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Overview of Staying Cool (Unit of the Framing Pathways to Answers Education Module)

STAYING COOL: A SHORT OVERVIEW

Introduction

The MESSENGER Education Modules (MEMs) are diverse packages of educational materials developed for the MESSENGER mission to Mercury. There will be one MEM for each of three basic education themes: Comparative Planetology, The Solar System Through History, and Framing Pathways to Answers: The Scientific Process in Action. "Staying Cool" is one of the Education Units included in the "Framing Pathways to Answers: The Scientific Process in Action" Module. Each Unit contains Lessons at four grade levels (preK-1, 2-4, 5-8, and 9-12). This introduction serves to provide preK-12 educators with an overview of the Unit's contents.

The MESSENGER Module Framing Pathways to Answers: The Scientific Process in Action

This Module concentrates on how the scientific process can be applied to two fundamental types of problems:

- Solving engineering and design problems within a context of constraints.
- Exploring a phenomenon of nature by asking a question of that phenomenon, framing experimental pathways to acquire data, and interpreting that data in the context of a greater body of knowledge.

This theme also places research and exploration in a human context. Relevant MESSENGER stories include:

- Solving MESSENGER engineering problems
- Framing experimental pathways to do MESSENGER science [the MESSENGER science questions, with emphasis on the process]

Education Unit: Staying Cool

The focus of this Unit is to examine how science can be used to solve problems related to sunlight, heat, and staying cool in a hot environment. MESSENGER will operate in and explore the high-temperature, high-radiation environment near Mercury. It needs some of the sunlight and high-energy particle radiation to meet the scientific goals of the mission, but too much of either of these can be quite disastrous to the instruments and other components of the spacecraft.

The story of "Staying Cool," regardless of grade level, unfolds through a story constructed around three questions:

- How can we study Mercury? [Answer: using light and particle radiation both reflected and emitted from Mercury.]
- Are there any problems we might face? [Answer: too much light and particle radiation can be dangerous.]
- Are there ways to solve these problems? [Answer: we can use a variety of means to stay cool.]

Each grade level component of the "Staying Cool" Unit consists of one to three Lessons. Each Lesson addresses one of the essential questions above. As an example, the grade 5-8 component begins with the Lesson "Sensing the Invisible: The Herschel Experiment," in which students recognize that we can study Mercury in light reflected from its surface and the heat (infrared light) it gives off. Lesson 2, "Snow Goggles and Limiting Sunlight," provides the realization that while we study Mercury in light, too much light and heat can pose a danger to the spacecraft. In Lesson 3, "My Angle on Cooling: Effect of Distance and Inclination," students explore the means by which we can limit light and heat received.

At all grade levels the story is the same, but the lessons chosen explore phenomenology relevant to the specific science standards and benchmarks associated with a grade level. The content and concepts are far broader than MESSENGER science and engineering, as they should be if these educational materials are to be relevant to the curriculum. The MESSENGER story is used simply as one vehicle to address a broad curriculum, which includes an understanding of, e.g., light, heat, shadows, and energy transfer.

Students in grades preK-1 gather experiences that help them to realize that the Sun, an object in the sky, provides the light and heat necessary to warm the land, air and water. Sunlight heats the objects it illuminates; the more light an object is exposed to, the hotter it will get. It is possible to keep an object cooler by protecting it from exposure to light. One way to do this is to put it in the shade. Shadows form if the path of light is blocked by an object; light cannot reach the surface behind the object so that surface remains darker than the brightly lit area around it. By experimenting with objects and their shadows from different light sources, students can gather evidence that light travels in straight lines. As they compare

temperatures of objects in full sunlight or in the shade, they will also discover that shade can protect an object from exposure to light and thus from getting as hot as it would in full sunlight. With this knowledge, students will be able to find ways to keep things cool, just as designers of space missions must.

In grades 2-4, students build on the knowledge that the Sun provides the light and heat to maintain the temperature of the Earth. Light travels in a straight line until it strikes an object. Light can be reflected by a mirror, refracted by a lens or absorbed by the object. Students also begin to understand that phenomena can be observed, measured and controlled in various ways—even the unseen energy produced by the Sun. This process of observing, measuring and controlling is just what scientists do, too. Scientists use many different types of investigations and many different tools depending on the question they are trying to answer. Some tools can help us to distinguish between different forms of the Sun's energy.

In grades 5-8, students learn about sunlight and other forms of electromagnetic radiation. Since the Sun is hot, it sends much of its energy as visible light. It also sends out other forms of electromagnetic radiation, which we cannot see with our eyes, such as infrared radiation. Infrared radiation is the main form of radiation emitted by cool objects such as planets. In our exploration of the Solar System, we use tools such as visible and infrared light detectors to give us the information we need about the objects we want to study. However, too much light and radiation may cause the instruments, or the spacecraft itself, to heat up or saturate with light. Examination of different solutions to the problem of too much sunlight enables students to understand this concept in a concrete way. The students can then discover ways to protect objects (or ourselves) in a hot environment.

In grades 9-12, students discover the central role sunlight plays in our lives here on Earth. They understand that almost all life on Earth is dependent on the presence of sunlight. Sunlight—and other forms of electromagnetic radiation—is useful for observing the objects in the Solar System, from the Sun itself to other planets and even the tiniest pieces of ice and rock in interplanetary space. But too much light and radiation to which we (or other objects) are exposed can be quite dangerous. By examining simple solutions to staying cool in sunlight, students are able to realize how science can be used to design robust technological solutions to the problem of staying comfortable in a hot environment.

A Summary of Lessons in the Unit

Grade Level PreK-1 Component

- *Lesson: Cooler in the Shadows*

  - *Shadows*

  In this activity, students will explore making and tracking the shadows of different objects over the course of the day to discover patterns in the behavior of sunlight, temperature and shadows.

  - *Bear Shadow*

  Students demonstrate their understanding of shadows through a reading of the book *Bear Shadow* by Frank Asch.

  - *Shadows of the Neighborhood*

  In this activity, students will construct a model neighborhood to demonstrate their understanding of shadows. Many questions and suggestions for variants to the activities are presented to allow the teacher to tailor this lesson to particular needs.

  - *Creating Shadows of Model Earth*

  Students experiment with making shadows of a three-dimensional object including a globe to see how they can alter the size, shape and position of their shadows.

- *Design Challenge: What Will Keep My Lunchbox Cool?*

Students often have creative ideas for solving common problems. Their solutions are often limited to ideas rather than to reality and a product. The goal of this activity is to develop the young learner from a creative thinker to a problem solver. In this activity, students will take an everyday problem and design a practical solution. Youngsters will consider how to keep a lunchbox cool during a trip to the beach.

Grade Level 2-4 Component

- *Lesson: Sensing Energy*

Students explore the unseen energy produced by the Sun. Some chemical compounds change color when they absorb the energy of UV light. Students will explore the properties of objects that contain such chemicals (UV beads), specifically, what makes them change color. Students can begin their own investigation to determine the conditions required for the beads to change color or what can prevent the color change.

▼ *Design Challenge: How Do You Prevent Things from Getting Too Hot?*

This challenge provides a motivating experience for children to use a scientific approach, problem solving and cooperative teamwork. They are challenged to work as a team to design and build an effective sunshade for a model of the MESSENGER spacecraft.

Grade Level 5-8 Component

▼ *Lesson: Sensing the Invisible – The Herschel Experiment*

Students reproduce William Herschel's experiment of 1800 and find out that there is radiation other than visible light arriving from the Sun—in this case, they discover the presence of infrared radiation in sunlight. Students learn that since planets emit most of their light as infrared and not as visible light, infrared is an important tool in studying planets. Students also discuss current uses of infrared radiation and learn that it is both very beneficial and a major concern for the MESSENGER mission to Mercury.

▼ *Lesson: Snow Goggles and Limiting Sunlight*

By studying ancient solutions to the problem of excessive sunlight on human vision, students understand that too much of a good thing can be dangerous! We need some sunlight to see, but too much may be harmful to our eyes. In a similar way, the MESSENGER spacecraft needs some sunlight to operate and observe Mercury, but too much of it can heat up the spacecraft and cause serious damage.

▼ *Lesson: My Angle on Cooling – Effect of Distance and Inclination*

After discussing what heat is and how it travels, students discover that two ways to cool an object in the presence of a heat source are to increase the distance from it or change the angle at which it is faced. The students learn to distinguish which effect is more important for determining the seasons on Earth. They also discuss how the MESSENGER mission to Mercury takes advantage of similar cooling methods to keep the spacecraft comfortable in a high-temperature environment.

▼ *Design Challenge: How to Keep Gelatin from Melting?*

Students will design and build a platform that will be placed on top of a heat source. A 6 cm × 6 cm × 6 cm cube of gelatin will be placed on the platform, with a thermometer inserted in it. The goal is to keep the temperature inside the cube as cool as possible and prevent the gelatin from melting.

Grade Level 9-12 Component

▼ *Lesson: Star Power! Discovering the Power of Sunlight*

Students estimate the energy output of the Sun using a simple device and discover how much power sunlight provides to Earth. They also estimate what the effect closer to the Sun—at the distance of Mercury—might be. Sunlight and the rest of the electromagnetic spectrum are the main tools with which we study objects in the Solar System.

▼ *Lesson: Dangers of Radiation Exposure*

Radiation can affect living and mechanical things on Earth as well as in space. By estimating their yearly exposure rate to harmful high-energy radiation and cumulative effects over time, students can evaluate the various sources of radiation that are of greatest concern. Since MESSENGER will be subjected to much more intense radiation near Mercury than what a spacecraft near Earth experiences, students also discuss how solar radiation can be an important source of damage and destruction.

▼ *Lesson: Cooling with Sunshades*

After discussing basic properties of temperature and heat, and different ways in which heat can affect substances, students design a simple protective device (sunshade) against excessive sunlight. They also discuss how MESSENGER uses a sunshade to keep comfortable at Mercury's distance from the Sun.

▼ *Design Challenge: How to Keep Items Cool in Boiling Water?*

Students will design and construct a container that will keep items cool when placed in boiling water. A pat of butter will be placed in the container. The goal is to keep the temperature inside the container as cool as possible and prevent the butter from melting.

NASA Review of Staying Cool Education Unit

The Staying Cool Education Unit went through rigorous review by NASA's Science Missions Directorate in 2004. NASA's Office of Space Science's Education Product Review process tasked four educators and three researchers to conduct an intensive peer review of the entire Module. The reviews ranged from 'good' and 'very good' to an 'outstanding' grade given by five of the seven reviewers. The review resulted in NASA incorporating the Staying Cool unit into its 2004 NASA Earth and Space Science Education Workshop at Johnson Space Center.

CONNECTIONS TO THE NATIONAL SCIENCE EDUCATION STANDARDS

This Education Unit has been mapped to the National Science Education Standards, developed by the National Research Council, National Academy Press, Washington, D.C., 1996. A complete explanation of the content standards can be found at: http://www.nap.edu/html/nses/html/.

x - Core standards addressed o - Related standards	Grades PreK-1		Grades 2-4	
	Cooler in the Shadows	Design Challenge: How Can I Keep My Lunchbox Cool?	Sensing Energy	Design Challenge: How Do You Keep Things from Getting Too Hot?
SCIENCE AS INQUIRY CONTENT STANDARD A				
Abilities necessary to do scientific inquiry	o		o	o
Understanding about scientific inquiry	o		x	o
PHYSICAL SCIENCE CONTENT STANDARD B				
Properties of objects and materials				
Position and motion of objects				
Light, heat, electricity, and magnetism	x		x	
EARTH AND SPACE SCIENCE CONTENT STANDARD D				
Properties of earth materials				
Objects in the sky	x	x	x	
Changes in earth and sky				
SCIENCE AND TECHNOLOGY CONTENT STANDARD E				
Abilities of technological design				
Understanding about science and technology		x		x
Abilities to distinguish between natural objects and objects made by humans				x
SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES CONTENT STANDARD F				
Personal health				
Characteristics and changes in populations				
Types of resources				
Changes in environments				
Science and technology in local challenges		o		

Grades 5-8

x - Core standards addressed o - Related standards	Sensing the Invisible: The Herschel Experiment	Snow Goggles and Limiting Sunlight	My Angle on Cooling: Effect of Distance and Inclination
SCIENCE AS INQUIRY CONTENT STANDARD A			
Abilities necessary to do scientific inquiry	o	x	o
Understanding about scientific inquiry	o	x	o
PHYSICAL SCIENCE CONTENT STANDARD B			
Properties and changes of properties in matter			
Motions and forces			
Transfer of energy	x		o
EARTH AND SPACE SCIENCE CONTENT STANDARD D			
Structure of the Earth system			
Earth's history			
Earth in Solar System			x
SCIENCE AND TECHNOLOGY CONTENT STANDARD E			
Abilities of technological design		o	
Understanding about science and technology			
HISTORY AND NATURE OF SCIENCE CONTENT STANDARD G			
Science as a human endeadvor	o		
Nature of science	o		o
History of science	o		

Grades 9-12

x - Core standards addressed o - Related standards	Star Power! Discovering the Power of Sunlight	Dangers of Radiation Exposure	Cooling With Sunshades
SCIENCE AS INQUIRY CONTENT STANDARD A			
Abilities necessary to do scientific inquiry	o	o	o
Understanding about scientific inquiry	o	o	o
PHYSICAL SCIENCE CONTENT STANDARD B			
Structure of atoms			
Structure and properties of matter			
Chemical reactions			
Motions and forces			
Conservation of energy and increase in disorder	o		x
Interactions of energy and matter	x		
EARTH AND SPACE SCIENCE CONTENT STANDARD D			
Energy in the Earth system	x		
Geochemical cycles			
Origin and evolution of the Earth systems			
Origin and evolution of the Universe			
SCIENCE AND TECHNOLOGY CONTENT STANDARD E			
Abilities of technological design			o
Understanding about science and technology			
SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES CONTENT STANDARD F			
Personal and community health			
Population growth			
Natural resources			
Environmental quality			
Nature and human-induced hazards		x	
Science and technology in local, national, and global challenges			o

CONNECTIONS TO THE BENCHMARKS FOR SCIENCE LITERACY

This Education Unit has been mapped to the Benchmarks for Science Literacy, developed by the American Association for the Advancement of Science as part of Project 2061, Oxford University Press, New York, 1993. A complete explanation of the benchmarks can be found at: http://www.project2061.org/tools/benchol/bolframe.htm.

x - Core benchmarks addressed o - Related benchmarks	Grades PreK-1		Grades 2-4	
	Cooler in the Shadows	Design Challenge: How Can I Keep My Lunchbox Cool?	Sensing Energy	Design Challenge: How Do You Keep Things from Getting Too Hot?
THE NATURE OF TECHNOLOGY BENCHMARK 3				
Technology and science				
Design and systems				x
Issues in technology				
THE PHYSICAL SETTING BENCHMARK 4				
The Universe				
The Earth				
Processes that shape the Earth				
The structure of matter				
Energy transformations	x			
Motion				
Forces of nature				
COMMON THEMES BENCHMARK 11				
Systems				
Models				x
Constancy and change				
Scale				

Grades 5-8

x - Core benchmarks addressed o - Related benchmarks	Sensing the Invisible: The Herschel Experiment	Snow Goggles and Limiting Sunlight	My Angle on Cooling: Effect of Distance and Inclination
THE NATURE OF SCIENCE BENCHMARK 1			
The scientific world view			
Scientific inquiry	o		
The scientific enterprise			
THE PHYSICAL SETTING BENCHMARK 4			
The Universe			
The Earth			
Processes that shape the Earth			
The structure of matter			
Energy transformations			
Motion	x	x	
Forces of nature			
THE DESIGNED WORLD BENCHMARK 8			
Agriculture			
Materials and manufacturing			
Energy sources and use			
Communication			
Information processing			
Health technology			
COMMON THEMES BENCHMARK 11			
Systems			
Models		x	
Constancy and change			
Scale			
HABITS OF MIND BENCHMARK 12			
Values and attitudes			
Computation and estimation			
Manipulation and observation	x	x	x
Communcation skills			
Critical-response skills			

Grades 9-12

x - Core benchmarks addressed o - Related benchmarks	Star Power! Discovering the Power of Sunlight	Dangers of Radiation Exposure	Cooling With Sunshades
THE NATURE OF SCIENCE BENCHMARK 1			
The scientific world view			
Scientific inquiry			
The scientific enterprise		x	
THE PHYSICAL SETTING BENCHMARK 4			
The Universe			
The Earth			
Processes that shape the Earth			
The structure of matter			
Energy transformations	x		x
Motion			
Forces of nature			
THE DESIGNED WORLD BENCHMARK 8			
Agriculture			
Materials and manufacturing			x
Energy sources and use			
Communication			
Information processing			
Health technology			
HISTORICAL PERSPECTIVES BENCHMARK 10			
Displacing the Earth from the center of the Universe			
Uniting the Heavens and Earth			
Relating matter & energy and time & space			
Extending time			
Moving the continents			
Understanding fire			
Splitting the atom		x	
Explaining the diversity of life			
Harnessing power			
HABITS OF MIND BENCHMARK 12			
Values and attitudes			
Computation and estimation			
Manipulation and observation			
Communcation skills			
Critical-response skills			