

# **MESSENGER Education**

(draft 9/16/02 – M. Radnofsky & C. James)

## **INTRODUCTION**

Tonight, if you look up into the sky, you'll see the same bright lights that your ancestors admired, named, and utilized 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 both to increase our knowledge and to reach out to any other life forms that may exist in our universe. We have succeeded at doing the former, but have yet to achieve the latter.

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-20<sup>th</sup> 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 more deeply explore 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 could "see" in different spectra. These instruments would have to endure the stress of leaving the Earth's comfortable atmosphere with the thrust of a mega-ton rocket, and continue to function under the most hostile conditions imaginable: the cold vacuum of space, intense heat and radiation from the Sun, and quick changes between the two as a spacecraft speeds along at thousands of miles per hour.

## **EXPLORING THE SOLAR SYSTEM**

The most recent of our instruments is MESSENGER, the MErcury Surface, Space ENvironment, GEochemistry and Ranging mission, designed to orbit Mercury following two reconnaissance flybys. MESSENGER will investigate the following key science questions:

### **1) Why is Mercury so dense?**

All terrestrial planets have a dense, iron-rich core covered by a rocky mantle, but Mercury's core is 65% of the planet — twice as much as Earth. MESSENGER will look for clues on the planet's surface to explain this strange phenomenon.

## **2) What is the geologic history of Mercury?**

Mercury has some mysterious features that we can't yet explain: Between its largest old craters are slightly younger plains. Many scientists believe these were created by ancient lava flows, but no one is certain. MESSENGER will send back information about events and forces that shaped the planet's surface. Pictures of previously unseen portions of the planet (about 50%), will also be sent back to Earth.

## **3) What is happening in Mercury's core?**

One of our surprises from the first mission to Mercury (Mariner 10) was that it has a global magnetic field. In fact, Mercury is the only terrestrial planet besides Earth to have one. Mercury's magnetic field is weak, but the fact that it exists at all raises some interesting questions about what is happening deep inside the planet. MESSENGER will measure Mercury's libration (the amount it "wobbles" as it spins on its axis), and its gravitational field to tell us about the size of the planet's core and how much of it is solid.

## **4) What is the nature of Mercury's magnetic field?**

Earth has a "dipolar" magnetic field, meaning that the field is shaped like that of a bar magnet, with positively and negatively charged poles. Mercury's field is also dipolar. In contrast, the Moon and Mars have local magnetic fields centered on different spots. Although scientists have several theories about how much of Mercury's field comes from such smaller local fields, they are not certain about how those fields were formed. MESSENGER will examine Mercury's magnetic field over four Mercurian years (each 88 Earth days) in detail, to determine its exact strength and how its strength varies with position and altitude. We will also learn how the magnetic field behaves in response to solar activity.

## **5) What are the unusual materials at Mercury's poles?**

In 1991, scientists were excited to learn from Earth-based radar images that something inside the craters near the poles on Mercury were strongly reflecting radar pulses. The most common material to explain this behavior is ice ... but how could ice exist on the planet closest to the Sun? Since the planet doesn't tilt, the poles and surrounding craters remain permanently shadowed. Scientists hypothesized that water molecules from comets and meteorites may have reached these cold and shadowed craters, become trapped, frozen, and accumulated over billions of years. Others thought that water vapor from the planet's interior may have seeped out and frozen. Today's scientists hope that some of MESSENGER's instruments may tell us if the polar caps are made of water ice or other materials.

## **6) What is the nature of Mercury's atmosphere?**

Mercury is surrounded by an extremely thin layer of gas. It is so thin that, unlike the atmospheres of Venus, Earth, and Mars, the molecules surrounding Mercury don't collide with each other. Instead, they bounce from place to place on the surface, almost like rubber balls. MESSENGER will measure Mercury's atmospheric composition and compare these data with what we learn about its surface rocks, revealing clues as to the origin of the five different elements (hydrogen, helium, oxygen, sodium, and potassium) known to exist in the planet's atmosphere.

We go into space, to the Moon, and now to planets such as Mercury, even in the face of great risk, to push the boundaries of our problem-solving beyond current limits. We 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 address challenges that face us here on Earth.

As we identify the complex risks that must be overcome to safely venture out into the inhospitable vacuum of space (even in unmanned spacecraft), we work on engineering, scientific, and communications issues that transcend the limits of a single mission, and apply what we learn to all our information gathering, sharing, and storage. One important issue involves developing back-up systems to ensure that there is no loss of accumulated knowledge due to natural or mechanical catastrophes, to human failings, to the vagaries of unstable governments or changing religious beliefs, or to the fear of knowledge itself. How we study and save our society's knowledge base speaks to how we intend to teach others what we have learned.

## **STUDYING THE PLANET MERCURY**

The scientific work for MESSENGER consists of identifying and applying efficient processes to accomplish the mission, conducting experiments to test hypotheses, and making observations. To better understand the planet Mercury, scientists and engineers organize massive amounts of scientific information, combine it in unique ways, and conduct precision work to build miniaturized, powerful instruments that will yield answers to our major questions about other worlds, and thus about our own.

For example, Mercury has an unusually high ratio of metal to silicate. Understanding how this came to be can provide clues to how terrestrial planets were formed. The geological evolution of Mercury seems to be different from other planets: explanation for many of the surface features remains uncertain, and it is not known how big a role volcanism, for example, may have played there.

Furthermore, Mercury is the only terrestrial planet to have a global magnetic field. Why this is so remains a mystery, and MESSENGER is expected to help in answering this question by determining whether Mercury has a solid or molten core. If Mercury's core is solid, the global magnetic field must be generated by a different mechanism from that of Earth; if at least some of the core is molten, it remains to be explained how Mercury has avoided cooling off as quickly as simple calculations would predict. In addition to determining the composition of Mercury's exosphere and the source of its volatile species, MESSENGER will also investigate whether ice exists in Mercury's polar regions, as radar observations from Earth have suggested. Answering these questions will provide important points of comparison with the Earth, in determining how the processes controlling the evolution of the two planets are the same, and how the differences have led them down a different path to their present states.

## **TEACHING ABOUT THE MESSENGER MISSION**

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 man-made probe to the closest planet to our Sun to learn information, and we ask students to consider the processes and manpower needed to complete such a mission.

We continue by introducing students to different branches of science that must be studied for understanding the data that experts retrieve from the spacecraft. These include astronomy, physics, astrogeophysics, chemistry, astrogeochemistry, geology, astrogeology, dynamics, electrodynamics, hydrodynamics, fluid mechanics, thermodynamics, quantum mechanics, magnetism, meteorology, astrometeorology, optics, and geomorphology, to name a few.

We extend beyond the sciences to make interdisciplinary connections, including 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 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 challenges that motivate students to build better systems, design new 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 help teachers create an environment conducive to Socratic dialogue so that students are active participants in the acquisition of personal knowledge and in the construction of a common knowledge base. To do this, we strive to provide teachers an understanding of science so that they can recognize and promote the small, but relevant ideas that are related to larger, more significant theories.

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 Story**

The MESSENGER story, presented in grade-appropriate ways at four different levels (Pre-K–1, 2-4, 5-8, 9-12), is told through several lessons in each of the following three themes:

- **Comparative Planetology** - By studying Mercury, we look at the diversity of worlds and add to the knowledge base about the Solar System, its formation and evolution.
- **The Solar System Through History** - By studying Mercury, we learn about scientific discoveries and cultural interpretations from ancient civilizations to the present.
- **Framing Pathways to Answers: The Scientific Process in Action** - By studying Mercury and our efforts to reach there, we define and solve design and engineering problems, and approach scientific research in innovative and productive ways.

### **Pre-K – 1**

In the early elementary grades, MESSENGER lessons focus on literacy: both in science and in general reading/writing skills. Children are offered science content and a context in which to

practice and improve literacy skills; this combination fosters the development of both knowledge and skills, improves their motivation and interest in the subject area, and contributes to their overall educational success.

While MESSENGER lessons are fascinating science experiences, they also provide interdisciplinary connections across the curriculum in areas other than reading and writing. We show pathways to related subjects in all our lessons, giving children ample opportunity to use the literacy skills they are acquiring to access an entire academic curriculum.

The first unit is “Staying Cool” and falls under the theme, “Framing Pathways,” since one of the first ideas we introduce in the MESSENGER educational program is the concept of venturing into inhospitable environments to explore what is out there, despite the risks.

Some lessons that address this concept include: *Sources of Light; Stars and the Sun; Sources of Light; Shadows; Hot and Cold and In Between; In the Shade- How to Stay Cool; Materials That Protect- (Potholders, Fireman's Suit); Design Challenge: Keeping My Lunchbox Cool.*

## 2-4

As children proceed through elementary school, they require continued opportunities that allow them to engage in scientific exploration. This will help them to connect ideas and build concepts, while challenging old ideas and testing new ones in light of new experiences and evidence. Once they can do this in increasingly rigorous and reliable ways, children will be able to improve upon their own ideas in order to better understand – and contribute to – the world around them.

As with the other grade levels, this one will culminate with a Design Challenge; here, students will be asked to create some sort of solar shield to protect an object from the harsh effects of our Sun. Leading up to that final project will be lessons such as the following: *Astronomy With a Stick: Exploring the Sun's Movement; Heat From the Sun; Sensing Energy; Measurement of Heat; Absorption of Heat-Explorations of Colors and Materials; What Does Heat do to Materials?; What are Some Cool Materials?; How Much Solar Energy Can We Collect?*

## 5-8

In middle school, the MESSENGER educational program strengthens existing Earth science courses not only with lessons in Comparative Planetology, but with lessons such as *Terrarium!*, *Baseball Gravity Assist*, *Snow Goggles*, and *Wax People*.

To keep students interested in science at this transitional age, we offer a large number of hands-on activities that encourage both boys and girls in individual as well as group discovery.

There is often a wide range of abilities in middle school students, due in large part to the varying quality of their elementary education, and to individual maturing differences. We recognize teachers’ need to tailor lessons to a particular population, and we therefore provide a considerable amount of lesson adaptation suggestions, such as for students who are learning disabled, gifted, ESL, or have other special needs.

## 9-12

At the high school level, the MESSENGER educational program offers students an overall perspective of exploration, helping them combine fragments of accumulated knowledge into a meaningful whole.

The MESSENGER curriculum encourages high school students to take serious steps towards scientific careers or at least towards a more scientific approach to everyday problems and issues. Students will handle real data from the MESSENGER mission as transmitted to NASA scientists, and conduct their own investigations, analyzes, and interpretations.

Lessons include: *A Radioactive World, Composite Materials; Marble Trajectories; Time Synchronization; Water Spectrophotometer; and Building a Model MESSENGER.*

# National Science Education Standards Relevant to MESSENGER

---- D R A F T ----

## Unifying Concepts and Processes

- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement
- Evolution and equilibrium
- Form and function

## Science as Inquiry

- Abilities to do scientific inquiry
- Understanding about scientific inquiry

## Physical Science

- (K-4) Light, heat, electricity, magnetism
- (5-8) Motions and forces
- (5-8) Transfer of energy
- (9-12) Chemical reactions
- (9-12) Motions and forces
- (9-12) Conservation of energy and increase in disorder

## Life Science

- (9-12) Matter, energy, and organization in living systems

## Earth and space science

- (K-4) Objects in the sky
- (5-8) Earth in the Solar System
- (9-12) Geochemical cycles
- (9-12) Origin and evolution of the universe

## Science and technology

- (K-4) Abilities to distinguish between natural objects and objects made by humans
- (K-12) Abilities of technological design
- (K-12) Understanding about science and technology

## Science in personal and social perspectives

- (K-4) Changes in environments
- (5-8) Risks and benefits
- (5-8) Science and technology in society
- (9-12) Science and technology in local, national, and global challenges

## History and nature of science

- (K-12) Science as a human endeavor
- (5-8) Nature of science
- (5-8) History of science
- (9-12) Nature of scientific knowledge