, and Organization				●		●	●
• Evidence, Models, and Explanation	●	●	●	●	●	●	●
• Constancy, Change, and Measurement	●	●	●	●	●	●	●
• Evolution and Equilibrium	●	●	●		●	●	
Science as Inquiry							
• Abilities Necessary to Do Scientific Inquiry	●	●	●	●	●	●	
• Understandings About Scientific Inquiry	●	●	●	●	●	●	●
Physical Science							
• Structure and Properties of Matter	●	●	●	●	●	●	
• Motions and Forces	●	●	●	●	●	●	
• Conservation of Energy and Increase in Disorder	●	●	●		●		
• Interactions of Energy and Matter	●	●	●		●		
Earth and Space Science							
• Energy in the Earth System	●	●	●		●		
• Origin and Evolution of Planets						●	●
• Origin and Evolution of Planetary Systems						●	●
Science and Technology							
• Abilities of Technological Design							●
• Understandings About Science and Technology						●	●
History and Nature of Science							
• Science as a Human Endeavor						●	●
• Nature of Scientific Knowledge	●	●	●	●	●	●	●