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Planetary Exploration in Science Education

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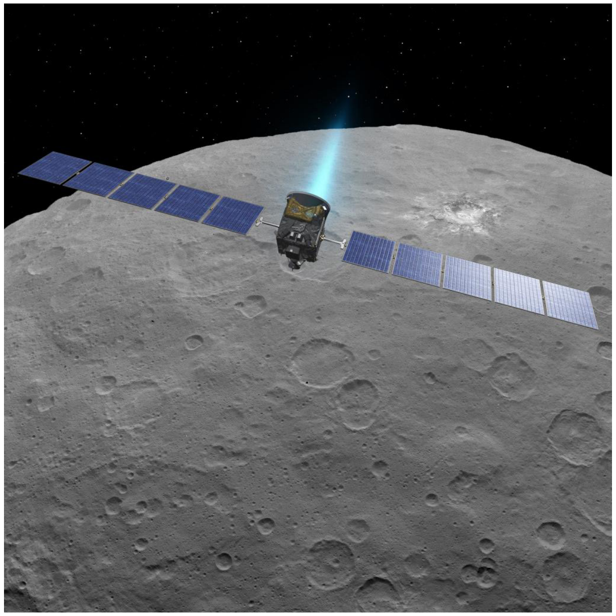
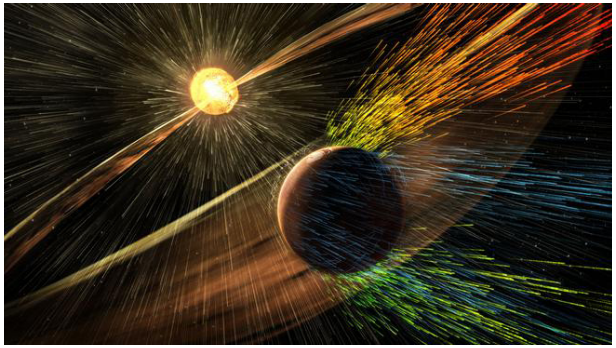
Exploring the Big Questions in Planetary Science

Planetary missions are giving us insight into a variety of bigger questions—how did the Earth and Solar System form? How do planets change over time? What are the conditions for life, and where might we find life? Why is Earth so different from the other planets? Educators can engage students of all ages in planetary exploration, connecting them to current research and the reasons for exploring.

To answer these big questions, we have sent robotic missions to explore our Solar System and planetary systems beyond our own. Recent NASA missions include New Horizon's 2015 flyby of Pluto, the Dawn mission's exploration of the dwarf planet Ceres and the asteroid Vesta, and MAVEN's ongoing survey of the Martian atmosphere and climate. Continuing missions include several Mars orbiters and the Curiosity and Opportunity rovers exploring Mars' geologic history. The Kepler mission has created a treasure trove of data regarding planets orbiting other stars, which is still being mined. Other countries have sent and are planning robotic missions to the Moon, Venus, and Mars. In 2016, the NASA Juno mission will arrive at Jupiter to examine its structure and composition, and OSIRIS-REx launches to the asteroid Bennu.



The Dawn mission's observations indicate that Ceres may have originally formed much farther from the Sun. There is other evidence that the planets may have migrated to their current positions early in the history of our Solar System. (NASA/JPL-Caltech)

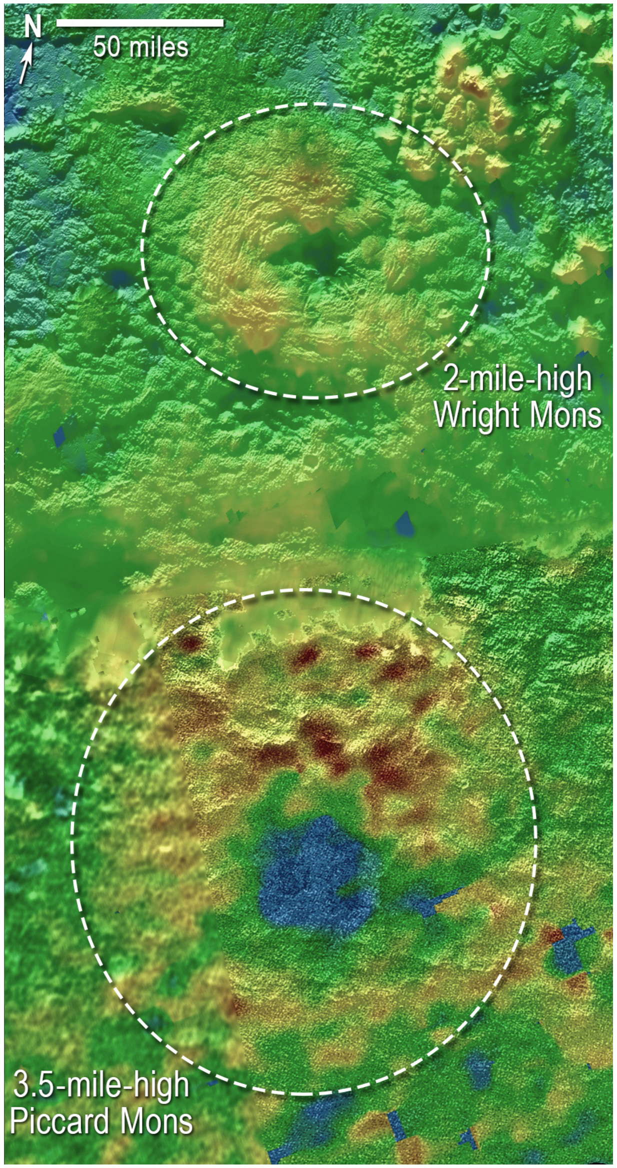


Planets can evolve over time. Cold Mars may have had a much thicker atmosphere early in its history, protected by a global magnetic field. MAVEN is studying how Mars' atmosphere was eroded over time, making Mars became the frozen world we see today. (NASA/GSFC)

Planetary Exploration and Technology

Beyond what we are learning about the planets and asteroids, we are also developing new technologies to gather the data needed to answer these questions. Different types of missions and instruments are needed to pull together the pieces to the puzzles we face.

After telescopes, the earliest planetary missions were flybys—these take less power and require less



Volcanism is pervasive throughout the Solar System. MESSENGER found extensive volcanic flows on Mercury, Mars has the largest volcanoes in the Solar System, and Jupiter's moon Io has the most frequent. Scientists were surprised by New Horizons' images of features resembling typical volcanoes on Pluto, shown here. (NASA/JHUAPL/SwRI)

advanced knowledge of a world than an orbiter. Flybys are still employed today as a means of making initial observations of distant worlds, like the New Horizons' flight past Pluto and its upcoming rendezvous with a Kuiper Belt Object.

Orbiters require more time and energy, but provide more extensive observations. The Dawn mission has an innovative ion propulsion engine that allows it to adjust its acceleration and altitude, which allowed it to enter into orbit around Vesta, then to travel to and orbit the Ceres.

The earliest instruments on flybys and orbiters included television cameras; today's missions include more advanced cameras and sensors to map out planetary features at a variety of wavelengths, and spectrometers to help determine composition. They can also have magnetometers to examine a planet's magnetic field, transponders on different frequencies to measure how a planet's gravity is affecting signals from the spacecraft, radiometers, and more.

After a planetary body has been examined enough, scientists may send a lander to take measurements from the ground, or even use a robotic rover to maneuver on the surface. The final step in robotic exploration would be to return a sample for study here on Earth, where our larger variety of instruments can study it at length and in greater detail than a lander. NASA has samples of the Moon returned by the astronauts, particles of a comet returned by the Stardust mission, particles from the Sun returned by the Genesis mission, meteorites from Antarctica which originated from a variety of sources (including the Moon and Mars), and cosmic dust gathered high in Earth's atmosphere from aircraft.

Planetary Exploration and the Nature of Science: Strange New Planet

One critical aspect of science education is teaching what science fundamentally is and how it is conducted. The Nature of Science includes exploring the relationship between science and technology (see the Next Generation Science Standards below.) The history of planetary exploration can be used to demonstrate this relationship. As scientists make new discoveries, they form new questions. Sometimes these questions inspire the design of new instruments. As new technology extends our capabilities, it gathers data that often surprise us, answering questions we didn't even know we had.

The activity *Strange New Planet* can be used and modified to demonstrate this relationship between science and technology. The activity was devised by Mars Education at Arizona State University, building on a teacher's initial design, to model the variety of missions such as Earth-based telescopes to landed missions. The original version is available at https://solarsystem.nasa.gov/docs/Strange_New_Planet.pdf, and a revised 5 E version is at https://marsed.mars.asu.edu/strange-new-planet.

Jaclyn Allen and Kay Tobola from Johnson Space Center's ARES education have modified this activity to emphasize this relationship between developing new questions with new data. The Lunar and Planetary Institute (LPI) education team has worked with them to incorporate this activity into workshops for teachers and has incorporated this activity into both workshops and family science events.

The materials are simple:

- Paper towel tubes for each team
- Blue plastic wrap to cover one end of each tube (and rubber bands to temporarily hold them into place)

- A place to put the planets (a small table or raised platform)
- Material to cover the planets
- One to three designed worlds with features that can be observed and from which inferences can be made
    - If you create 3 "planets" your teams can have different targets.
    - We have found sculpting clay (not play-dough) around a Styrofoam ball will result in a planet that can be re-used over months and years. Different colors and landscaped features can be used to simulate ice, volcanoes, oceans, craters, and even green life.
    - Make sure that at least one planet does not look like those we have seen before—with recognizable features like craters or ice caps or volcanoes but not closely resembling Earth. These should be strange "new" planets.
    - Very thin cotton or batting material can be used to simulate clouds or gas from an eruption.
    - If you intend for your students to select items for a return sample, add materials that can be used to interpret characteristics; for instance, Jaclyn Allen frequently added whole cloves as an indication of organic material.

Procedure:

In the classroom, students usually work in teams of 4. Let them know that they will make observations and infer characteristics of "newly discovered" planet.

- Set up one or more planets, covered, in a clear area away from the students. Ideally the planets are elevated on a box or a cup, to make it easier to observe the entire hemisphere.
- For each of the steps below, the teams select a new student to make the observations (while the others look away). That student shares the observations with the team; this mimics the science process in which scientists receive data from an instrument/observer; not all scientists are involved in the initial gathering of data.
- Teams then record their data, their inferences, and the new questions they have about the planet(s). After each step, each team must have and report out scientific questions in order to continue with a new mission; NASA never sends a mission without science questions they want answered.

Note: Classroom discussion at each step can include sharing each team's new questions, and their thoughts on the next logical step to answer these questions. What technology would be cost-effective and appropriate for the next step? For instance, after the planets are first observed in Step 1, would it be appropriate to send a spacecraft to go land on the planet(s)? (They don't have enough information to justify the expense, nor enough data to determine where the best spot to land would be, etc.)

- **Step 1: Observing from a ground-based telescope.**
  One student from each team observes the newly discovered planet(s) from a distance (such as 6 meters), through a paper towel tube covered with blue plastic wrap, for a short time (such as 5 seconds) before the objects are covered again. (Typically the observers can't distinguish colors or features and may not be able to distinguish whether there is one planet or two if they are close to each other.)
- **Step 2: Observing from an Earth-orbiting telescope.**


(LPI)

  A new student from each team observes the new planets from the same distance through a paper towel tube without the blue plastic wrap. Observations will now include colors but will still be limited. Teachers should not try to limit the students' observations and may be surprised by the variety of resulting reports.
- **Step 3: Planetary flyby.**


(LPI)

  A new student from each team walks past the planet(s) in a short period of time (e.g. 7 seconds), but is only able to see one side of the planets; if you have positioned key features (like an active volcano) on the other side, they won't see it.

- **Step 4: Planetary Orbiter.**

(LPI)

A student from each team walks around the planet(s) once in a short period of time (e.g. 10 seconds).

- **Step 5: Planetary Lander/ Sample Return.**

(LPI)

If the planet(s) have been created with materials to return and bring back to the teams (such as cloves, small pebbles, etc.) each team should decide in advance which spot on the planet and what object they would like to obtain a sample return from.

- Whole group discussion at the end should include explicit conversations about the relationships between new science questions and the mission needed to answer them, as well as the practical limitations that determined what the next mission would be for each step. Discussions should also include the relationship between observations and new questions.

Options and alterations:

- Many teachers participating in this activity have asked whether they could record the data using their phones or tablets—taking pictures or videos to share with their team. Educators should be prepared to take advantage of different ideas that students may suggest to engage the students further in this activity.

(LPI)

- In one workshop, participants asked to hold a "conference" halfway through the steps, to share out and report their data and inferences with each other, which mimics the way that scientists collaborate to compare their findings and to engage in scientific argumentation over their interpretations of the data.
- For informal education settings, we have invited children (primarily ages 5-8) to work in pairs to each observe a different planet, separated from each other by a divider. Instead of covering and uncovering the planets, the children proceeded to move closer to the planets for each step (marked by masking tape), starting many meters away from the planets. The children shared their observations and inferences by walkie-talkie with each other at each step.

Strange New Planet: Connections to Next Generation Science Standards:

Appendix H: The Nature of Science

Scientific Investigations Use a Variety of Methods

- Science investigations begin with a question.
- Science methods are determined by questions.
- Science investigations use a variety of methods and tools to make measurements and observations.

Scientific Knowledge is Open to Revision in Light of New Evidence

- Science knowledge can change when new information is found.
- Science explanations can change based on new evidence.
- Scientific explanations are subject to revision and improvement in light of new evidence.
- Science findings are frequently revised and/or reinterpreted based on new evidence.

Science is a Human Endeavor

- Most scientists and engineers work in teams.
- Creativity and imagination are important to science.
- Advances in technology influence the progress of science and science has influenced advances in technology.

- Technological advances have influenced the progress of science and science has influenced advances in technology.

Science Addresses Questions About the Natural and Material World

- Scientific knowledge is constrained by human capacity, technology, and materials.

Appendix F: Science and Engineering Practices in the NGSS

Asking Questions and Defining Problems

- Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships

Planning and Carrying Out Investigations

- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.

Constructing Explanations and Designing Solutions

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Resources

For more about the big questions in planetary science, go to

NASA Science: science.nasa.gov/big-questions/

Solar System Exploration: solarsystem.nasa.gov/

For more information about the different planetary missions and their discoveries, go to:

Solar System missions: solarsystem.nasa.gov/missions/

Astromaterials (Planetary Sample Returns): curator.jsc.nasa.gov/index.cfm

Dawn Mission: dawn.jpl.nasa.gov/mission/

Mars Missions: mars.nasa.gov/

New Horizons Mission: pluto.jhuapl.edu/

Juno Mission: www.nasa.gov/mission_pages/juno/main/index.html

Other Planetary Activities

There are other activities that also help students understand the planetary exploration and mission process, including the compromises that need to be made to ensure a successful mission. They include:

MarsBound: marsed.asu.edu/lesson_plans/marsbound
Students engage in a mission planning simulation that mirrors a Mission to Mars. Students create a mission that has to balance the return of science data with mission limitations such as power, mass and budget. There are different versions for grades 3–5, middle school, and high school

Planning a Mission to the Lunar South Pole: www.lpi.usra.edu/education/workshops/unknownMoon/Friday/DivinerActivity.pdf
After evaluating an assortment of data, students decide which of seven locations situated in the lunar south polar region is the most suitable for a future settlement, taking into account four environmental factors — temperature, water supply, illumination, and communication.

Unlocking the Mysteries: discovery.nasa.gov/multimedia/mysteries.cfml
After learning about the current explorations to planets, asteroids, comets, and more, students respond to a request from NASA for ideas for the next generation of robotic space missions. Students take on the roles of scientists and engineers to design a mission to investigate the cosmic unknowns while learning that space exploration requires many people with different skills, talents, and abilities to work together to achieve their goals. There are also ways to connect planetary science further to the Nature of Science.

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Blue Marble Matches: http://ares.jsc.nasa.gov/education/eeab/bmm.cfm
This activity is designed to introduce students to geologic processes on Earth and model how scientists use Earth to gain a better understanding of other planetary bodies in the solar system. As part of the process, students learn that scientific debate and using evidence to back up interpretations are key elements of science. Students should realize that not all scientists agree, which is an important aspect of how science progresses.

Planet Swap/ Revising Ideas
Version 1: www.lpi.usra.edu/education/workshops/SSE/activities_resources/Planet_Swap.docx
Version 2: www.psi.edu/sites/default/files/images/epo/DPS2015/Sentence%20activity%202.pdf
This activity to help students understand how science is revised with new information. Students work in groups to select words to overturn, and after each 5 words attempt to predict the meaning of the sentence.

Observations and Inferences
Mars version: www.lpi.usra.edu/education/workshops/mars/2014/Tuesday/ObservationsInferences.docx
Solar System version: www.psi.edu/sites/default/files/images/epo/DPS2015/revised%20Observations%20and%20Inferences.pdf
Students examine a photo or a table and decide which of the statements for each is an observation or an inference; teachers should plan on having a discussion with them and determining which items arguably fall into either category depending on interpretation.

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