MESSENGER Education Module

Framing Pathways to Answers: The Scientific Process in Action

Unit 1: Staying Cool
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Challenger Center for Space Science Education is an international, not-for-profit education organization that was founded in April 1986 by the families of the astronauts tragically lost during the Challenger space shuttle mission.

Using space as a theme and the power of simulations as a teaching tool, Challenger Center programs create an exciting and cooperative learning environment that exposes students to the challenges and successes of teamwork, problem solving, communication, and decision making. These positive learning experiences raise students’ expectations of success; foster in them a long-term interest in math, science, and technology; and motivate them to pursue careers in these fields.

Our mission is to create a scientifically literate population that can thrive in a world increasingly driven by information and technology. Our vision for the future is a global community where today’s students command their own destinies by using higher order thinking skills, the lessons of teamwork, and strong communication frameworks. That vision is based on a realistic assessment of the skills needed for success in the 21st century.

Now firmly in our second decade, Challenger Center has developed into a kaleidoscope of learning innovations that serve as a gateway to knowledge. Our network of Challenger Learning Centers, and diverse classroom programming, excite students’ natural curiosities and encourage them to learn. Innovative teacher training workshops give instructors a deeper understanding of how to teach the subjects of science and mathematics, and the confidence that the programs they are using are content-rich and consistent with current scientific understanding. All Challenger Center program development and delivery teams include staff educators and space scientists to ensure accuracy in both pedagogy and content.

Challenger Center recognizes that in order to make change happen within education, we must reach all parts of the education system: students, teachers, schools, and communities. We have developed a full array of hands-on and minds-on multidisciplinary programs to accomplish this. Visit www.challenger.org for more information.

Challenger Center is the lead organization in developing the grade 5-8 and 9-12 components of this Education Unit for the MESSENGER mission to Mercury.
Carnegie Academy for Science Education (CASE)

Founded in 1902 by Andrew Carnegie as his institution for discovery, the Carnegie Institution of Washington (CIW) has been, since then, a pioneering force at the forefront of scientific research and education. Headquartered in an historic building in Washington, D.C., the Institution conducts research in five departments across the country, in the fields of plant biology, astronomy, developmental biology, and the earth and planetary sciences.

In 1988 the Carnegie Institution opened its doors to children from two neighborhood public schools and invited them to learn science at First Light, a free, all-day, inquiry-based Saturday program. Enrollment is open to all interested children attending DC Public Schools (DCPS) in grades 3 to 6 on a first-come, first-served basis. Encouraged by external advisors and DCPS elementary school principals and parents, the teaching methods developed at First Light became the basis for the Carnegie Academy for Science Education (CASE) teacher training program. Fifty teachers, primarily from schools involved with First Light, attended the first Summer Institute in 1994 where they learned science content and how to teach science and associated mathematics through inquiry based and interactive methods. Every summer since then teachers have attended the Institute, the only long-term professional development program in science and mathematics for DCPS teachers. Over 500 teachers from more than 50 schools have been trained. CASE has gained the respect of DCPS elementary teachers and principals for providing excellent professional development in science and mathematics.

CASE is the lead organization in developing the grade preK-1 and 2-4 components of this Education Unit for the MESSENGER mission to Mercury.
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Mercury is the closest planet to the Sun. Since it never strays far in the sky from the Sun’s glare, early astronomers had a difficult time viewing it, and considered it a “wandering star” appearing just before sunrise or just after sunset.

Mercury travels around the Sun faster than any other planet. During one year on Earth, Mercury makes over four orbits around the Sun. On the other hand, Mercury rotates slowly around its axis—almost 60 times more slowly than Earth. The amazing outcome is that a single day (e.g., sunrise to sunrise) on Mercury takes two of Mercury’s years.

Mercury’s orbit around the Sun is much more oval-shaped (“eccentric”) than Earth’s. This means that unlike the Earth, whose distance from the Sun does not vary much during the year, Mercury’s distance from the Sun varies by about 40% during its year. As a result, the size of the Sun seen from Mercury’s surface changes by about 40%—and it is always more than twice as big as we see it from Earth!

Mercury is the second smallest planet in the Solar System, larger only than Pluto and not much bigger than our Moon. The surface of Mercury is very Moon-like, covered with ancient craters, while its interior is like Earth’s, with a large core of iron. Mercury has a thin atmosphere, and no moons of its own. It is a world of extreme temperatures in which the surface can heat to over 450°C (850°F) during the day and cool to −180°C (−300°F) at night. The huge daily temperature changes take place because Mercury’s atmosphere is so tenuous that it is virtually a vacuum and cannot moderate the temperatures like Earth’s atmosphere does. For the same reason, even though much of the atmosphere on Mercury is made of oxygen, you would not be able to breathe there—there just is not enough oxygen to fill your lungs. One breath on Mercury would give you less than one hundred trillionth of the mass of the air you breathe in at sea level on Earth!

Some basic facts about Mercury

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Actual value</th>
<th>Compared to Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>4900 km</td>
<td>38% of Earth’s diameter</td>
</tr>
<tr>
<td>Mass</td>
<td>3.3 x 10^{23} kg</td>
<td>6% of Earth’s mass</td>
</tr>
<tr>
<td>Mean density</td>
<td>5400 kg/m^3</td>
<td>About the same as Earth’s</td>
</tr>
<tr>
<td>Moons</td>
<td>None</td>
<td>One (The Moon)</td>
</tr>
<tr>
<td>Orbital period</td>
<td>88 Earth days</td>
<td>1/4 of Earth’s</td>
</tr>
<tr>
<td>Rotation period (around its axis)</td>
<td>59 Earth days</td>
<td>59 times longer than Earth’s</td>
</tr>
<tr>
<td>Length of one day (sunrise to sunrise)</td>
<td>176 Earth days</td>
<td>176 times longer than Earth’s</td>
</tr>
<tr>
<td>Average distance from the Sun</td>
<td>58 million km</td>
<td>0.39 AU (Sun-Earth distance)</td>
</tr>
<tr>
<td>Magnetic field</td>
<td>Yes</td>
<td>Weaker than Earth’s</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>Extremely tenuous</td>
<td>Virtually a vacuum in comparison</td>
</tr>
<tr>
<td>Average surface temperature</td>
<td>170°C (330°F)</td>
<td>150°C (270°F) hotter than Earth’s</td>
</tr>
</tbody>
</table>
MESSENGER is an unmanned NASA spacecraft that will be launched in 2004 and arrive at Mercury in 2009. It is only the second spacecraft to study Mercury, and the first since the 1970s, when Mariner 10 rendezvoused with the planet. MESSENGER is the first spacecraft to observe Mercury from orbit and not just fly by. Its observations will allow us to see the entire surface of the planet for the first time.

The acronym MESSENGER stands for MErcury Surface Space ENvironment, GEochemistry and Ranging. The name highlights the scientific topics of the mission, but it is also a reference to the name of the ancient Roman messenger of the gods, Mercury, after whom the planet is named.

Sending a spacecraft to Mercury is complicated. The planet is so close to the Sun that MESSENGER will be exposed to up to 11 times more sunlight than it would in space near Earth. To prevent the intense heat and radiation from having catastrophic consequences, the mission has been planned carefully to make sure the spacecraft can operate reliably in the harsh environment. To rendezvous with Mercury on its orbit around the Sun, MESSENGER will use a complex route: it will fly by Venus twice and three times by Mercury before entering into orbit around Mercury.

The MESSENGER spacecraft is built with cutting-edge technology. Its components include a sunshade for protection against direct sunlight, two solar panels for power production, a thruster for trajectory changes, and fuel tanks. The instruments aboard MESSENGER will take pictures of Mercury, measure the properties of its magnetic field, investigate the height and depth of features on Mercury’s surface, and in general observe the properties of the planet and its space environment in various parts of the electromagnetic spectrum and via particle radiation studies.

During its mission, MESSENGER will attempt to answer several questions about Mercury. How was the planet formed and how has it changed? Mercury is the only rocky planet besides Earth to have a global magnetic field; what are its properties and origin? What is the nature and origin of Mercury’s very tenuous atmosphere? Does ice really exist near the planet’s poles?

Mercury is an important subject of study because it is the extreme of the terrestrial planets (Mercury, Venus, Earth, Mars): it is the smallest, one of the densest, it has one of the oldest surfaces and the largest daily variations in surface temperature—but is the least explored. Understanding this "end member" of the terrestrial planets holds unique clues to the questions of the formation of the Solar System, evolution of the planets, magnetic field generation, and magnetospheric physics. Exploring Mercury will help us understand how our own Earth was formed, how it has evolved, and how it interacts with the Sun.

For more information about the MESSENGER mission to Mercury, including information on the spacecraft design, instruments and discussion of science background and goals, visit http://messenger.jhuapl.edu/
Introduction
Tonight, if you look up into the sky, you’ll see the same bright lights that your ancestors admired, named, and used to find their way when they were lost, or to explain unusual events in their lives. With today’s technological imaging, you can better see those stars, planets, moons, comets, meteors, asteroids, and now even artificial satellites.

As humans, we have always strived to increase our knowledge about the Universe. For centuries, we explored from the comfort of our own planet, Earth, where we could breathe air, sit on firm land, take notes on stone, paper, or computers, and teach others what we know through our writing and speaking. When we first ventured out into space in the mid-20th century, we had to change the way we gather, store, and share information. Now it would be done with machines that help us "see" in increasingly sophisticated ways, as we explore more deeply away from our home planet.

One of the ways we have learned to gather new information about other planets is to send out data-gathering instruments that are sensitive to a variety of influences. These instruments have to endure the stress of leaving the Earth’s comfortable atmosphere atop a rocket, and continue to function under the most hostile conditions imaginable: the cold vacuum of space, the intense heat and radiation from the Sun, and the quick changes between the two as a spacecraft speeds along at thousands of miles per hour.

We go into space, to the Moon, and now to planets such as Mercury, even in the face of great risk, to push our problem-solving capabilities beyond current limits, and explore uncharted regions of the Universe. It is the nature of human exploration. We also do this because the potential benefits are too great to ignore. Indeed, it is only if we continue to explore beyond our reach that we will be able to better understand our own world, and address challenges that face us here on Earth.

MESSENGER Education and Public Outreach Program
One of the most recent of our instruments investigating other worlds in the Solar System is MESSENGER, the MErcury Surface, Space ENvironment, GEochemistry and Ranging mission, designed to study the planet Mercury. It will be launched in 2004, enter into orbit around Mercury in 2009 and observe the planet and its space environment for one year.
The goals of the mission not only include gathering massive amounts of information about the mysterious planet Mercury, but to also take the nation along for a thrilling ride of exploration. Indeed, bringing a sense to the general public of how mission planners overcome challenges and achieve triumphs has been taken on as a national responsibility.

The Education and Public Outreach (E/PO) team assembled to meet this challenge is an extensive network of individuals from the following organizations: American Association for the Advancement of Science (AAAS); Carnegie Institution of Washington Carnegie Academy for Science Education (CASE); Center for Educational Resources (CERES) at Montana State University (MSU) – Bozeman; Challenger Center for Space Science Education (CCSSE); Johns Hopkins University Applied Physics Laboratory (JHU/APL); NASA’s Minority University-Space Interdisciplinary Network (MU-SPIN); National Air and Space Museum (NASM); Science Systems and Applications, Inc. (SSAI); and Southwest Research Institute (SwRI).

To meet the goal of education and public outreach on a national level, a comprehensive set of activities coordinated with MESSENGER events has been designed to enliven education from kindergarten through college and to excite the public. These activities include education materials development, teacher training through an educator fellowship program, unique student investigations related to the MESSENGER mission, a television documentary, museum displays, and special outreach to underserved communities and minority students.

A few examples of these exciting initiatives include:

**MESSENGER Education Module Development**
A set of MESSENGER Education Modules (MEMs) will be produced in connection with the mission. The Modules are standardized presenter’s packages that can be used by educators and teacher trainers. They consist of a diverse mix of educational materials and multimedia resources and are intended for use nationwide in preK-12 classrooms. At the core of the MEMs are concept-based, inquiry-driven lessons intended for use in classrooms nationwide. These standards-based lessons address Solar System science, planetary observations through history, and the engineering associated with building and sending a spacecraft to another world. Carnegie Institution of Washington Carnegie Academy for Science Education is overseeing the development of the grade level preK-1 and 2-4 components. Challenger Center for Space Science Education is developing the grade level 5-8 and 9-12 components.
The MESSENGER Fellowship Program
The MESSENGER E/PO Program will sponsor a nationwide teacher training initiative whereby a cadre of Fellows—master science teachers at the elementary, middle, and high school levels—will receive training on the MEMs and conduct educator workshops nationally, training up to 27,000 grade preK-through-12 educators over the mission lifetime. Challenger Center for Space Science Education is responsible for developing and managing the Fellowship program.

Journey through the Universe Program
Training for educators on the MEMs will also be conducted as part of Challenger Center’s Journey through the Universe program. Established in 1999, the program reaches out to underserved communities nationally, providing programming for teachers, students, and families. For more information, visit: www.challenger.org/journey.

MESSENGER Online
An extensive Web environment has been developed for the MESSENGER E/PO Program. Some aspects of the Web site include online science courses and classroom materials for preK-12 teachers. Among other services, the Web site will allow download of MEMs by an international audience.
Teaching about the MESSENGER Mission—MESSENGER Educational Pedagogy

For the purposes of teaching about the MESSENGER spacecraft and mission design, and for making that information relevant to the lives of young people today, we have created an educational program, which parallels the 10-year MESSENGER mission. We start from the notion of sending a human-made probe to the closest planet to the Sun, and we ask students to consider the processes and humanpower needed to complete such a mission.

We continue by introducing students to different branches of science that must be studied for an understanding of the data retrieved from the spacecraft. These include astronomy, physics, chemistry, geology, thermodynamics, magnetism, and optics, to name just a few.

We extend beyond the sciences to make interdisciplinary connections to, e.g., mathematics, technology, social studies, and all aspects of literacy to strengthen students’ abilities across the curriculum, helping them discover cultural as well as scientific understandings of the planets, the Sun, and the skies.

We develop students’ literacy of science by using appropriate scientific vocabulary and concepts, while also helping them build their literacy through science, as we use inherently fascinating scientific phenomena as a means of promoting reading and writing.

We launch design challenges that motivate students to build systems, design experiments, discover improved ways of doing things, and observe the world around them, in an effort to provide them the required context to best learn the skills they will need throughout life, in all areas.

We approach science education by asking essential questions that drive the quest for knowledge, by giving students ample opportunities to explore situations that embody important scientific ideas, and by encouraging them to express their ideas about what they are exploring. Teachers are then able to choose appropriate ways of helping students test their ideas, to discover which ideas apply more widely and may be more scientifically-derived than what they had previously thought.
We design activities that require first-hand observations as well as in-depth study of existing data. In both cases, students are allowed to develop ideas more fully as they work through their own creative thinking and problem-solving, rather than through rote memorization. It is essential that children change their own misconceptions as a result of what they find themselves, not merely by accepting other ideas they have been told are better than their own.

We encourage creativity and thinking outside the box, while making sure that national science standards are directly addressed in every lesson. Children learn science best through a process that helps them link ideas and develop new concepts. We make full use of science process skills (observing, measuring, hypothesizing, predicting, planning and carrying out investigations, interpreting, inferring, and communicating) to help them make sense of the world around them. In addition to traditional summative evaluations at the end of a lesson, we offer forms of formative assessment throughout the teaching process, so that the teacher is aware of students’ evolving ideas and skills. Furthermore, this information is an integral part of effective teaching, since it can significantly change the direction of a given lesson to better address problems or misconceptions that persist.

In general, we provide a context for understanding the significance of scientific ventures and engineering feats such as the MESSENGER mission, and we open the door to students who will both understand and build the future.

The MESSENGER Education Themes and MESSENGER Stories
The MESSENGER Education Modules will concentrate on the following themes:

▲ Comparative Planetology – Understanding the planets as individual worlds and as part of a larger family by studying their similarities and differences. It is a look at what we know about our family of planets, and what we do not know. It also addresses what is currently known about Solar System formation and evolution. MESSENGER stories relevant to this theme include what Mercury tells us about the family of planets, and how MESSENGER observations are specifically framed to change our view of the Solar System.
▲ **The Solar System Through History** – How we have come to know what we know about the Solar System. The student will explore the Solar System through the eyes of, and resources available to, past generations. MESSENGER stories relevant to this theme include different cultures’ views of Mercury through history as a case study of planetary observations; and how MESSENGER science and engineering stands on the shoulders of past generations.

▲ **Framing Pathways to Answers: The Scientific Process in Action** – An exploration of the scientific process as 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 thematic overview also places research and exploration in a human context. Relevant stories within this theme include solving MESSENGER engineering problems to make the mission possible, and framing experimental pathways to do MESSENGER science.

Each theme defines an Education Module that is a story in one to three Units, each like a chapter of a book. Each Unit is associated with its own sub-story told though as many as three Lessons at each of four grade levels: PreK-1, 2-4, 5-8, and 9-12. As an example, the “Framing Pathways” Module includes a Unit on Staying Cool and another Unit on Spacecraft Design. Besides the Lessons, a Unit might also contain design challenges — tasks intended to give the students the opportunity to put the concepts learned in the Lessons into an innovative use by challenging the students to come up with an experimental design addressing a specific engineering problem.

An example of a MESSENGER Education Module:

**Framing Pathways to Answers: The Scientific Process in Action**

**UNIT 1: STAYING COOL**

(available in 2003)

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Lesson 1</th>
<th>Lesson 2</th>
<th>Lesson 3</th>
<th>Design Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>PreK - 1</td>
<td></td>
<td></td>
<td></td>
<td>Design Challenge</td>
</tr>
<tr>
<td>2 - 4</td>
<td>Lesson 1</td>
<td></td>
<td></td>
<td>Design Challenge</td>
</tr>
<tr>
<td>5 - 8</td>
<td>Lesson 1</td>
<td>Lesson 2</td>
<td>Lesson 3</td>
<td>Design Challenge</td>
</tr>
<tr>
<td>9 - 12</td>
<td>Lesson 1</td>
<td>Lesson 2</td>
<td>Lesson 3</td>
<td>Design Challenge</td>
</tr>
</tbody>
</table>

**UNIT 2: SPACECRAFT DESIGN**

(available in 2005)

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Lesson 1</th>
<th>Lesson 2</th>
<th>Lesson 3</th>
<th>Design Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>PreK - 1</td>
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</tr>
<tr>
<td>5 - 8</td>
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<td>Lesson 2</td>
<td>Lesson 3</td>
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</tr>
<tr>
<td>9 - 12</td>
<td>Lesson 1</td>
<td>Lesson 2</td>
<td>Lesson 3</td>
<td>Design Challenge</td>
</tr>
</tbody>
</table>
Connections to Science Education Standards and Benchmarks

MESSENGER Educational Modules (MEMs) focus on not only what science is taught but also how science is taught. Many state and local districts use National Science Education Standards and Project 2061 Benchmarks as the foundation for their science curriculum. The MESSENGER Modules are mapped to the standards, with a standards matrix found in each Unit. The MEMs emphasize activities that encourage students to ask questions and become deeply involved in work that is based on their own ideas. MEMs stress inquiry-based, process-driven approaches to science education.
**How to Use a Lesson**

Each Lesson within the MESSENGER Education Units has been instructionally designed with a variety of components, each serving a specific function as a means of delivering a comprehensive and powerful inquiry-based lesson. This document offers teachers an explanation of each section in a Lesson.

Lesson Components:

▲ **Title and Grade Level of Lesson** – Provides a general idea of the lesson theme for a given grade level range.

▲ **Duration of Lesson** – Provides anticipated duration of the lesson in the classroom.

▲ **Lesson Summary** – After reading the summary, the teacher should understand the underlying principles of the lesson, including how it fits into the overall theme of the Unit.

▲ **Essential Question** – This overarching question provides teachers with the main focus of the lesson. Students should be able to answer this question at the completion of the lesson.

▲ **Objectives** – These objectives are measurable outcomes expected of students.

▲ **Concepts** – The lesson should provide insight and provoke questions about fundamental concepts.

▲ **MESSENGER Mission Connection** – Each lesson relates to a specific aspect of the MESSENGER mission to Mercury. This section explains the reason why this lesson is included in the MESSENGER Education Module (MEM).

▲ **Standards & Benchmarks** – The National Science Education Standards and the American Association for the Advancement of Science Project 2061 Benchmarks are the driving force behind these lessons. Each lesson addresses 1-3 core standards and benchmarks, and may address many more related standards and benchmarks.

▲ **Science Overview** – This section provides the teacher with background information essential to facilitating the activities in the lesson. Enough information is provided so that answers to most of the questions the teacher (or students) may have can be found in the Science Overview. For a more comprehensive discussion of the topics in the Overview, a science textbook is an appropriate source. The teacher can choose to read or skim as much of this material as they find necessary, which may depend on their personal science background. This section is not intended to be used by the students, although sections may be shared with the students at the discretion of the teacher.

▲ **Lesson Plan** – The lesson description provides specific instructions for the teacher. It includes everything the teacher requires to carry out the lesson. Teachers are strongly encouraged to adapt the procedures to best meet their needs in their own classroom. (See Lesson Plan description below.)
Internet Resources & References – A list of web sites that will enhance or clarify the concepts within each Lesson. These include the MESSENGER web site, National Science Education Standards, Benchmarks for Science Literacy, and any web sites that may aide in understanding the Science Overview.

Student Worksheets – Worksheets may be copied and given to individual students. They supply the students with everything they need in order to perform the activities. There may be additional worksheets that apply what they have learned from the activity to other concepts within the lesson. Some worksheets are optional or offer challenges for advanced students; these worksheets are clearly marked.

Answer Keys – Includes correct or suggested answers for teachers. Used to aid in assessment.

MESSENGER Information Sheet – This can be copied and handed out to the students to provide them with background information about the MESSENGER mission to Mercury.

Each Lesson Plan includes the following:

Preparation – Suggests classroom organization, varied student groupings, set-up strategies, materials distribution, etc.

Materials – Lists the supplies, books, etc. needed by the teacher and students.

Warm-up & Pre-assessment – Strategies for getting students interested and motivated to participate in a lesson. Suggests ways to find out what students already know, including misconceptions they may have. (May occur in warm-up, homework discussions, or separately).

Procedures – Steps to be followed by the teacher to conduct an activity.

Discussion & Reflection – A guide to activities or discussion topics to help students better understand what they have been learning, anchor that new learning into existing knowledge, and to clarify any issues.

Lesson Adaptations (in Special Education, Talented and Gifted, and English as a Second Language Programs) – Offers variations on the Lesson Plan to accommodate the needs of these students. Some lessons do not have adaptations.

Extensions – The extensions allow students to develop higher and more complex levels of understanding concerning concepts and information that they have learned. Some lessons do not have extensions.
▲ Curriculum Connections – Describes the nature of the relationship between the science lesson and other traditional subject areas such as math, history, geography, art, music, English, physical education, technology, foreign languages, etc.

▲ Closing Discussion – Provides strategies for ending a lesson in a meaningful way for the students.

▲ Assessment – Suggests verbal, written or performance-based assessment strategies to verify progress during the lesson or activity.

In addition, Teaching Tips boxes appear throughout the Lesson Plan.
LESSON OVERVIEW

LESSON SUMMARY
Students will explore the unseen energy produced by the sun.

OBJECTIVES
Students will understand that
- light has components that are both visible and invisible to our eyes.
- exposure to light can be measured and controlled
- exposure to light can change the properties of an object

ESSENTIAL QUESTION
How can a spacecraft be protected from the Sun’s visible and invisible radiation?
The atmosphere on Earth provides a measure of protection to the planet, and everything on it, from the harmful effects of exposure to sunlight. Once the MESSENGER Craft leaves the atmosphere, it will be more exposed to the dangerous invisible forms of the Sun’s energy. As the craft gets closer to Mercury, this exposure will intensify. The potential for damage to the craft and its instruments is very high. MESSENGER team scientists are constantly refining their design of the craft so that exposure to the Sun’s energy will be minimized.

**Concepts**
- The Sun produces energy—both visible and invisible to our eyes.
- The light we see is visible energy from the Sun reflected off surfaces.
- Some of the Sun’s energy is received on Earth as ultra-violet energy that can produce skin burns and cancer.
- There are ways of blocking UV radiation.

**MESSENGER Mission Connection**

The atmosphere on Earth provides a measure of protection to the planet, and everything on it, from the harmful effects of exposure to sunlight. Once the MESSENGER Craft leaves the atmosphere, it will be more exposed to the dangerous invisible forms of the Sun’s energy. As the craft gets closer to Mercury, this exposure will intensify. The potential for damage to the craft and its instruments is very high. MESSENGER team scientists are constantly refining their design of the craft so that exposure to the Sun’s energy will be minimized.
STANDARDS & BENCHMARKS

NATIONAL SCIENCE EDUCATION STANDARDS

Standard D2 Objects in the Sky
- The Sun provides the light and heat necessary to maintain the temperature of the Earth.

Standard A2 Understandings About Scientific Inquiry
- Scientists use different kinds of investigations depending on the questions they are trying to answer. Types of investigations include describing objects, events, and organisms; classifying them; and doing a fair test (experimenting).

Standard B8 Light, Heat, Electricity, and Magnetism
- 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.

FROM THE NSES NARRATIVE

“Young children begin their study of matter by examining and qualitatively describing objects and their behavior. The important but abstract ideas of science, such as atomic structure of matter and the conservation of energy, all begin with observing and keeping track of the way the world behaves. When carefully observed, described, and measured, the properties of objects, changes in properties over time, and the changes that occur when materials interact provide the necessary precursors to the later introduction of more abstract ideas in the upper grade level.”

“By experimenting with light, heat, electricity, magnetism, and sound, students begin to understand that phenomena can be observed, measured, and controlled in various ways. The children cannot understand a complex concept such as energy. Nonetheless, they have intuitive notions of energy—for example, energy is needed to get things done; humans get energy from food. Teachers can build on the intuitive notions of students without requiring them to memorize technical definitions”.

We are a star-powered planet, and our star, the primary source of energy on Earth, is the Sun. Objects on Earth absorb some of that energy, and reflect or radiate away the rest. Light and heat are just two forms of energy or radiation emitted by the Sun. The word “radiation” is just a way to describe how energy is transmitted through space and through air.

Visible light is a form of energy to which our eyes are sensitive. Here on Earth, visible light is usually produced when material is heated so that it glows. For example, in a regular light bulb, electricity flowing through a filament in the bulb heats it up and causes it to glow. As a result, light and heat are produced.

The Sun, too, produces light, but this energy is caused by nuclear reactions deep within the Sun. The Sun is really just a mass of hot gasses that explode in a way similar to a nuclear bomb. However, in the Sun, the explosions have been going on for five billion years and are expected to continue for another five billion!

Visible light is only one kind of solar radiation (energy produced by the Sun). Other forms include gamma, X-rays, ultraviolet (UV), infrared and radio waves. We cannot see these forms of energy (though some animals can see a little infrared), but we have other ways of detecting their presence. For example, if we stay outdoors too long, we might get a sunburn, which is caused by the Sun’s ultraviolet (UV) energy. We can also use instruments to measure the presence of such invisible forms of energy. This lesson will use UV Detection Beads which change color in the presence of UV radiation.

Only some of the Sun’s energy reaches us on the Earth. Much of it is stopped by the Earth’s atmosphere. For example, most UV energy is absorbed by ozone in the upper atmosphere, but some of it still gets through. The UV energy that passes through the Earth’s atmosphere can not only harm us by burning our skin, but it can cause other problems such as skin cancer and damage to our eyes.

The amount of Sun’s energy (including the harmful ultraviolet) arriving at the Earth’s surface depends on several things:

- How many clouds are overhead and how thick and dark they are. How cloudy is it? (though remember that you can get sunburned even if it is cloudy!)
- The altitude. How high up from the sea level are you?
- The amount of humidity. How much water vapor is in the air?
- How much dust and dirt is in the air?

These factors determine how much light there is on the ground for us to see, but also how much invisible energy is present. The question of invisible forms of the Sun’s energy is important especially for spacecraft, because they fly outside of the Earth’s protective atmosphere, and are more subject to their very dangerous effects.
Lesson Plan: Sensing Energy

This activity will address the following questions:
What types of energy does the Sun produce?
How can we sense different types of solar radiation?

Preparation

Assemble the needed materials [e.g. in the center of each table, on each student’s desk, etc.]

Warm-up & Pre-assessment

The warm-up show begins a process that develops understanding of solar radiation. At this age level, we are interested in exploring three aspects of energy from the Sun – light, heat, and UV. There are other activities in this module that can be used to develop more ideas about the sun’s energy. Since the kids may know about the light, we begin here.

To reveal children’s ideas about light, ask them to think of everything they know about light from everyday experiences. Prompt with questions as needed:

- Think of as many things as possible that give off light.
- Using my senses other than sight, how else might I sense that a light bulb is turned on?

Materials

- Five or six Ultra-violet Detection Beads* per child
- lamps, overhead projector, a grow-light for plants
- 9 empty, opaque film canisters per group
- Colored filters
- a white piece of cloth
- a black piece of cloth
- a baseball cap
- water
- paper clips
- plastic wrap
- a paintbrush or sponge
- Sunglasses
- Sunblock lotion sunscreen (spf 5 or 8, and 30)
- Flashlight
- UV eyeglasses
**Teaching Tip**

Give the children the opportunity to explain their ideas by asking them to draw and write down their explanations.

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**Procedures**

**Part 1**

1. Provide each student with a few of the Ultra-violet light Detection Beads. Explain that they have a detection tool in their hand that will turn color when a special kind of energy is present.

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**Teaching Tip**

Individual beads may be hard for some students to hold. String the beads and secure them with a knot if necessary.

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2. Have the students move around the room, looking at the color of their beads, placed under different sources of light (e.g. lamps, overhead projector, a grow-light for plants) Note that fluorescent lighting will not change the beads’ color. As the students move towards the window they should notice that their beads will begin to change color. Take them outside if possible; it need not be a bright sunny day.

3. Class discussion: Prompt students with the following questions to help them develop an explanation for the changes they are seeing in the UV beads.

- What do you notice about the beads? (They should say a change in color)
- What color were they before? What color are they now?
- Are all the beads changing color? If not why not? If so, why do you think?
Teaching Tip

It is important for the students’ to explore their ideas. Allow the students time to explore their beads and develop their own mini-investigations.

Some students may think that it is the Sun’s light that is changing the color of the bead. Other may think that it is the Sun’s heat. Encourage the students to think of different ways of testing their ideas.

Part 2

1. Find an area in full sunlight.
2. Arrange the students into groups of 3-4 and distribute materials.
3. Have each group of students put three UV beads in each film canister (You will not be using the lids unless you want to prevent the beads from escaping during the walk to the outdoors. Remove lids once outside. Different coverings will be tested in this experiment

4. Instruct students to test the following nine scenarios (if it is difficult to do all 9 tests at the one time, break the experiment into a couple of separate sessions):
   - Canister 1. (control) Set it on a desk or the ground with nothing over it.
   - Canister 2. Lay a white piece of cloth over it.
   - Canister 3. Lay a black piece of cloth over it.
   - Canister 4. Put sunglasses over this canister.
   - Canister 5. Put a baseball cap over this canister.
   - Canister 6. Fill this canister with water. String the beads on a paper clip so that they will sink.
   - Canister 7. Cover this canister with plastic wrap.
   - Canister 8. Cover this canister with plastic wrap and then apply a coat of sunscreen (spf 5 or 8) to the plastic with a paintbrush or sponge.
   - Canister 9. Repeat the instructions for the previous canister using an spf 30 sunscreen.
5. Tell students to let their canister sit for five minutes in the sunlight- either outdoors or in a sunny window.

6. While waiting for the results to appear, conduct a whole group discussion to have the students predict what might happen in each of the canisters. Prompt with questions if necessary, such as:
   - What do you think will happen to your beads? Why?
   - Will the same thing happen to everyone else’s beads?
   - What colors do you predict they will become? What makes you say that?

7. After five minutes, have students check the canisters one at a time and record the results on Worksheet 1. Before checking they will need to move the canister to the shade and look quickly. The response time of the beads is very rapid. If the beads are not examined in the shade immediately and if the students look too slowly, the results will not be valid.

**Teaching Tip**

Ensure that all students have observed the beads in their group. Only one student need fill out the worksheet, however. Others may also do so if you prefer.
DISCUSSION & REFLECTION

The point of this exploration is to think further about the Sun’s energy.

Have each group discuss their observations amongst themselves for two or three minutes, and perhaps choose a spokesperson for the entire class discussion, if necessary.

Bring the groups together, and discuss the basic findings, and what caused them. Prompt with questions such as:

- The beads in which canisters changed color?
- Did they all change into the same colors?
- Why do you suppose that certain beads changed color and not others?
- Look at the results from the different canisters, and compare two, now three canisters.
  What do you notice? What is different from each canister? For example, is white cloth different from black cloth in changing the amount of UV radiation that reaches the beads?
  What can you conclude about which materials best blocked ultra-violet radiation?

LESSON ADAPTATIONS

For students who know about other planets, ask them to speculate about how much of the Sun’s power reaches them. Ask about visible light, heat, and UV radiation. You may want to mention here the other forms of solar energy discussed in the Science Overview (including gamma, X-rays, infrared and radio waves).

Prompt with study questions or research topics such as:

- How would the Sun’s energy be different on different planets such as Mercury or Pluto?
- What features about the other planets make them different from Earth? Why are those features important when we think about light, heat, and UV radiation?

To make this lesson more relevant to students’ knowledge of biology in the early grades:

- Explain how insects use their ability to sense ultra-violet radiation. Butterflies and bees see ultraviolet light as a distinct color that makes certain markings on flowers very vivid to them and guides them to the nectar tubes.
Curriculum Connections

- Health: Invite the school nurse or dermatologist to talk with students about the importance of using sunscreen to protect their skin from ultra-violet light.

Assessment

Ultra-violet beads offer third and fourth graders a fine opportunity to develop a scientific investigation or fair test. Ask your students to design their own test to show how the beads respond under different conditions.

The following list outlines some useful expectations on how to assess such investigations.

Exemplary:

- Students plan controlled investigations of predictions with a rationale based on scientific thinking.
- Students repeat procedures to confirm observations.
- Students apply measurement to represent their ideas.
- Students select appropriate charts and graphs to record and then interpret their findings.
- Students make conclusions that relate their findings to scientific thinking and propose further questions for investigation.

Emerging

- Students make predictions that guide the formation of fair testing procedures.
- Students defend their procedures and rationale for selecting them.
- Students carry out fair tests, knowing why they are fair.
- Students select and make appropriate measurements.
- Students complete a chart or graph to record and help interpret their findings.
- Students draw conclusions and attempt to relate their findings to scientific thinking.

Formative

- Students describe what they expect to happen when something is changed and supporting that idea with some scientific thinking.
- Students use suitable equipment to make and record adequate and relevant observations.
- Students record what they find and compare it to what they expected.
- Students make appropriate measurements.
INTERNET RESOURCES & REFERENCES

UV Detection beads can be purchased from Educational Innovations Inc. (1-888-912-7474) or on-line www.teachersource.com.
**Worksheet 1**

Record observations of UV beads in film canisters.

<table>
<thead>
<tr>
<th>CANISTER</th>
<th>START COLOR</th>
<th>END COLOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canister 1. (control) on the ground with nothing over it</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canister 2. covered with a white piece of cloth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canister 3. covered with a black piece of cloth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canister 4. covered with sunglasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canister 5. covered with a baseball cap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canister 6. filled with water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canister 7. covered with plastic wrap</td>
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<td></td>
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<tr>
<td>Canister 8. covered with plastic wrap and a coat of sunscreen (spf 5 or 8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canister 9. covered with plastic wrap and a coat of sunscreen (spf 30)</td>
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