Classifying Space Objects 88

2-3
40- to 50-minute sessions

INVESTIGATION

ACTIVITY OVERVIEW

Students learn to identify different kind of objects found in space, with a focus on those observed in our Solar System. Students compare characteristics of the objects and sort them into groups based on common features. This classification process allows students to become familiar with the various objects found in space.

KEY CONCEPTS AND PROCESS SKILLS

(with correlation to NSE 5–8 Content Standards)

1. The Sun, Earth and other planets, moons, and smaller objects make up the Solar System. (EarthSci: 3)
2. One way to gather data is through direct observations. Accurate and complete observations are important for making conclusions about the natural world. (Inquiry: 1)
3. Space objects are grouped into categories by such characteristics as size, composition, and motion in space. (EarthSci: 3)

KEY VOCABULARY

asteroid

comet

dwarf planet

galaxy

meteor

moon

planet

star

MATERIALS AND ADVANCE PREPARATION

For the teacher

	8	sets of 7 Classification Cards
	1	Transparency 88.1, "Space Objects"
*	1	overhead projector
	1	Scoring Guide: UNDERSTANDING CONCEPTS (UC)

For each group of four students

	1	set of 23 Space Object Data Cards
*	1	piece of chart paper (optional)
*	1	marker (optional)

For each student

	1	copy of Scoring Guide: UNDERSTANDING CONCEPTS (UC) (optional)

**Not supplied in kit*

Masters for the Scoring Guides are in Teacher Resources III: Assessment.

TEACHING SUMMARY

Getting Started

1. Students share their current knowledge of the Solar System.

Doing the Activity

2. Students classify space objects based on characteristics.

Follow-Up

3. Students compare classification systems.
4. (UC ASSESSMENT) Discuss the limitations of the scientifically accepted classification system

BACKGROUND INFORMATION

Classifying Space Objects

The space object definitions that are presented in this activity are the current descriptions used by the scientific community. The classification system, however, is imperfect because the names and groupings were created before telescopes provided more information on the objects. For example, some astronomers suggest that terrestrial planets, asteroids, and comets are actually a continuum of objects that orbit the Sun, as opposed to distinct groups. Terrestrial planets are the most rocky and have almost circular orbits, while comets are composed of rock, dust, frozen water, and gases and have highly elliptical orbits. Asteroids' characteristics put them in the middle of the planet–comet continuum. For every category created so far, there are objects that don't quite fit the features of that group or that straddle characteristics of another type of object.

An example of a celestial object that challenges the accepted classification system is Jupiter. In its composition Jupiter appears more like a star than a planet: it consists of a shell of gaseous hydrogen, almost 60,000 km (37,000 miles) thick, overlying a layer of liquid metal hydrogen formed by high pressure, and a core of rock and ice. Also, Jupiter gives off energy as the Sun does, but that is a result of the pressure of gravity compressing the planet, instead of nuclear reactions. Astronomers have wondered whether Jupiter could have been much hotter earlier in its history. Another reason for speculation about Jupiter is its large number of moons.

Asteroids, Comets, and Meteors

Small Solar System Bodies (SSSB) are objects in the solar system that are neither planets or dwarf planets. Of these, asteroids, comets and meteors are sometimes grouped together because of their similarities, but they are distinct objects. Asteroids are irregularly shaped pieces of rock moving through space. They can belong to a group or ring of asteroids such as the one between Mars and Jupiter. In that ring there are thousands of rocky objects that range from 10 meters in diameter to almost 1,000 km. The largest asteroid known is called Ceres, which is almost as wide as the state of Texas. Some of the asteroids in the Solar System pass closer to the Sun than Earth does, while others have orbits that take them well beyond Jupiter. The Kuiper Belt beyond Pluto is a recently discovered asteroid ring that has pieces that are larger than the planet Pluto.

Most meteors are thought to be fragments of asteroids or rock and dust that burn up in the atmosphere as they approach the Earth (or another planet) through the pull of gravity. The meteor is the visible path of a fragment that we observe. It is also commonly called a shooting star or falling star. The streak is due to the heat produced by the ram pressure (not friction, as is commonly assumed) of atmospheric entry. A meteor shower is caused when a large number of meteors burns up simultaneously, which occurs when the Earth's orbit passes through debris from a comet. If the meteor penetrates the atmosphere and impacts the surface of the Earth, it is called a meteorite. Impacts from natural extraterrestrial objects have created craters on Earth, the Moon and other planets.

A comet, which usually has a diameter of a few kilometers, is composed largely of frozen carbon dioxide, methane and water with dust and various mineral aggregates mixed in. Like asteroids, comets are part of the Solar System because they travel in an orbit around the Sun. The orbit of a comet, however, is typically highly elliptical, which can reach distances that is many times more distant than Pluto's orbit. A comet will remain frozen when it is traveling far from the Sun but the frozen substances will change to gas as the comet approaches the Sun. This gives the comet its signature "tail" made of gas and dust that is driven off the comet's surface by the Sun's energy. Thus, a comet's tail always points away from the Sun, regardless of the comet's path of motion.

TEACHING SUGGESTIONS

GETTING STARTED

1. Students share their current knowledge of the Solar System.

✓ Ask students to order the following space objects from smallest to largest:

Earth

Sun

the Solar System

GPS satellite

the Moon

The correct order is:

GPS satellite

the Moon

Earth

Sun

the Solar System

Ask students, ***What features other than size could you use to compare space objects?*** Have students brainstorm characteristics that could be used to distinguish celestial objects. Their responses may include composition, motion, shape, and mass. Let students know that in this activity, they will be coming up with a system to classify different objects based on the objects' common features.

DOING THE ACTIVITY

2. Students classify space objects based on characteristics.

Distribute the Space Object Data Cards, and review any terms on the cards that need clarification. Make sure students understand, for example, the terms *orbit*, *diameter*, *kilometer* and *kilogram* before beginning the activity.

Review the quantitative measurements provided on the cards. The mass of many of the objects is quite large, making comparisons difficult to visualize. You might want to discuss the mass measurements of the larger objects that are given in exponential notation. Even if students are not familiar with exponential notation, it may help them read the large numbers if they know that the exponent represents the number of decimal places after the first digit.

Units used for distance on the cards are kilometers, but the enormity of some of the numbers provides an opportunity to talk about common units used in astronomy. Optionally, you may want to discuss the astronomical unit (AU), which is the distance from the center of Earth to the center of the Sun, or 1.5×10^8 km. Students will be formally introduced to AUs in Activity 90 where they make a scale for the distances to the planets. Another common measurement unit is the light-year, which is the distance light travels in a year, or about 9.46×10^{15} km. This unit, however, is not appropriate for the distances used in this activity. Explain why these units are convenient for discussions of distances to the outer planets or outside the Solar System.

Have students complete the procedure. Groups should work together to organize the various Space Object Data Cards and record the groupings they have formed. Most importantly, they should record the characteristics they used to form each of the groupings. If students are having problems, suggest that they use only one criterion to begin their sorting, but allow them to work as independently as possible.

For Procedure Step 5, hold a brief class discussion about how students classified the space objects. Allow members of each group to briefly show their system and describe the choices they made. You could also provide chart paper and markers for students to display their systems. Highlight the similarities and differences between the systems that the different groups used by listing them on the board or overhead. This discussion will model what the procedure asks students to do in Step 8.

Do not hand out the sets of Classification Cards to each group until Procedure Step 6. Before they complete this step, it may be helpful to review the definitions of the terms shown on the Classification Cards (asteroid, comet, dwarf planet, galaxy, manufactured object, moon, planet, and star).

FOLLOW-UP

3. Students compare classification systems

Students so far have done the activity without knowing the names of the space objects. Project Transparency 88.1, "Space Objects," matching the objects' numbers on the cards with their names or descriptions. Ask students if knowing the name or description changes how they want to group their objects.

Students may notice the absence of a meteor group in the Classification Cards. Although meteors are observable by the naked eye, they are not considered a distinct group of celestial objects. Presently, it is unclear whether meteoroids are considered Small Solar System Bodies. A meteor is any rock less than 100 meters in diameter that has been captured by Earth's gravity and has entered Earth's atmosphere. For example, a meteor could have been an asteroid that is the remains of a collision and has been pulled to Earth by gravity. Not only are meteors in the atmosphere instead of space, but their origin is uncertain. While many astronomers believe that most meteors are asteroids, they could also be comets or other cosmic material.

Make sure students understand that the cards mostly show objects found in the Solar System. This could dispel the misconception that the universe is heavily laden with planets when, in fact, scientists are not sure about the ratio of stars to planets in the universe. There are also many more categories of objects—such as Cepheids, pulsars, and black holes—that are found outside the Solar System.

4. (UC Assessment) Discuss the limitations of the scientifically accepted classification system.

Explain to students that the categories for the Classification Cards are the accepted scientific classifications. These categories are not exhaustive and have limitations. The classification of Pluto (Space Card 9) for example, was recently changed from planet to dwarf planet with much debate. The controversy brought into question the definition of a planet. As of early 2007, Pluto is formally classified as a dwarf planet, but this may change in the future.

Emphasize the importance of classification systems, as imperfect as they may be: they allow scientists to organize and make sense of vast amounts of data and allow scientists from all over the world to communicate with each other and share information in a common scientific vocabulary. As scientists gather more data, the classification system will develop further.

Analysis Question 2 can be scored with the Understanding Concepts (UC) Scoring Guide to assess whether students understand the main idea of the activity. The question focuses on the characteristics of different objects. Review with your students your expectations for their responses, and let them know that you will use the UC Scoring Guide to give them feedback. If appropriate, distribute a copy of the UC Scoring Guide to students. For more information about the scoring guides, see Teacher Resources III: Assessment.

SUGGESTED ANSWERS TO QUESTIONS

1. *How did your group classify the objects? Describe your system.*

   Students may choose a variety of systems, including those that depend on object shape, what the object orbits, mass, composition, or diameter.

2. *(UC Assessment) List the eight major categories of objects described in the Astronomers' Classification System. For each classification, write down at least two of the major features of that category.*

   Level 3 Response:

   Asteroid: An asteroid is a piece of rock moving through space. There is an asteroid belt between Mars and Jupiter.

   Comet: Comets are made of rock, dust, water and gases. They have very large orbits around the Sun. They have a tail when close to the Sun.

   Dwarf Planet: A dwarf planet is like a planet in that it is round and orbits the Sun. But it is different in that it has not cleared its orbit of other objects.

   Manufactured Object: A Manufactured Object in space is trash in space or working equipment. A satellite is an example of a Manufactured Object in space.

   Moon: A moon is a round object that orbits a planet. Moons can be made of rock, "ice," or both. Some are big, and some are small.

   Planet: A planet is a spherical object that orbits a star. They do not give off light like a star.

   Star: A star is a huge ball of hot gas that gives off energy and light. Stars can be different sizes and temperatures.

   Galaxy: A galaxy is a group of billions of stars. They can be different shapes like round, spiral, or irregular. Our galaxy is called the Milky Way.

3. *Carefully read the article below.*

   a. *Why was Pluto's classification changed?*

   Pluto's classification changed because astronomers did not want to have to keep adding planets to the Solar System that are like Pluto. Pluto is different than the other planets, so scientists got together and made a new classification called dwarf planets.

   b. *Do you agree with the changes made by the International Astronomical Union? Explain your choice using evidence from the article.*

   Student responses may vary. Students who support the new definitions may feel that the categories are generally right although not perfect in all situations. They also may feel that the International Astronomical Union is representative enough to make a fair decision. Other students may support the ideas in the petition protesting Pluto's demotion. They may feel that the new categories are not acceptable because they have some inconsistencies with previous categories.

Space Objects

Space Object Number	Name or Description of Object	Classification
1	GPS satellite	manufactured object
2	astronaut glove	manufactured object
3	the Moon	moon
4	average comet	comet
5	Jupiter	planet
6	average asteroid	asteroid
7	the Sun	star
8	Deimos	moon
9	Pluto	dwarf planet
10	Neptune	planet
11	Earth	planet
12	Saturn	planet
13	small star	star
14	Mars	planet
15	Uranus	planet
16	Venus	planet
17	Mercury	planet
18	large star	star
19	Ceres	dwarf planet
20	Hale Bopp	comet
21	M82	galaxy
22	Milky Way	galaxy
23	Ganymede	moon
24	Eris	dwarf planet

Where in the Solar System Am I? 89

1-2
40- to 50-minute sessions

INVESTIGATION

ACTIVITY OVERVIEW

Students use a table of planet characteristics to identify four different planets. They place themselves in a science-fiction scenario in which they live in the future and receive messages from friends who are visiting other planets. They use the descriptions of planets to identify planets in our Solar System based on their characteristics.

KEY CONCEPTS AND PROCESS SKILLS

(with correlation to NSE 5–8 Content Standards)

1. Each planet has a set of unique characteristics. (EarthSci: 3)
2. Earth's unique characteristics include an average surface temperature of 15°C, a large amount of surface water, and an oxygen-rich atmosphere. (EarthSci: 1)
3. The motions of a planet determine phenomena such as the day and the year. (EarthSci: 3)
4. Other places have one or more moons. (EarthSci: 3)

KEY VOCABULARY

rotation
revolution

MATERIALS AND ADVANCE PREPARATION

For the teacher

1 Scoring Guide: RECOGNIZING EVIDENCE (RE)

For each student

1 Student Sheet 89.1, "Planet Information"

1 Scoring Guide: RECOGNIZING EVIDENCE (optional)

**Not supplied in kit*

Masters for the Scoring Guides are in Teacher Resources III: Assessment.

TEACHING SUMMARY

Getting Started

1. Introduce the fictional scenario.

Doing the Activity

2. (RE ASSESSMENT) Students identify four planets based on their characteristics.

Follow-Up

3. Discuss the unique characteristics of Earth.

TEACHING SUGGESTIONS

GETTING STARTED

1. Introduce the fictional scenario.

Have students read the introduction, and ask a student to read aloud the fictional scenario presented in the introduction. Ask students, ***If you had the opportunity in the future to go to another planet, would you?*** Many students would be excited to have an adventure, but others may be fearful or risk-averse. Discuss their ideas about what might and might not be possible in the future.

DOING THE ACTIVITY

2. (RE ASSESSMENT) Students identify four planets based on their characteristics.

Distribute Student Sheet 89.1, "Planet Information." Make sure students understand the headings in the table such as the ones shown below. Specifically, ask students to identify what physical explanation causes the characteristic for the column headings shown on the right (not all headings are included in this discussion). Many other factors affect the characteristics listed on Student Sheet 89.1. You might want to encourage eager students to do some research on their own about the composition and atmosphere of individual planets.

Explanations of Some Headings

Characteristic	Cause
Rotation Period	Speed that planet spins on its axis
Revolution Period	Revolution speed and distance from Sun
Average Temperature	Distance from Sun, atmosphere, and internal heat of planet
Travel Time	Distance from Earth, which is related to distance from Sun but also depends on the position of planets in their orbit

Students' identification of the planets in this activity can be scored using the RECOGNIZING EVIDENCE Scoring Guide. If you will score their work this way, let students know that you will use the scoring guide to provide feedback on the quality of their work.

When students complete the Procedure, discuss the four planets and how students identified them. The table below summarizes the evidence that students might use while comparing the messages to Student Sheet 89.1.

Sample Student Evidence for Identifying Planets

Message from	Planet	Evidence
Kayla	Mercury	• Large, bright Sun = close to Sun • Extreme hot and cold • No moon • Craters = rocky surface • No clouds or weather = no atmosphere.
Len	Mars	• Very cold, but not extremely cold • Dusty = rocky surface • 2 moons • day length almost equal to Earth's = rotation period 1.03 Earth days
Eva	Jupiter	• Huge size (known from Activity 88) • No solid surface = gaseous planet • 5 hours daylight and 5 hours nighttime = 10-hour rotation period (0.4 Earth days) • Many moons and thin rings • Presence of helium and hydrogen in atmosphere • Red spot (not direct information, but students may know)
Ronin	Uranus	• No solid surface = gaseous • 27 moons and rings • Revolution period = 30,681 Earth days (30,681 Earth days a year ÷ 4 seasons = approximately 7,500 days per season or days for winter) • Decade to get there • Temperature (-130°C) in summer

FOLLOW-UP

3. Discuss the unique characteristics of Earth.

Ask students, ***What makes the planets you identified unwelcoming to humans?*** Responses can refer to any of the characteristics in the table. For example, the average temperature of other planets is much hotter or colder than Earth's. Students also might point out differences in day length that would make it hard for humans to adapt.

Discuss Earth's unique characteristics in relation to the needs of life of plants and animals. Ask several students to pick a characteristic of Earth that is particularly important to life as we know it and to explain why it is valuable. For example, humans are suited to the atmosphere around the Earth, which is unlike other planets. Other planets have little or no atmosphere or one with a very different chemical composition.

Finally, have students reflect how Earth's features will influence the future of space travel. Ask students, ***Do you think that in the future people will visit other planets, as was imagined in this activity?*** Students should draw on what they know about the planets to answer this question. They may respond that some of the planets are too far away to make visiting feasible. However, students may support the idea of going to Mars or another neighboring planet if humans are able to improve space travel technology significantly.

SUGGESTED ANSWERS TO QUESTIONS

1. *Write a message from a planet in our Solar System other than the ones already used in the four messages presented in this activity. In your message describe several features that would help someone else identify the planet.*

   Answers will vary depending on the planet chosen, but descriptions should include evidence consistent with the information on Student Sheet 89.1.

Name ________________________________ **Date** ______________

Planet Information

Planets	Rotation Period (in Earth days)	Revolution Period (in Earth days)	Average temp. (°C)	Surface Composition	Atmosphere (Main Components)	Satellites and Rings	Approx. Minimum Travel Time from Earth*
Mercury	58.66	88	179	rocky	No true atmosphere; Trace amounts of sodium and helium	0	5 months
Venus	243	224	482	rocky	Carbon dioxide (96%) Nitrogen (3.5%)	0	3 months
Earth	1	365.25	15	rocky	Nitrogen (77%) Oxygen (21%)	1 moon	—
Mars	1.03	687	– 63	rocky	Carbon dioxide (95%) (Very thin layer)	2 moons	8 months
Jupiter	0.42	4,332	– 121	gaseous	Hydrogen (81%) Helium (18%)	60 moons + rings	5 years
Saturn	0.45	10,775	– 125	gaseous	Hydrogen (97%) Helium (3%)	31 moons + rings	7 years
Uranus	0.71	30,681	– 193	gaseous	Hydrogen (83%) Helium (15%) Methane (2%)	27 moons + rings	10 years
Neptune	0.67	60,193	– 173	gaseous	Hydrogen (83%) Helium (13%) Methane (2%)	13 moons + rings	12 years

* Because planets are in constant motion, the distance between them is constantly changing.

Drawing the Solar System 90

2-3
40- to 50-minute sessions

MODELING

ACTIVITY OVERVIEW

Using a distance scale, students calculate the distance from the Sun to each planet in the Solar System. They make a model of the Solar System by drawing the scaled distance to each planet. Using the same scale, they investigate the diameters of the planets and discover that the scale used for distances in the Solar System is inadequate for drawing an accurate model of each planet. The activity is supported by a literacy strategy that helps students articulate their prior knowledge and reflect on the development of the main concepts in the activity.

KEY CONCEPTS AND PROCESS SKILLS

(with correlation to NSE 5–8 Content Standards)

1. The Sun is the central and largest body in the Solar System. (EarthSci: 3)
2. Earth is the third planet from the Sun in a system that includes seven other planets. (EarthSci: 3)
3. Mathematics is essential for answering questions about the natural world. (Inquiry: 1, 2)

KEY VOCABULARY

astronomical unit
model
proportion
scale

MATERIALS AND ADVANCE PREPARATION

For the teacher

1 Transparency 90.1, "Scaled Sun-to-Planet Distances"

* 1 overhead projector

For each pair of students

* 1 calculator (optional)

For each student

* 1 ruler

1 Student Sheet 90.1, "Talking Drawing 1: The Solar System"

1 Student Sheet 90.2, "Talking Drawing 2: Scaled Sun-to-Planet Distances"

**Not supplied in kit*

TEACHING SUMMARY

Getting Started

1. (LITERACY) Students draw their idea of the layout of the Solar System.
2. (MATHEMATICS) Review the concept of scale and how to make drawings to scale.

Doing the Activity

3. (MATHEMATICS) Students calculate scaled distances in the Solar System.
4. (MATHEMATICS) Students explore scaled diameters of the planets.

Follow-Up

5. Students reflect on the models used in the activity.
6. Make a physical model of the Solar System. (optional)

TEACHING SUGGESTIONS

GETTING STARTED

1. (LITERACY) Students draw their idea of the layout of the Solar System.

Tell students that in this activity they will get information about the distance to the Sun for each of the planets in the Solar System that will add to what they learned about the planets in previous activities. Next, explain that before they complete the activity, they will each draw a picture of the Solar System. Distribute Student Sheet 90.1, "Talking Drawing 1: The Solar System," and give students 5 to 10 minutes to complete it. The student sheet instructs them to begin a Talking Drawing, which is a literacy strategy that elicits their current knowledge about the location of the planets in the Solar System. In the Analysis Questions students will be asked to reflect on what they learned in this activity in the context of their prior knowledge. For more information on Talking Drawings, see the Literacy section of Teacher Resources II: Diverse Learners.

DOING THE ACTIVITY

2. (MATHEMATICS) Review the concept of scale and how to make drawings to scale.

Discuss the concepts of accuracy and scale. A **scale** is a ratio between the actual size of an object and its size on a model. The maps in an atlas, for example, show a distance scale that someone can use to figure out the distance from one city to another. Emphasize that to make an accurate a model that is not the same size as reality, every dimension must be reduced (or increased) by the same proportion or ratio. If you were making a picture of a basketball and a softball and you drew a circle for that basketball at 4 cm = 1 cm ($^1/_4$ scale) and the softball at 2 cm = 1 cm ($^1/_2$ scale), the two drawings would be about the same size. The drawings are accurate if viewed separately, but not if viewed together.

Let students know that in this activity they will make a scaled drawing that models the location of the planets relative to the Sun. Emphasize that they will use the same scale when calculating the planets' distance from the Sun and measuring and plotting each planet's location.

3. (MATHEMATICS) Students calculate scaled distances in the Solar System.

Read aloud, or have a student read, Step 1 of the Procedure. Explain that by using this scale they can more precisely draw and compare distances of the planets from the Sun. Explain how to convert the actual measurements on Student Sheet 90.2. "Talking Drawing 2: Scaled Sun-to-Planet Distances," to scaled measurements by reviewing the procedure step with the students. You might demonstrate on the board or an overhead how to do the first conversion.

Have students complete Part A of the Procedure. Circulate around the room, stopping to help groups who need additional assistance converting the actual distances into scaled measurements. When students have completed Part A, use Transparency 90.1, "Scaled Sun-to-Planet Distances," for students to compare their results.

Introduce the **astronomical unit** (AU)—the distance between the between Earth and the Sun. Discuss why this unit is convenient for astronomers to discuss distances in astronomy. On the chalkboard or a transparency convert some of the distances in the activity to AUs to show how they are calculated and written.

4. (MATHEMATICS) Students explore scaled diameters of the planets.

When students move on to Part B of the Procedure, they will be led through an inquiry about the planets' diameters. If the same scale that they used for the Sun– planet distances were applied to the diameters of the planets, many of the planets would be too small to draw accurately, or even be seen, on the page. This makes it difficult to create on paper a complete and accurate model of the Solar System that is easy to view. If the diameters are scaled to a reasonable size to put on a normal page, or even a poster-sized piece of paper, the distances between planets would be too large to fit. Students should realize that the scale used in Part A is not appropriate for Part B.

Encourage students to use their knowledge of this scale problem to evaluate the images in the Student Book of various models of the Solar System. None of these models are accurate for both size of the planets and distance from the Sun. They tend to show the planet size better than the distances because it is easier to fit on the page or model. For example, Model 4 give an accurate two-dimensional picture of each planet and shows how they relate to the Sun, but the diameters and sun-planet distances are grossly inaccurate. Emphasize that in most published diagrams of Solar System sizes, an attempt is made to show the planet size somewhat to scale, but the distance between planets is usually quite inaccurate. For this reason, these diagrams often generate misconceptions. The table below outlines some of the aspects of the models that students may discuss.

Sample Student Evidence for Identifying Planets

Model	Accurate Aspects of Model	Inaccurate Aspects of Model
1	Shows planets as moving objects Can physically manipulate planets through their orbits Shows position of the Sun Shows position of the planets (order only)	Scaled size of Sun to planets Scaled size of planets with respect to each other Sun-planet distances Color of planets Composition of planets Shows some, but not all, moons Includes Pluto as a planet
2	Shows position of the planets (order only) Shows path of orbits Shows planets scattered throughout orbits Shows position of the Sun Color of planets Shows the Earth's Moon	Scaled size of Sun with respect to planets Scaled size of planets with respect to each other Sun-planet distances Composition of planets Includes Pluto as a planet
3	Shows position of the planets (order only) Color of planets Shows the Earth's Moon	Does not show orbits Does not shows position of the Sun Scaled size of Sun with respect to planets Scaled size of planets with respect to each other Composition of planets Shows some, but not all, moons Includes Pluto as a planet
4	Shows position of the planets (order only) Shows position of the Sun Shows composition of Sun Color of planets	Does not show orbits Does not show position of the Sun Scaled size of Sun with respect to planets Scaled size of planets with respect to each other Composition of planets

■ FOLLOW-UP

5. Students reflect on the models used in the activity.

As a conclusion to the activity, ask students to reflect on their ideas about the size of objects in the Solar System. They will probably respond that they did not realize there were scaling problems with drawing the Solar System on an ordinary piece of paper. Many students may understand for the first time how much space there is between objects in the Solar System, both in terms of actual distances and in the relative sizes of the planets.

Remind students that although we use a model that puts the planets in line with each other, all the planets are continually orbiting the Sun at different rates. This means that the planets are not lined up, as students drew them in this activity. Also, the distance between planets is much greater when they are located on opposite sides of the Solar System. The shortest possible route to Mars, for example, is only available when Earth and Mars are on the same side of the Sun and lined up with it. A sketch of the two planets orbiting around the Sun shows that most of the time Earth and Mars are somewhere between a minimum of 78 million km, and a maximum of 378 million km apart. Point out that this has major implications for sending a mission to Mars and back.

This idea exemplifies a disadvantage of a commonly used model and has consequences for space exploration. Consider the spacecraft Pioneer 11 situation: Jupiter overtakes Saturn about every 20 years. They are on the far sides of their orbits from each other around 1970, 1990, and 2010. Launched from Earth in April 1973, Pioneer 11 looped around Jupiter in December 1974, and arched back all the way over the Solar System to visit Saturn. This journey is so long that the spacecraft did not reach Saturn until September 1979.

SUGGESTED ANSWERS TO QUESTIONS

1. Astronomers often measure distances in the Solar System using a unit called the astronomical unit (AU). One AU is about 150,000,000 km—the distance between Earth and the Sun.

a. Why do you think the AU is used to measure distance in the Solar System?

Distances are so large that measurements in normal units, like meters or kilometers, become very long and hard to use. For example, the distance from the Sun to Jupiter is 5.2 AU, which is a much easier number to use than 778,000,000 km.

b. Why do you think the AU is not used to measure distance on Earth?

Any distance on Earth would be a small, hard-to-use fraction of an AU. For example, the circumference of Earth is 40,000 km, which is only 0.00027 AU.

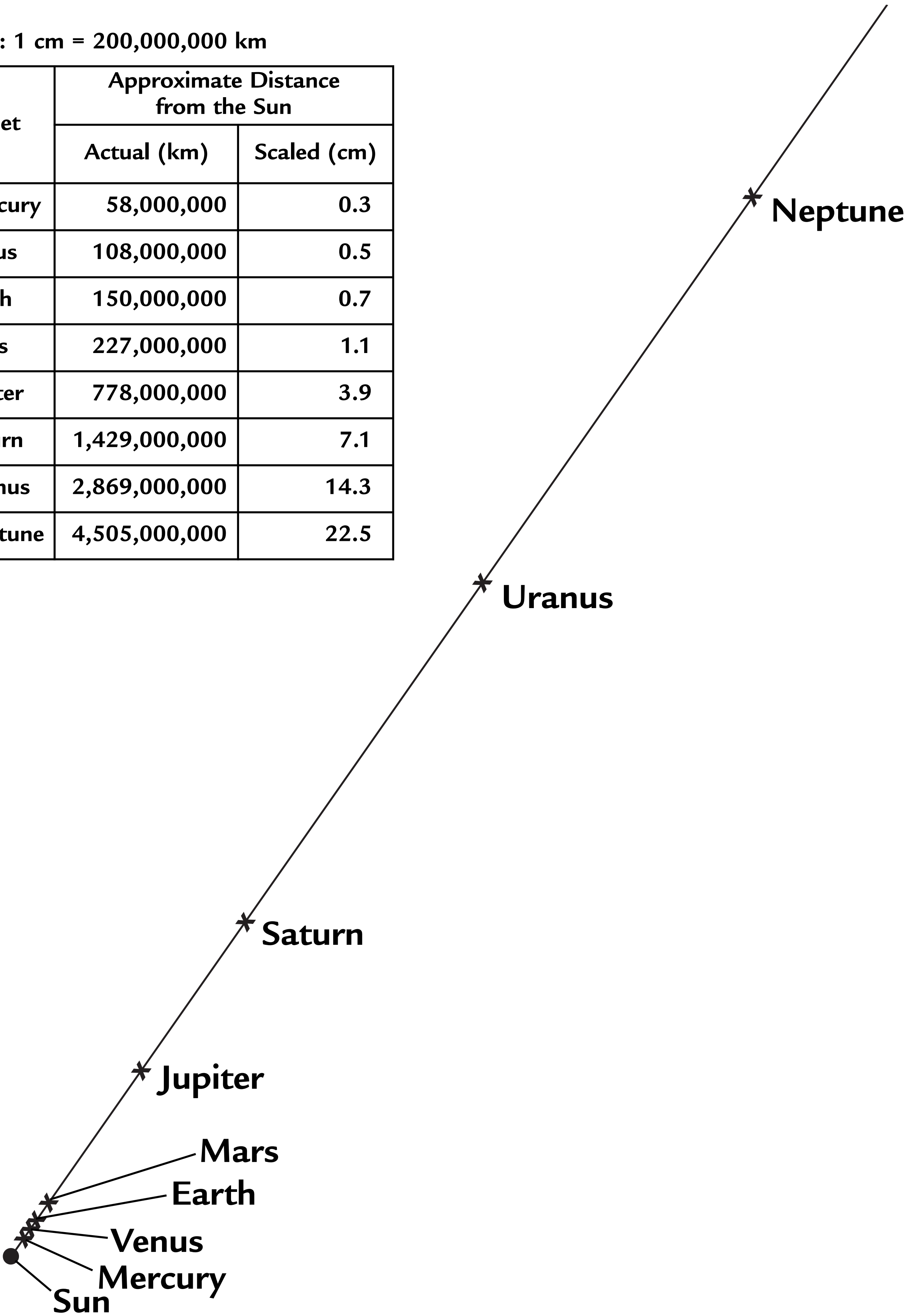
2. What are the main advantage(s) and the main disadvantage(s) of drawing a picture of the Solar System on a piece of regular notebook paper?

The main advantages of drawing the Solar System is that your drawing allows you to compare the distances of planets from the Sun or to compare the relative sizes of the planets. The main disadvantages are that the drawing does not show the correct position of the planets relative to each other in time (they are never in a straight line in space), and you cannot show accurately the diameters of the planets and the scaled distances from the Sun on the same drawing.

Scaled Sun-to-Planet Distances

Scale: 1 cm = 200,000,000 km

Planet	Approximate Distance from the Sun	
	Actual (km)	Scaled (cm)
Mercury	58,000,000	0.3
Venus	108,000,000	0.5
Earth	150,000,000	0.7
Mars	227,000,000	1.1
Jupiter	778,000,000	3.9
Saturn	1,429,000,000	7.1
Uranus	2,869,000,000	14.3
Neptune	4,505,000,000	22.5



Name ______________________________ Date ______________

Talking Drawing 1: The Solar System

1. Close your eyes and think about *what the Solar System looks like*. Now, open your eyes and draw what you imagined.

Name ______________________ Date ______________

Talking Drawing 2: Scaled Sun-to-Planet Distances

Scale: 1 cm = 200,000,000 km

Planet	Approximate Distance from the Sun	
	Actual (km)	Scaled (cm)
Mercury	58,000,000	
Venus	108,000,000	
Earth	150,000,000	
Mars	227,000,000	
Jupiter	778,000,000	
Saturn	1,429,000,000	
Uranus	2,869,000,000	
Neptune	4,505,000,000