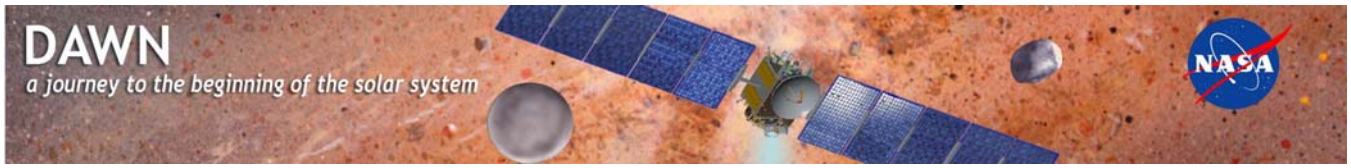

Ceres and Pluto: Dwarf Planets as a New Way of Thinking about an Old Solar System

TEACHER GUIDE

BACKGROUND

The decision by the International Astronomical Union (IAU) in 2006 to define the terms “planet” and “dwarf planet” has caught the attention of the public and students from grade school to graduate school. The IAU’s decision has not changed the structure of the solar system; it has merely presented a different way of classifying the bodies that make it up. Planets are the Greek word for “wanderers” that were known as lights that moved in the sky. This middle school activity, developed for NASA’s Dawn mission, utilizes a researched-based instructional strategy called direct vocabulary instruction to help students understand the new definitions of planet and dwarf planet.

Many of us have grown up with an understanding that our solar system is comprised of remnants from its early formation 4.5 billion years ago, primarily: bodies such as the Sun, planets, asteroids and comets; gas and dust, as well as a large volume of space. Many school children have learned the names and locations of the planets relative to the Sun using a mnemonic such as My Very Exceptional Mother Just Sat Upon Nine Porcupines (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto). The last of these bodies to be discovered, Pluto, has recently been reclassified as a dwarf planet. Pluto’s reduced status has even resulted in a new term as we enter 2007: someone or something has been “Plutoed” if that person or thing has been downsized in its prominence.

However, this is only part of the story. The new category of dwarf planet has brought attention to the largest body in the asteroid belt (a region of space lying between Mars (1.5 AU) and Jupiter (5.2 AU), where the great majority of the asteroids are found.), Ceres, one of the two targets for NASA’s Dawn mission, which also has been reclassified as a dwarf planet. This has led Dawn Co-Investigator Dr. Lucy McFadden to coin the term “Ceresed” to mean someone or something that has been promoted or upgraded in its prominence.

The way objects are classified can change over time. For instance, Ceres was considered a planet for nearly fifty years before it was “demoted” to an asteroid or minor planet about 150 years ago. Now Ceres has been “promoted” to a dwarf planet. See James Hilton’s essay on this topic[1].

The publicity generated by the IAU in 2006 has created a teachable moment for schools around the world to consider the definitions of “planet,” “dwarf planet,” and “asteroid” with the potential for a better understanding of our solar system and how discoveries and our changing understanding over time necessitates a change in the language we use to talk about it. This activity will engage students in these new definitions through the use of direct vocabulary instruction. For a more complete discussion of this instructional strategy, refer to *Building Background Knowledge*[2].

[1] http://aa.usno.navy.mil/faq/docs/minorplanets.php

[2] Marzano, R. J. (2004). Building background knowledge for academic achievement. Alexandria VA: Association for Supervision and Curriculum Development.

When many of us think about vocabulary instruction, we recall the days in school in which we were given a list of words and a dictionary. We were off to the races copying a definition onto a piece of paper. But how effective is this approach? How well does it work in helping a student make meaning of new words? It has been argued that the use of dictionary definitions is not effective instructionally (Marzano, 2004).

An alternative approach, direct vocabulary instruction, promises to make vocabulary instruction more effective and enjoyable for students. Educational researcher, Bob Marzano, recommends a six step approach to direct vocabulary instruction that will be used as the basis of this activity.

Direct Vocabulary Instruction: A Six Step Approach

1. The teacher provides a description, explanation, or example of the new term.
2. Students restate the explanation of the new term in their own words.
3. Students create a nonlinguistic representation of the term.
4. Students do activities that help them add to their knowledge of vocabulary terms.
5. Students are asked to discuss the terms with one another.
6. Periodically students are involved in games that allow them to play with the terms**.**

By giving students opportunities to engage with the terms in various ways, direct vocabulary instruction increases the likelihood they will internalize accurate, meaningful definitions. As students use oral language, visual representations, and social interaction to learn new terms, "direct vocabulary instruction has an impressive track record of improving students' background knowledge and comprehension of academic content" (Marzano, 2004).

***National Science Education Standards* Addressed[3]**
Science as Inquiry (Grades 5-8)
Understandings About Scientific Inquiry

- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. all of these results can lead to new investigations.

Earth and Space Science (Grades 5–8)
Earth in the Solar System

- The earth is the third planet from the sun in a system that includes the moon, the sun, eight[4] other planets and their moons, and smaller objects, such as asteroids and comets.

Language Arts Standards Addressed[5]
Standards 7: Uses reading skills and strategies to understand and interpret a variety of informational texts (Grades 6-8)

- Uses new information to adjust and extend personal knowledge base

[3] National Research Council. (1996). *National Science Education Standards*. Washington DC: National Academy Press.
[4] With the IAU's new nomenclature there are now seven other planets
[5] *Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education,* by John S. Kendall and Robert J. Marzano (2000, 4th ed.): Mid-continent Research for Education and Learning (McREL), Aurora, CO.; www.mcrel.org/standards/

Procedure:

PRE-ASSESSMENT

At the beginning of the lesson, ask students to describe what a planet is in their own words. Have students record their thoughts in their student activity sheet, notebook or on a piece of paper.

Step 1:
A. Provide a description, explanation, or example of the terms. The following is the IAU definition of a dwarf planet, planet as well as a definition of asteroid.

A **dwarf plane**t is a celestial body that

(a) is in orbit around the Sun,
(b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape,
(c) has **not** cleared the neighborhood around its orbit, and
(d) is not a satellite.

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(b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape,
(c) **has** cleared the neighborhood around its orbit, and
(d) is not a satellite.

All other objects (including asteroids) except satellites orbiting the Sun shall be referred to collectively as “Small Solar-System Bodies.” The following is a definition of the word asteroid which was not defined by the IAU, but falls within its definition of small solar system bodies. In the early 1800’s the term asteroid was used to describe Ceres and Pallas because of their small “starlike”” appearance when observed in the night sky.

An **asteroid (or minor planet)**

(a) orbits the Sun inside the orbit of Jupiter
(b) **does not** have sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium shape (it is not round shaped),
(c) **has not** cleared the neighborhood around its orbit, and
(d) is not a satellite.

B. Provide nonlinguistic representations of the new term. The following is an image of Ceres (Image 1) an example of a dwarf planet and the location of Ceres within the solar system (Image 2). Note in the image at left that the inner planets and Jupiter have cleared most of the neighboring bodies from their orbits while Ceres and Vesta have not. Note also that Ceres is nearly round, while Vesta (Image 3) is more irregular in shape.

Image 1: Ceres (dwarf planet)
Hubble Space Telescope

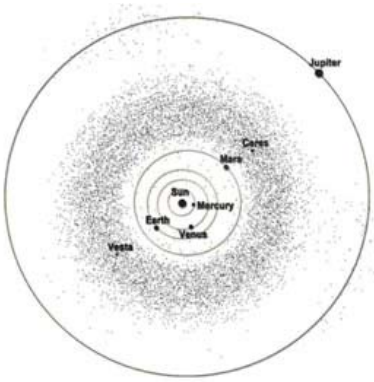


Image 2: The Asteroid Belt
Solar System Dynamics Group, JPL

C. Use the images and the explanation together as you describe an example of the terms. Show image 2 that demonstrates that Ceres clearly qualifies as a dwarf planet since it orbits the Sun, is not a satellite, and has not cleared its neighborhood. Explain that for the inner planets and Jupiter, there are very few other objects in the vicinity of their orbit around the Sun whereas Vesta and Ceres have many other asteroids in relatively nearby orbits. Some students may point out that Jupiter and some of the inner planets have not completely cleared the neighborhood of other bodies. You may want to use the analogy, that when kids are asked to clean their rooms, there are degrees of clearing out that happens. Clearly, there is a difference between the degree of clearing between a planet such as Earth and a dwarf planet such as Ceres. Use image 1 to show that a dwarf planet is spherical in shape and image 3 to show that asteroids are not as round as dwarf planets.

Image 3: Vesta
(asteroid or minor planet)

Hubble Space Telescope

Step Two: Students restate the explanation of the new term in their own words. Have students work in groups or individually to develop this explanation of a dwarf planet in their own words. Have them record this on a piece of paper and share with the class.

Step Three: Students create a nonlinguistic representation (picture) that would help them understand each of the terms. Have them record this on a piece of paper and share with the class.

Step Four: Students engage in activities that expand their understanding of vocabulary terms
A number of the following activities can be boost vocabulary comprehension including:
• Comparing terms using a three-way Venn diagram.
• Classifying other images and examples as either planets or dwarf planets.
• Generating metaphors using terms (e.g., planets are wanderers on a clear path)
• Generating analogies using terms (e.g., a dwarf planet is to planet as a minivan in traffic is to a van on the open road)

See sample activities below.

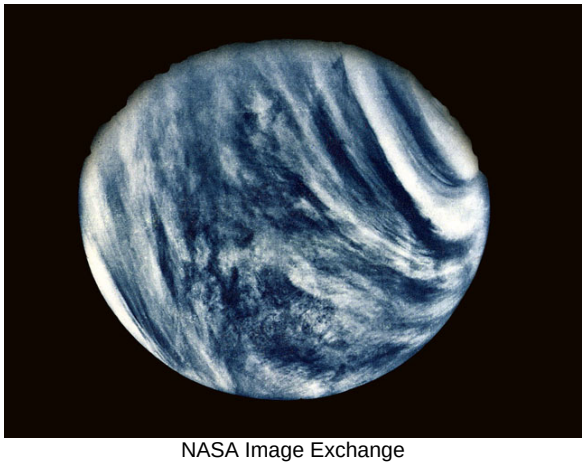
Step Five: As you continue your study of the solar system, periodically ask students to discuss the terms “planet,” “dwarf planet,” and “asteroid” with one another.

Two activities are presented on the next few pages. These pages can be used with students.

Step Six: There are many vocabulary games that teachers can use to involve students in new words. One such game called “Pass-a-Word” is described in Literacy Plus: Vocabulary Games and Activities[6]. In this game students think of as many words as possible that relate to the target word. Every 15 seconds, the list is passed to the next student who repeats the process. At the end of the time limit, repeated words are crossed out and scores can be developed based on the complexity of the term.

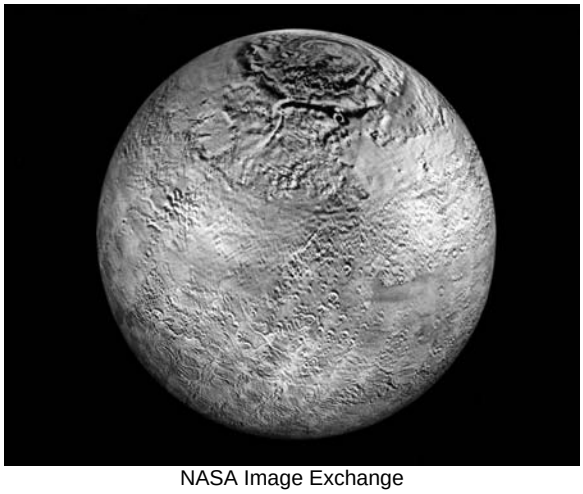
[6] Marzano, L., &Christensen, N. (1992). *Literacy plus*: Games for vocabulary and spelling. Columbus, OH: Zaner-Bloser..

1. Classify Examples of Terms:
Have students use the following images and information to classify the bodies as a planet, dwarf planet, or asteroid.



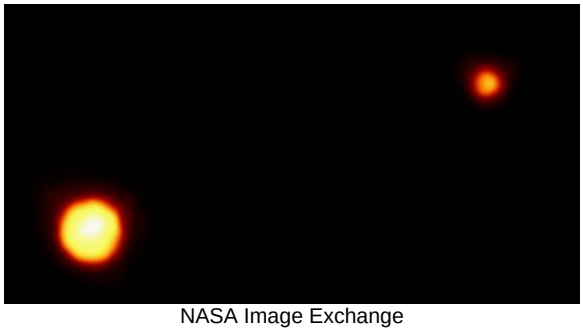
NASA Image Exchange

Has Cleared Neighborhood



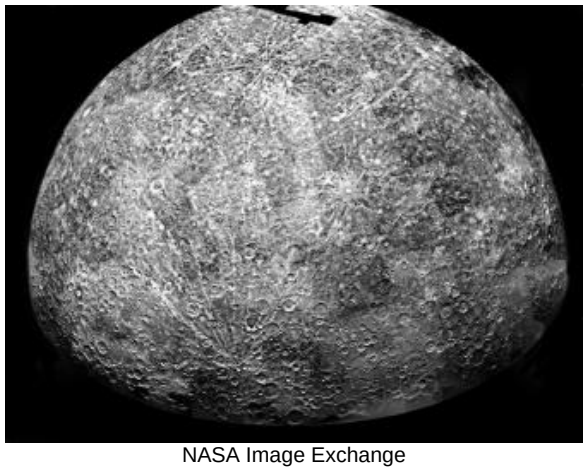
NASA Image Exchange

Has Not Cleared Neighborhood



NASA Image Exchange

Has Not Cleared Neighborhood

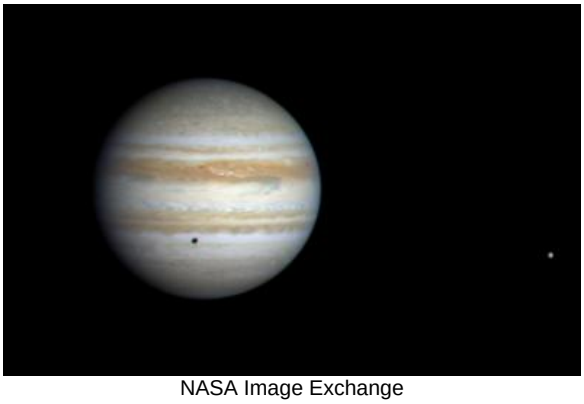


NASA Image Exchange

Has Cleared Neighborhood

NASA Image Exchange

Has Not Cleared Neighborhood

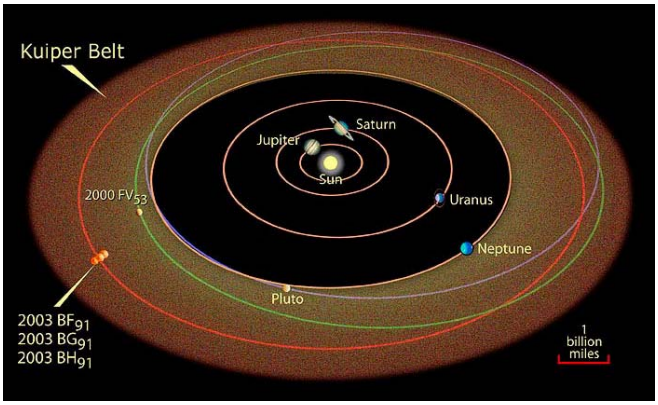


NASA Image Exchange

Has Cleared Neighborhood

NASA Image Exchange

Has Not Cleared Neighborhood



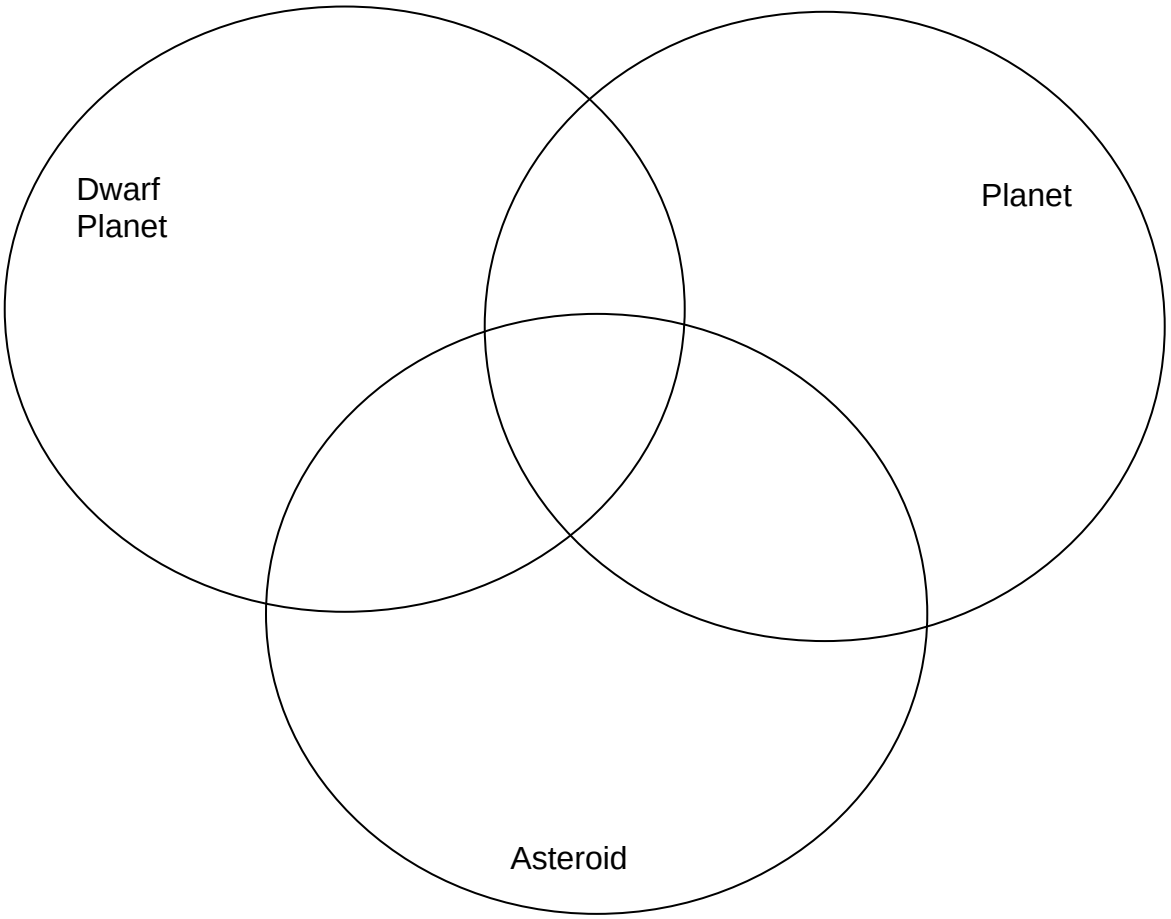
http://whyfiles.org/011comets/images/kuiper_belt.jpg

Kuiper Belt Object

Kuiper Belt is a ring of small icy bodies that orbit the Sun beyond the orbit of Neptune.

2. Comparing Terms:

Have students use the Venn Diagram to compare the terms planet, dwarf planet, and asteroid. Begin by placing the following terms in the diagram: Earth, Ceres, Vesta, Pluto.



We will compare terms by comparing examples of these terms Earth, Ceres, Vesta, and Pluto. Have students learn about these bodies by referring to the following resources.

http://www.nineplanets.org/

http://ssd.jpl.nasa.gov/

Lodders, K. & Fegley, B. 2005. The planetary scientists companion. USA: Oxford University Press.

McFadden, L., Johnson, T. V., & Weissman, P. R. 2007. Encyclopedia of the solar system. USA: Academic Press.

Then they can use their knowledge of Earth and the completed Venn Diagram to complete the following comparison matrix:

Comparison Matrix Earth (Planet) and Ceres (Dwarf Planet)				
Characteristic	**Earth**	**Ceres**	**Vesta**	**Pluto**
Location in the Solar System relative to other bodies	Between the orbits of Venus and Mars. 1 AU from Sun	Between the orbits of Mars and Jupiter About 2.76 AU from Sun	Between the orbits of Mars and Jupiter About 2.36 AU from Sun	Beyond the orbit of Neptune About 39 AU from Sun
Size and Shape	Diameter is 12,756 km and is round	Diameter is 960 km and is round	Diameter is 530 km and is somewhat round	Diameter is 2,280 km and is round
Mass and Gravity Compared with Earth	Mass: 5.974×10^{24} kg Gravity: 1.00	Mass: 8.7×10^{20}kg Gravity: 0.0001	Mass: 3.0×10^{20} kg Gravity: 0.00005	Mass: 1.1×10^{22} kg. Gravity: 0.08
Density	5.5 g/cm^3	2.0 g/cm^3	2.4 g/cm^3	2.0 g/cm^3
Presence of Water	Yes	Water ice layer under crust	Not likely	Perhaps 30% water ice
Internal Structure	Core, Mantle, Crust	Differentiated: Rocky Core, Water Ice, Thin Crust	Differentiated:	Unknown
Surface Features	Varied: Oceans, Tundra, Forests, Deserts, Mountains	bright and dark spots	Basin in southern region, bright and dark spots	Unknown
Number of moons	1	0	0	2
Magnetic Field	Yes	?	?	?

Comparison Matrix Earth (Planet) and Ceres (Dwarf Planet)				
Characteristic	**Earth**	**Ceres**	**Vesta**	**Pluto**
Length of Day Compared with Earth	1 day (24 hours)	9 Earth Hours	5.3 Earth Hours	6.38 Earth Days
Length of Year	1 Earth Year (365 Days)	4.6 Earth Years	3.63 Earth Years	248.6 Earth Years
Atmosphere	Nitrogen (78%) Oxygen (21%)	Unknown	Unknown	Methane? Nitrogen? Carbon Dioxide?

Conclusion:
Conclude the lesson by stating that while the International Astronomical Union has chosen one characteristic (the extent to which a body has cleared its orbital neighborhood of other bodies) as the distinguishing characteristic of a planet versus a dwarf planet, there are many other characteristics to consider. Many planetary scientists would rather see a definition that focused more on characteristics of the body itself rather than where it is or what is near it. By completing a comparison matrix, students opened opportunities for further debate as to what a planet truly is. The more that we learn about our solar system, the more our classification schemes are challenged to include new discoveries.

POST-ASSESSMENT
Have students refer to their original definitions that they developed at the beginning of the lesson. Have them write a paragraph that explains how their understanding of a planet has changed or not as a result of this lesson.

RESOURCES

August 10, 2006
http://www.npr.org/templates/story/story.php?storyId=5631291
Dwarf Planets May Finally Get Respect
David Kestenbaum, National Public Radio

IAU 0603, August 24, 2006
http://www.iau.org/iau0603.414.0.html

New York Times
Aug. 27, 2007 to September 15, 2007
http://topics.nytimes.com/top/news/science/topics/dwarfplanet/index.html

NASA Image Exchange
http://nix.nasa.gov/
The NASA Image eXchange (NIX) is a web-based search engine for searching one or more of NASA's online multimedia collections. Searching is performed using keywords. NIX returns thumbnail sized images, textual descriptions, image numbers, links to higher resolution images, and links to the organization that stores each image.

Planetary Scientists and Astronomers Oppose New Planet Definition
August 31, 2006
http://www.plutotoday.com/news/viewpr.html?pid=20725

Wikipedia
http://en.wikipedia.org/wiki/Dwarf_planet
Contains a list of dwarf planets and other candidates. This site also has references to other news articles on the subject, as well as discussion. It should not necessarily be construed as fact. Not all of the information on the topic has appeared in peer reviewed astronomical journals. Peer review is a necessary but not sufficient condition for factual information.

When did the asteroids become minor planets?
http://aa.usno.navy.mil/hilton/AsteroidHistory/minorplanets.html