Jet Propulsion Laboratory
California Institute of Technology

A New Way to Explore the Solar System

Educational
Outreach Program

For the creative teacher who wishes to inspire students about the wonders of space exploration.

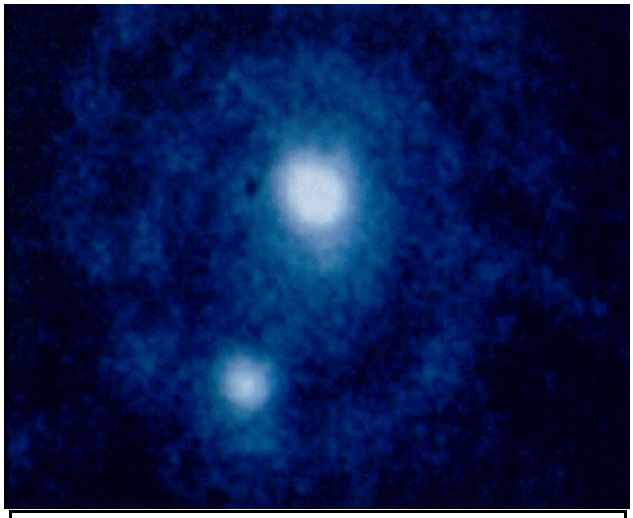
ASTRONOMY: THE SCALE OF THE UNIVERSE

PLANETS

BACKGROUND DISCUSSION

What is a *planet?* Originally planets included the seven objects in the sky that moved in distinctly different ways than the seemingly fixed firmament of stars. These magnificent seven included: the Sun, the Moon, Mercury, Venus, Mars, Jupiter and Saturn, all visible to the naked eye. Earth was considered to be the center of the universe.

Later, with the confirmation of the Sun as the center of the Solar System, humanity gradually accepted Earth's humble position as the third planet out from the Sun.



Pluto, as seen from the Hubble Space Telescope.

Numerous theories about the formation of the Solar System congealed around what is now known as the *Solar Nebular Theory*. Basically, scientists infer that a huge cloud of hydrogen gas was shocked by a supernova explosion of a nearby star, which sent things whirling. Eventually a protosun formed surrounded by a disk of hot debris.

Planets may have formed as condensations of hot gaseous material into clumps that then swept up other debris until the interplanetary space was swept virtually clean by the orbital actions of the protoplanets. Another possibility is that as the gas whirled, variations in the density caused clumps that accreted to form the planets. By accretion or by condensation, or by some combination of the two processes, the planets formed. The exploration of Pluto and other planetary bodies is partly intended to shed light on the origins of the planets.

EDUCATIONAL OBJECTIVES

1.To provide basic background information about the history and current thinking about the features of planets.

2.To provide teachers with an experience-based framework for using the theory of multiple intelligences to teach about planets.

MATERIALS: Paper for drawing, along with a variety of crayons, colored pencils, markers, pens and pencils.

SETTING: This activity works best in a relatively open area such as a playground or nearby park, an auditorium or multi-purpose room. Ambient music provides a thoughtful atmosphere.

TIMETABLE: Activity generally takes about 40-60 minutes .

ACTIVITY INSTRUCTIONS

The study of planets lends itself to the multiple intelligences approach in such a way that lessons can be designed seamlessly, moving through each of the seven intelligences, each modality resonating and enriching the others.

For teachers, *The Planet You* can be a way to explore the contours of a multiple intelligences approach with a view toward adapting existing curriculum material. *The Planet You* has been conducted as a teacher enhancement workshop on many occasions for national and international educator conferences.

The Planet You can be used as an introductory activity, to stimulate thinking about planets and to provide a basis for research and discovery. Or it can be used in the middle or at the end of unit about the planets of the Solar System as a way to integrate new learning experientially. Any of the lesson segments can be conducted as a stand-alone activity or as a way to motivate student interest in the planets themselves.

Role of the Teacher as Facilitator: As each exploration is introduced the teacher gives instructions that are meant to draw out the expressiveness of each student. As students participate, the teacher engages them by observing the activities, sometimes entering into groups to listen in unobtrusively.

Start by putting on some music to inspire thinking about planets. (Suggestions: Holst's *Planets*, other classical pieces easily associated with space, or background free-form jazz). The presence of music transforms the classroom and signals that something a little different is about to transpire. Let the music continue throughout the session.

MATHEMATICAL/LOGICAL EXPLORATION

Create a list of features that characterize what a planet is.

Discuss the topic of planets, raising a series of questions:

- If you discovered a new object in the night sky what criteria would you use to decide whether it is a planet?
- What are some distinguishing features about a planet?
- What do you have to do in this Solar System to qualify as a planet?

The idea is not to fish for *right answers* but to inspire *good questions* to explore for further development. This allows the teacher to assess the range of understanding and prior concepts within the class.

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Activity Instructions
The Planet You

INTRAPERSONAL EXPLORATION
Think of yourself as a planet. Consider the features of the Planet You. Reflect in a guided relaxation/meditation about The Planet You.
Sample Script: It's really it's not so surprising that the idea persisted for so many centuries, that Earth was considered the center of the universe. We live the psychological *truth* that everything centers around YOU.

Imagine the Planet *YOU*. Consider the planet-like aspects of who you are? What features do you think you should include? What shape, what surface, Does it have a core, does it have influence beyond its surface boundaries. Take a deep breath, Close your eyes for a moment, and really consider you, yourself, as the planet.

Through the next series of activities you are all invited to share some thoughts about your own *Planet You.*

V I S U A L / S P A T I A L EXPLORATION
Draw the Planet You.
Sample Script: Now, take a piece of paper, some colors and pencils and draw the Planet *You*. Let your imagination go. Participate in the age-old tradition of personifying the planets. Be prepared to share your own Planet *You* with those around you, giving a quick description of your drawing.

LINGUISTIC EXPLORATION
Write About the Planet You.
Sample Script: As you finish your drawing, write a brief passage about some aspect of the planet you have drawn: a description, a poem, a song, what it might be like to visit there, a day in the life of the inhabitants. Be prepared to read your passage aloud to those around you.

MUSICAL EXPLORATION
Consider the sounds and rhythms of the Planet You.
Sample Script: Musicality includes rhythm and sound. On Earth, we experience the rhythms of day and night, the seasons, months, and years. Sounds result form our hearing of vibrations moving through our environment. From the features of your *Planet You*, what sorts of rhythms and sounds would likely occur?

INTERPERSONAL EXPLORATION
Get together in a small group, tell others in the group about the Planet You.
Sample Script: Now find a group of people nearby you to share your drawing and your writing. Tell each other about the Planet *YOU*.

KINESTHETIC EXPLORATION
As a small group select one or several example(s) to dramatize for everyone. Be sure to include each person in the group as a participant.
Sample Script: To inspire the action, let's take a moment to warm-up and move together. Everyone stand up, stretch, roll your hands. Move a bit in every direction. Consider your entire range of movement as your *kinesphere*. How far can you reach up, or out, in every direction. Okay, now get back with your small group to plan a presentation which we will share with everyone in a few minutes.

Select from among the planets in your group and work out a skit based on the ideas. You may go into detail about one planet or a group of planets. You may create a configuration, a solar system. In your skit, you may wish to include narration, sound, action—be sure to involve everyone in the group.

SYNTHESIS: USING ALL SEVEN INTELLIGENCES
Using the combination of intelligences and talents within each group, take turns watching each group present an idea based on the Planets they have created and described.
The alert teacher can comment on the applicability of the creative ideas that emerge in each presentation.

VARIATIONS
Within each area of intelligence, activities can be extended or adapted. Planets can be sculpted in 3-D. Plays can be written and performed based on the ideas of *The Planet You.*

INTERNET RESOURCES
NASA's Jet Propulsion Laboratory focuses on Solar System exploration:
http://www.jpl.nasa.gov
Current thinking on planets and planetary science updates:
http://www.soest.hawaii.edu/PSRdiscoveries/

By R.Shope/J. Giuliano 10/15/97 Contact: Jackie Alan Giuliano, Ph.D. (818) 354-6903 or *jackie@deepteaching.com*

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ASTRONOMY—SCALE OF THE UNIVERSE

INTERPLANETARY DISTANCES: A.U. ! OVER THERE!

BACKGROUND DISCUSSION

How do we measure the distances between planets? Today we can measure interplanetary distances precisely by timing the round trip of radar or laser beams bounced off the reflective surfaces of planets. Before modern times, astronomers used more indirect methods. They worked out the relative distances between the planets visible to the naked eye by comparing the angles formed between the planets, the Sun, and the Earth as they traced out their orbital paths.

Without knowing the actual or absolute distance in miles or kilometers, astronomers could tell the *relative* distances, using the angular distance between the Sun and Earth as the rule, called an Astronomical Unit (A.U.). Early estimates of the absolute distance between the planets were calculated through the ingenious use of basic geometry. While observing planets on a regular basis is no longer an aspect of our modern everyday intuition, the concept of the Astronomical Unit is still useful to help us comprehend interplanetary distances within our Solar System. And of course such information is used on a daily basis by those involved in navigating spacecraft to explore the planets.

The Solar System and the A. U.

For interplanetary distances we use the *Astronomical Unit*, a unit of measurement that corresponds to the average distance between the Sun and Earth: about 93 million miles or 150 million kilometers (Figures

EDUCATIONAL OBJECTIVES

1. To communicate basic knowledge about the size of the Solar System by creating an interactive and experiential scale model of the relative distances between the planets and the Sun.
2. To learn about the Astronomical Unit as a measuring unit.
3. To learn how the AU was first calculated as an absolute distance.

MATERIALS: No materials needed— just a leader and enthusiastic participants!

SETTING: This activity works best in a relatively open area such as a playground or nearby park, an auditorium or multi-purpose room—or even in a long hallway.

TIMETABLE: Activity generally takes about 25 minutes.

ACTIVITY INSTRUCTIONS

The conceptualization of the scale of the Solar System is not likely to be communicated in any single exercise. It is an awareness that grows with repeated exposure to different ways of thinking about our universe. This approach is intended to increase the likelihood that students will emerge with a greater appreciation of the vastness of the Solar System—even for astronomers and space scientists, the scale is awe-inspiring!

Role of the Teacher as Facilitator:

As each exploration is introduced the teacher gives instructions that are meant to draw out the expressiveness of each student. As students participate, the teacher engages them by posing questions that inspire critical thinking about the content embedded in the activity—the scale of the Solar System and how humanity has come to grasp this notion.

MATHEMATICAL/LOGICAL EXPLORATION

Inspire a discussion about units of measure that includes notions about measuring the size of the Solar System.

Relate the stories of other units of measure, such as the foot (being the size of King Henry VIII's actual foot), thereby introducing the notion of units of measurement as sometimes arbitrary, yet also appropriate relative to the scale needed. Ask students to consider what sort of unit of measurement they think would be practical when considering the Solar System. Then describe the Astronomical Unit as the relative distance between the Sun and Earth, which corresponds to an absolute distance (some 93 million miles or 150 million kilometers).

KINESTHETIC EXPLORATION

Involve students in creating a living scale-model of the Solar System, using the students as the planetary bodies themselves.

The abbreviation for Astronomical Unit, AU, conveniently provides a pun to invite the first student volunteer. "AU! (Hey, you!) Over there, will you come over here? Stretch out your arms to be our scale-model of an Astronomical Unit!" The child's name might further personalize the scaled unit—"this is our Sarah Unit" or "our Rafael unit," our SU or RU. As the student's arms are outstretched like wings, begin at one end and let the class count aloud as the AU is calibrated into tenths, counting from 0 to 1 in tenths, marking off each relative distance from wingtip to wingtip.

KINESTHETIC EXPLORATION (Continued)

With the information from the AU table, invite students to become the Sun and the planets, placing them at the proper distance beginning with Mercury and on out to Pluto. Place the Sun at the zero point (at the AU fingertips), Mercury at 0.4 AU (in front of the shoulder nearest the Sun), Venus at 0.7 AU (in front of the other shoulder), and Earth (at the fingertips opposite the Sun). From there, measure the distances using the outstretched arms of the AU until all of the planets are placed at the proper distance to scale. (Be aware that until 1999, Pluto is in just a bit closer than Neptune.) Encourage students to create a dynamic presence when playing the parts of the planets.

KINESTHETIC VARIATIONS

1. Once the idea has been demonstrated students may work in teams of 11-15 in a group to create their own scale model of the Solar System, so that everyone has a *direct experience* of being one of the planetary bodies. Each team selects a way to represent an AU. Each team member acts as one of the objects in the Solar System. The more information the students have available, the more detailed the scale model can be. For instance, students might include moons, comets, and asteroids.

2. With additional time, teams can work out the orbital path of each planetary body, and set the Solar System in motion with these calculations. Or teams might consider creating costumes and props to highlight the identity of the planetary objects.

INTRAPERSONAL EXPLORATION

Now that you have participated in "AU Over There," consider the features of the planetary body you played or one that you observed. Reflect on how you felt about yourself and about the planet that you played or observed.

Through the next series of activities students are all invited to share some thoughts about the planetary body they played or observed. It was once thought that Earth was the center of the universe. What evidence from you own experience do you have that tells you that Earth is not at the center? Do we sometimes act as if we were the center of the universe ourselves? Philosophers often speak about finding our own center. In what sense do we have a center of ourselves?

VISUAL/SPATIAL EXPLORATION

Draw the planetary body you played or observed.

Sample Script: Now, take a piece of paper, some colors and pencils and draw the planetary body you played or watched as you think it really looks. Be prepared to share your ideas with those around you, giving a quick description of your drawing.

LINGUISTIC EXPLORATION

Write about the planetary body you played or observed.

Sample Script: As you finish your drawing, write a brief passage about some aspect of the planet you have drawn: a description, a poem, a song, what it might be like to visit there, a day in the life of the inhabitants. Be prepared to read your passage aloud to those around you.

MUSICAL EXPLORATION

Consider the sounds and rhythms of the planet you played.

Sample Script: Musicality includes rhythm and sound. On Earth, we experience the rhythms of day and night, the seasons, months, and years. Sounds result form our hearing of vibrations moving through our environment. From your knowledge of the features of the planetary body you played, what sorts of rhythms and sounds would likely occur there?

INTERPERSONAL EXPLORATION

Get together in a small group, tell others in the group about your reflections about the planet you played.

Sample Script: Now find a group of people nearby you to share your drawing and your writing. Tell each other about the planet you played.

RESEARCH QUESTIONS

How do astronomers determine whether an object in the night sky is within the Solar System or beyond?

Is the shortest distance between two planets a straight line? (In a sense this is a trick question— it makes a difference whether we are talking about the distance "as light travels" or the distance "as a planet travels." What is the difference?)

The relative distances of the visible planets were observed and recorded by ancient skywatchers. What naked eye observations are necessary to determine the relative distance of the visible planets?

Since its discovery in 1930, Pluto has only moved about one quarter of its orbit around the Sun. How do we observe, predict, and refine our understanding of its orbital path?

What other units of measurement can we use to function within the Solar System?

GOING INTO DEPTH

Open any book about the Solar System or Astronomy and you can easily find the definition of an Astronomical Unit and its expression in miles (93 million) or kilometers (150 million). But it is difficult to find the story of how astronomers first came up with good estimates for the actual length of an A.U. in terms of miles or kilometers.

The absolute distance between Sun and Earth was not fully calculated until recent times, first accomplished by an astronomer named Cassini. He and a colleague each measured the position of Mars from points 4000 miles apart (*around* the Earth) in order to compute the *parallax* formed by the difference between the apparent position of Mars from each location. The result was the measurement of an angle of about .0034°. Using basic trigonometry, adjusting for the curvature of the Earth, Cassini estimated the distance to Mars (1.5 AU) and by extrapolation estimated the value of one AU as about 87 million miles— pretty close for the 1700's!

How did he do it? What observations and basic principles allowed astronomers to calculate this value? Can you re-create Cassini's calculations?