Solar System Scale & Size

Grades: K-8 Prep Time: ~20 Minutes Lesson Time: ~60 minutes



WHAT STUDENTS DO: Explore Size and Distance Relationships among Planets

Students will create a model of the solar system using beads and string, and compare planetary sizes using common types of fruit and seeds. In this collection, this lesson follows the simple balloon model in Lesson 2, covering the relationships of size and distance in the solar system. It reinforces concepts students have just encountered in terms of scale and distance and the way in which models assist us in understanding.

NRC CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES
WHAT IS THE UNIVERSE & WHAT IS EARTH'S PLACE IN IT? *NRC Core Question: ESS1: Earth's Place in the Universe*	*Students will be able*
What are the predictable patterns caused by Earth's movement in the solar system? *NRC ESS1.B: Earth and the Solar System*	**IO1: to construct** a simple model .

See Section 4.0 and Teacher Guide at the end of this lesson for details on Instructional Objective(s), Learning Outcomes, Standards, & and Rubrics.

1.0 About This Activity

This activity is part of the Imagine Mars Project, co-sponsored by NASA and the National Endowment for the Arts (NEA). The Imagine Mars Project is a hands-on, STEM-based project that asks students to work with NASA scientists and engineers to imagine and to design a community on Mars using science and technology, then express their ideas through the arts and humanities, integrating 21st Century skills. The Imagine Mars Project enables students to explore their own community and decide which arts-related, scientific, technological, and cultural elements will be important on Mars. Then, they develop their concepts relating to a future Mars community from an interdisciplinary perspective of the arts, sciences, and technology. http://imaginemars.jpl.nasa.gov

The Imagine Mars lessons leverage *A Taxonomy for Learning, Teaching, and Assessing* by Anderson and Krathwohl (2001) (See *Section 4* and *Teacher Guide* at the end of this document). This taxonomy provides a framework to help organize and align learning objectives, activities, and assessments. The taxonomy has two dimensions. The first dimension, cognitive process, provides categories for classifying lesson objectives along a continuum, at increasingly higher levels of thinking; these verbs allow educators to align their instructional objectives and assessments of learning outcomes to an appropriate level in the framework in order to build and support student cognitive processes. The second dimension, knowledge, allows educators to place objectives along a scale from concrete to abstract. By employing Anderson and Krathwohl's (2001) taxonomy, educators can better understand the construction of instructional objectives and learning outcomes in terms of the types of student knowledge and cognitive processes they intend to support. All activities provide a mapping to this taxonomy in the Teacher Guide (at the end of this lesson), which carries additional educator resources. Combined with the aforementioned taxonomy, the lesson design also draws upon Miller, Linn, and Gronlund's (2009) methods for (a) constructing a general, overarching, instructional objective with specific, supporting, and measurable learning outcomes that help assure the instructional objective is met, and (b) appropriately assessing student performance in the intended learning-outcome areas through rubrics and other measures. Construction of rubrics also draws upon Lanz's (2004) guidance, designed to measure science achievement.

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. This five-part sequence is the organizing tool for the Imagine Mars instructional series. The 5E stages can be cyclical and iterative.
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2.0 Materials

Required Materials

Please supply:

For Solar System Bead Model

- Large craft pony beads in 11 suggested colors (1 of each listed below) per student
    - Yellow (Sun)
    - Opaque Red (Mercury)
    - Cream (Venus)
    - Clear Blue (Earth)
    - Clear Red (Mars)
    - Black (Asteroid belt)
    - Orange (Jupiter)
    - Clear Gold (Saturn)
    - Dark Blue (Uranus)
    - Light Blue (Neptune)
    - Brown (Pluto - dwarf planet)

- 4.5 meters of string for each student
- Small piece of cardboard to wrap the Solar System string around (10 cm X 10 cm) after the project is complete
- Measuring tapes (with centimeters), meter sticks, or other metric measuring tools

Teacher Tip: Buying the String: To prevent tangling frustrations, a specific type of string is strongly suggested. You will be looking for string that is thicker than twine, but thinner than yarn. It is 100% cotton, 4-ply knitting and weaving yarn that many times can be bought on a large cone.

Differentiation Tip: Solar System Beads For younger students or to speed up the activity:

1. The string may be pre-cut and a set of Solar System beads may be put into a plastic baggie for each student.
2. A pre-measured marking grid can be put on a table top so the students can mark their measured distances, then tie off the beads.
3. If students will be marking their string ahead of time for each planet, tape newspaper to the floor to prevent marking the floor. 4 cm will need to be added to each planet distance measurement to accommodate tying of the bead (double knot).

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For "Farmer's Market Solar System (Class Demo)

- 1 Honeydew Melon
- 1 Cantaloupe
- 1 Lemon
- 1 Lime
- 2 Grapes
- 1 Macadamia Nut
- 3 Peppercorns

Please Print:

From Student Guide:

(A) Solar System Predictions – 1 per student
(B) Solar System Beads – 1 per student
(C) Planet Bead Calculations – 1 per student
(D) Farmer's Market Solar System – 1 per student

Optional Materials

From Teacher Guide:

(E) Farmer's Market Solar System Key
(F) Solar System Cut-outs
(G) "Solar System Size and Scale" Assessment Rubrics
(H) Alignment of Instructional Objective(s) and Learning Outcome(s) with Knowledge and Cognitive Process Types

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3.0 Vocabulary

Astronomical Unit (AU)	a standard measurement used within the solar system; Earth is 1 AU from the Sun
Models	a simulation that helps explain natural and human-made systems and shows possible flaws
Planet	a sphere moving in orbit around a star (e.g., Earth moving around the sun)
Prediction	the use of knowledge to identify and explain observations or changes in advance (NSES, 1996)
Relationship	the connection among and between objects
Scale	a measurement that will represent a standard measurement for comparison among objects
Solar System	our solar system has 8 planets moving in orbit around the sun, along with dwarf planets such as Pluto, comets, asteroids, and moons; some other stars, like the Sun, have solar systems (planets and other bodies orbiting them) too
System	an organized group of related objects or components that form a whole (NSES, 1996)

4.0 Instructional Objectives, Learning Outcomes, Standards, & Rubrics

Instructional objectives, standards, and learning outcomes are aligned with the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which serves as a basis for upcoming "Next-generation Science Standards." Current National Science Education Standards (NSES) and other relevant standards are listed for now, but will be updated when the new standards are available.

The following chart provides details on alignment among the core and component NRC questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework and education standards.
- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO)**.
- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics** (see Teacher Guide at the end of this lesson).

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Quick View of Standards Alignment:

The Teacher Guide at the end of this lesson provides full details of standards alignment, rubrics, and the way in which instructional objectives, learning outcomes, 5E activity procedures, and assessments were derived through, and align with, Anderson and Krathwohl's (2001) taxonomy of knowledge and cognitive process types. For convenience, a quick view follows:

WHAT IS THE UNIVERSE & WHAT IS EARTH'S PLACE IN IT?

NRC Core Question: ESS1: Earth's Place in the Universe

What are the predictable patterns caused by Earth's movement in the solar system?

NRC ESS1.B: Earth & the Solar System

Instructional Objective *Students will be able*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*	
IO1: **to construct** a simple model	**LO1a. to compare** the relative size and distance of the Earth, Earth's Moon, and Mars **LO1b. to use** a calculated scale for establishing relative distances **LO1c. to predict** using a model **LO1d. to explain** scientific processes (scale, use of models)	**NSES: UNIFYING CONCEPTS & PROCESSES** **Grades K-12:** **A1: Systems, order and organization** **A2 Evidence, models, and explanations** **NSES (D): EARTH & SPACE SCIENCES: Earth in the Solar System** **Grades 5-8:** D3a	**Rubrics in Teacher Guide**

This activity also aligns with:

NRC SCIENCE & ENGINEERING PRACTICES

2) Developing and using models
5) Using mathematical and computational thinking

NRC SCIENCE & ENGINEERING CROSSCUTTING CONCEPTS

4) Systems and system models

21ST CENTURY SKILLS

- Critical Thinking and Problem Solving
- Communication
- Collaboration
- Initiative and Self-Direction

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5.0 Procedures

PREPARATION (~45 minutes)

Constructing the "Solar System Beads"

A. For each student, have available: string cut in 4.5 m lengths, colored beads, cardboard, tape, and measuring tools.

Printing:

B. Handouts (A) – (D) in the Student Guide at the end of this lesson.

Preparing the "Farmer's Market Solar System"

C. Have fruits on hand for students to examine, or provide cutouts found in *(F) Farmer's Market Solar System, Low-cost Cutouts*

STEP 1: ENGAGE (~10 minutes)

Making Predictions

A. Ask students to imagine taking a vacation, visiting all of the planets and other cool destinations in the solar system. When we plan a vacation or trip here on Earth, we have to think about how far away things are, and how long it will take us to get to each place. Ask students to start with their predictions of how long it would take to reach each planet or other body from Earth by drawing relative distances. They should use *(A) Solar System Predictions* in the Student Guide at the end of this lesson. Their predictions are represented by a drawing of what students believe the distance to be between the planets (to the scale of a regular size piece of paper). Ask them to draw all of the planets, including the Sun and Asteroid Belt, showing what they believe to be the relative distances between these bodies. Students may need a reminder about all of the planets and their order in the Solar System.

Ask students to make a second prediction, this time with additional information. Explain to them that if we were to drive a car at highway speeds to the Sun, it would take about 163 years to get there. If we were to travel at the same speed to Mars, it would take 81 years. To get to dwarf planet Pluto, it would take 6,357 years! Obviously, we travel faster than a car when we use a rocket to blast off (e.g., to Mars, spacecraft travel at ~12,000 miles per hour), but the highway comparison gives students an idea of relative distance.

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Differentiation Tip: For older or more advanced students, have students calculate mathematically.

Curiosity Connection Tip: For making a connection to NASA's Mars Rover "Curiosity," please show your students additional video and slideshow resources at:
http://mars.jpl.nasa.gov/participate/marsforeducators/soi/

STEP 2: EXPLORE (~10 minutes)
Finding the Scale

A. Hand out *(B) Solar System Beads Instruction Shee*t and (*C) Planet Beads Calculation Worksheet*.

B. Have students complete the table in *(C) Planet Beads Calculation Worksheet*, converting the various AU distances to centimeters, and complete the chart provided.

C. Have students measure and cut a piece of string 4.5 meters long.

D. Using the calculated cm distances, tie the bead onto the string using a double knot.

E. When students finish the activity, review the models, then wrap the Solar System string (with beads) around the cardboard holder.

Differentiation Tip: Solar System Beads For older or more advanced students, measurements can be made each time from the Sun to the planet and tied on after each measurement. Thus, no additional 4 cm length will be needed in completing the model in this way.

STEP 3: EXPLAIN (~20 minutes)
Explaining the relationship between their predictions and results.

A. Have students complete the questions on *(C) Planet Beads Calculation Worksheet.*

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STEP 4: ELABORATE (~10 minutes)

A. For this step, allow students to examine the fruits, nuts, and peppercorns (or cut-out shapes in the Teacher Guide). Explain to students, now that they have an idea of the scale and distance between planets, that it will also apply to the size of the planets. Ask them to predict the size of each planet in the solar system using these materials and the *(D) Farmer's Market Solar System Worksheet*. They may use some fruits, nuts, and peppercorns more than once. Ask them to work collaboratively to discuss potential sizes.

B. Once students are finished, using *(E) Farmer's Market Solar System Key*, reveal the Farmer's Market Solar System for students to compare their results.

STEP 5: EVALUATE (~20 minutes)

Assessing Proposed Strengths and Weaknesses of Missions.

A. By completing the final two questions on *(D) Farmer's Market Solar System Worksheet*, students will reflect on what they have learned. In a group discussion, ask them to compare their initial predictions with what they now know. This conversation is a good time to reinforce the idea that science is all about not knowing at first, but finding ways (e.g., using models, making predictions) to gain new knowledge. It is also a good time to reinforce that they are capable of being scientists by following their curiosity, making predictions, collecting data, and revising their original ideas with new information.

6.0 Extensions

Students may be curious about why Pluto is no longer considered a planet, and our solar system now has 8 planets instead of 9 as we once thought. Have a discussion about classification—looking at common characteristics to group like things. Explain how, before we began exploring the solar system with spacecraft and before we had more powerful telescopes and other tools, we didn't realize that Pluto was a lot more like other bodies, called dwarf planets, than it is like the 8 planets in our solar system. It's a good opportunity to discuss that science is about continuously revising our models as we discover new things.

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7.0 Evaluation/Assessment

In the Teacher Guide, use the *(G) "Solar System" Rubric* as a formative assessment that aligns with the NRC Framework, National Science Education Standards, and the instructional objective(s) and learning outcomes in this lesson.

8.0 References

Anderson, L.W., & Krathwohl (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* New York: Longman.

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The Partnership for 21st Century Skills (2011). *A framework for 21st century learning.* Retrieved March 15, 2012 from http://www.p21.org/

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(A) Student Handout. Solar System Predictions

NAME:_____

1. Draw your predictions of the Solar System. Your teacher will give you directions.

Prediction 1:	Prediction 2:

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(B) Student Instruction Sheet. Solar System Beads

Introduction:

We think about planets *revolving around* the Sun, but do not think about *how far* each planet *is* from the Sun. Astronomers use the distance from the Sun to the Earth as an "Astronomical Unit," or AU. This unit gives us an easy way to calculate the distances of the other planets from the Sun.

Astronomical Unit: 1 AU = ~150 million kilometers (93 million miles)

Directions:

You will construct a distance model of the Solar System to scale, using colored beads as planets. The chart on the next page shows the planets and asteroid belt in order along with their distance from the Sun in astronomical units.

For this activity 1 AU = 10 cm

1. Complete the chart by multiplying each AU distance by our scale factor of 10 cm per AU. This procedure will give you the measurement of each planet in cm for your model.

2. Use the new distance (in cm) to construct a scale model of our Solar System.

3. Start your model by cutting a 4.5 m piece of string.

4. Use the distances that you have calculated in the chart below to measure the distance from the Sun on the string to the appropriate planet and tie the colored bead in place

5. When you are finished, complete the "Planet Bead Calculation Sheet" and show your model to your teacher.

Note:

If you were traveling at the speed of light (~300,000 kilometers per second), it would take 8 minutes to travel from the Sun (Earth's nearest star) to the Earth (1 AU). It would take 4.3 years at the same speed to reach the next nearest star to Earth, Alpha Centauri.

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(C) Student Worksheet. Planet Bead Calculation Sheet

Planet	AU	Scale Value (cm)	Color
Sun	**0.0**		
Mercury	**0.4**		
Venus	**0.7**		
Earth	**1.0**		
Mars	**1.5**		
Asteroid Belt	**2.8**		
Jupiter	**5.0**		
Saturn	**10.0**		
Uranus	**19.0**		
Neptune	**30.0**		
Pluto (Dwarf Planet)	**39.0**		

Compare your bead model to the predictions you made in *(A) Solar System Predictions*.

1. How close was your prediction to the actual model? What are the differences and similarities between the model and your predictions?

2. When you go home and show your family or friends your bead model, what will you tell them was the most surprising thing you learned about the solar system?

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(D) Student Worksheet. Farmer's Market Solar System

Working with your partner or group, discuss the fruits and vegetables your teacher has provided. For each body in the solar system, select one of these as a representation of their size in relationship to each other. In the justification column, explain why you believe this particular fruit or vegetable to be the best choice.

Planet	Object	Justification
Mercury		
Venus		
Earth		
Moon		
Mars		
Jupiter		
Saturn		
Neptune		
Uranus		
(Pluto)		

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(E) Teacher Resource. Farmer's Solar System Key

Planet	Object	Justification
Mercury	Peppercorn	
Venus	Grape	
Earth	Grape	
Moon	Peppercorn	
Mars	Macadamia Nut	
Jupiter	Honeydew	
Saturn	Cantaloupe	
Neptune	Lemon	
Uranus	Lime	
(Pluto)	Peppercorn	

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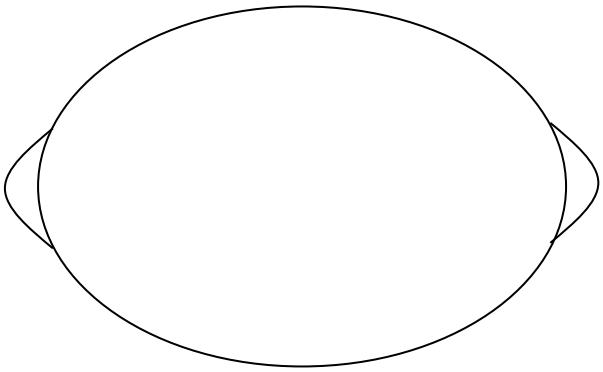
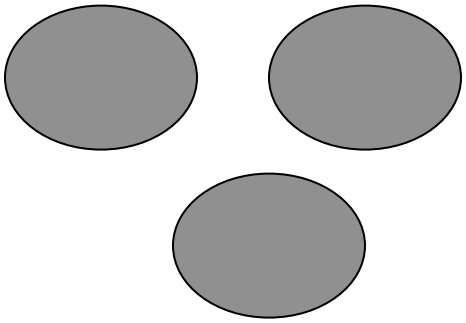
(F) Teacher Resource. Farmer's Market Solar System, Low-cost Cutouts (1 of 3)

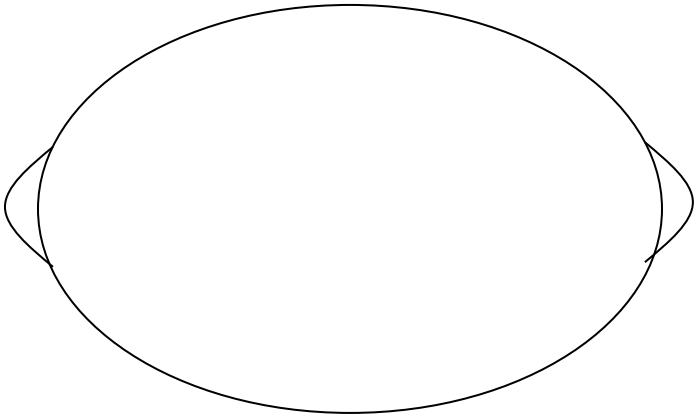


Lime

Macadamia Nut



Grapes



Lemon

Peppercorns

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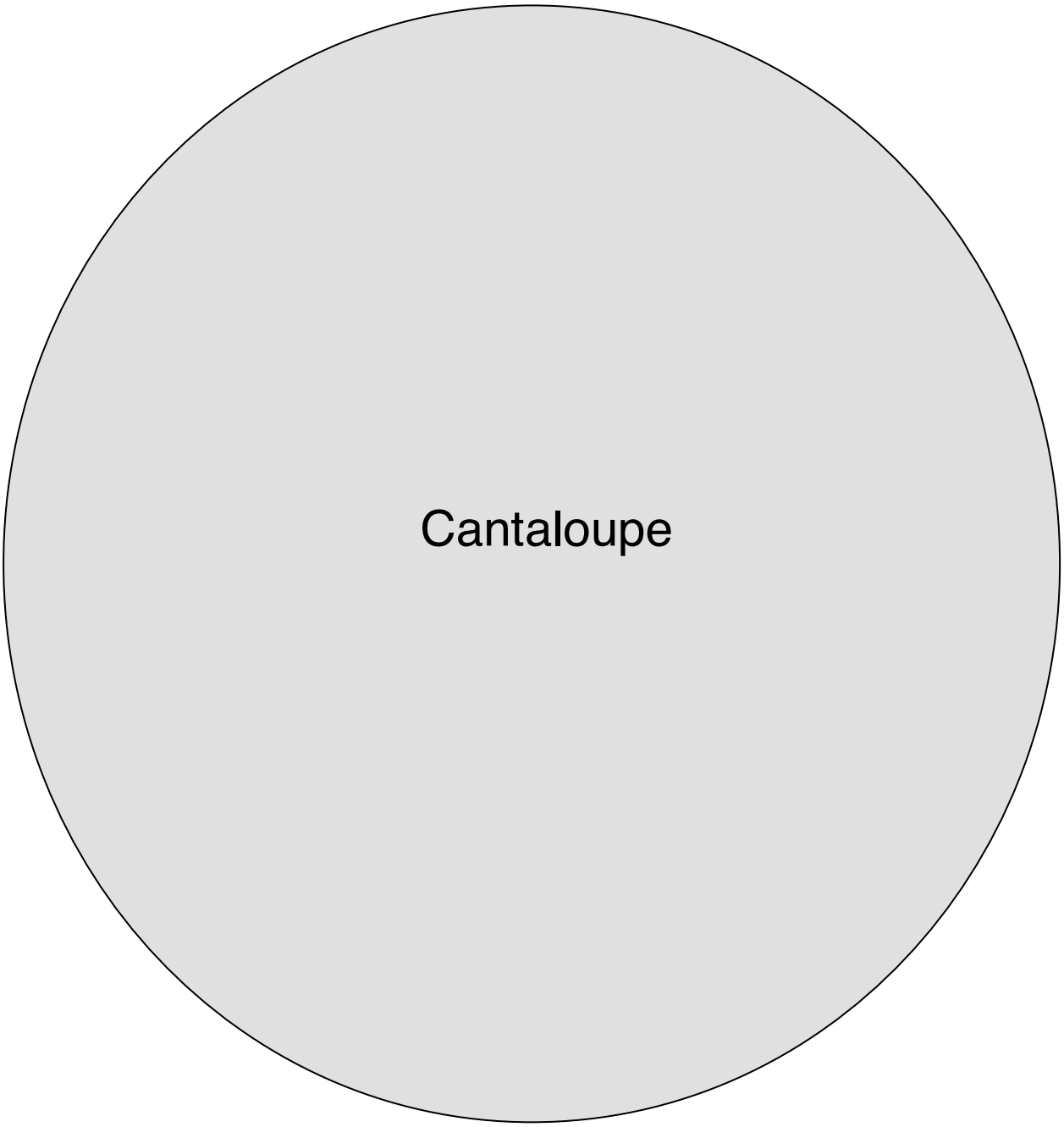
(F) Teacher Resource. Farmer's Market Solar System, Low-cost Cutouts (2 of 3)



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(F) Teacher Resource. Farmer's Market Solar System, Low-cost Cutouts (3 of 3)

Honeydew Melon

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(G) Teacher Resource. Solar System Rubric (1 of 2)

You will know the level to which your students have achieved the **Learning Outcomes**, and thus the **Instructional Objective(s)**, by using the suggested **Rubrics** below.

Instructional Objective 1: To construct a simple model

Related Standard(s) (will be replaced when new NRC Framework-based science standards are released):

National Science Education Standards (NSES)
Systems, Order, & Organization

Grades K-12
(Partial) The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once. Scientists and students learn to define small portions for the convenience of investigation. The units of investigation can be referred to as "systems." A system is an organized group of related objects or components that form a whole. Systems can consist, for example, of organisms, machines, fundamental particles, galaxies, ideas, numbers, transportation, and education…. Prediction is the use of knowledge to identify and explain observations or changes in advance. The use of mathematics, especially probability, allows for greater or lesser certainty of predictions….

Evidence, models, and explanations

Grades K-12
Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations. Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Different terms, such as "hypothesis," "model," "law," "principle," "theory," and "paradigm" are used to describe various types of scientific explanations. As students develop and as they understand more science concepts and processes, their explanations should become more sophisticated. That is, their scientific explanations should more frequently include a rich scientific knowledge base, evidence of logic, higher levels of analysis, greater tolerance of criticism and uncertainty, and a clearer demonstration of the relationship between logic, evidence, and current knowledge.

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(G) Teacher Resource. Solar System Rubric (2 of 2)

National Science Education Standards (NSES)
(D) Earth & Space Sciences

The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system. (Grades 5-8: D3a)

Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1a: to compare the relative size and distance of the Earth, Earth's Moon, and Mars	Answers are correct and work is shown.	Answers are correct and some work is shown.	Answers are mostly correct and some work is shown.	Answers are not correct/no work is shown.
LO1b: to use a calculated scale for establishing relative distances	Procedures are carried out correctly.	Procedures are carried out mostly correctly.	Procedures are carried out somewhat correctly.	Procedures are not carried out correctly.
LO1c to predict using a model	Prediction is logical and based on evidence from prior examinations of the model planets. Predictions show insightful interpretation of the data.	Prediction is logical and based on evidence from prior examinations of the model planets.	Prediction is logical and uses some evidence from prior examinations of model planets.	Prediction is not logical or based on evidence from prior examinations of the model planets.
LO1d to explain scientific processes (scale, use of models	Answer is thoughtful and complete.	Answer is complete.	Answer is somewhat complete.	Answer is not complete.

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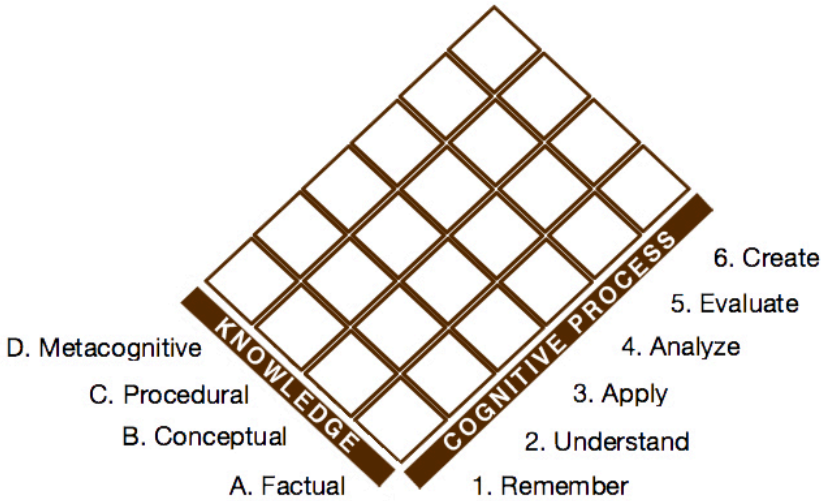
(H) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (1 of 3)



This lesson adapts Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process, each with types and subtypes (listed below). Verbs for objectives and outcomes in this lesson align with the suggested knowledge and cognitive process area and are mapped on the next page(s). Activity procedures and assessments are deslgned to support the target knowledge/cognitive process.

Knowledge	Cognitive Process
A. Factual **Aa:** Knowledge of Terminology **Ab:** Knowledge of Specific Details & Elements **B. Conceptual** **Ba:** Knowledge of classifications and categories **Bb:** Knowledge of principles and generalizations **Bc:** Knowledge of theories, models, and structures **C. Procedural** **Ca:** Knowledge of subject-specific skills and algorithms **Cb:** Knowledge of subject-specific techniques and methods **Cc:** Knowledge of criteria for determining when to use appropriate procedures **D. Metacognitive** **Da:** Strategic Knowledge **Db:** Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge **Dc:** Self-knowledge	**1. Remember** **1.1** Recognizing (Identifying) **1.2** Recalling (Retrieving) **2. Understand** **2.1** Interpreting (Clarifying, Paraphrasing, Representing, Translating) **2.2** Exemplifying (Illustrating, Instantiating) **2.3** Classifying (Categorizing, Subsuming) **2.4** Summarizing (Abstracting, Generalizing) **2.5** Inferring (Concluding, Extrapolating, Interpolating, Predicting) **2.6** Comparing (Contrasting, Mapping, Matching **2.7** Explaining (Constructing models) **3. Apply** **3.1** Executing (Carrying out) **3.2** Implementing (Using) **4. Analyze** **4.1** Differentiating (Discriminating, distinguishing, focusing, selecting) **4.2** Organizing (Finding coherence, integrating, outlining, parsing, structuring) **4.3** Attributing (Deconstructing) **5. Evaluate** **5.1** Checking (Coordinating, Detecting, Monitoring, Testing) **5.2** Critiquing (Judging) **6. Create** **6.1** Generating (Hypothesizing) **6.2** Planning (Designing) **6.3** Producing (Constructing)

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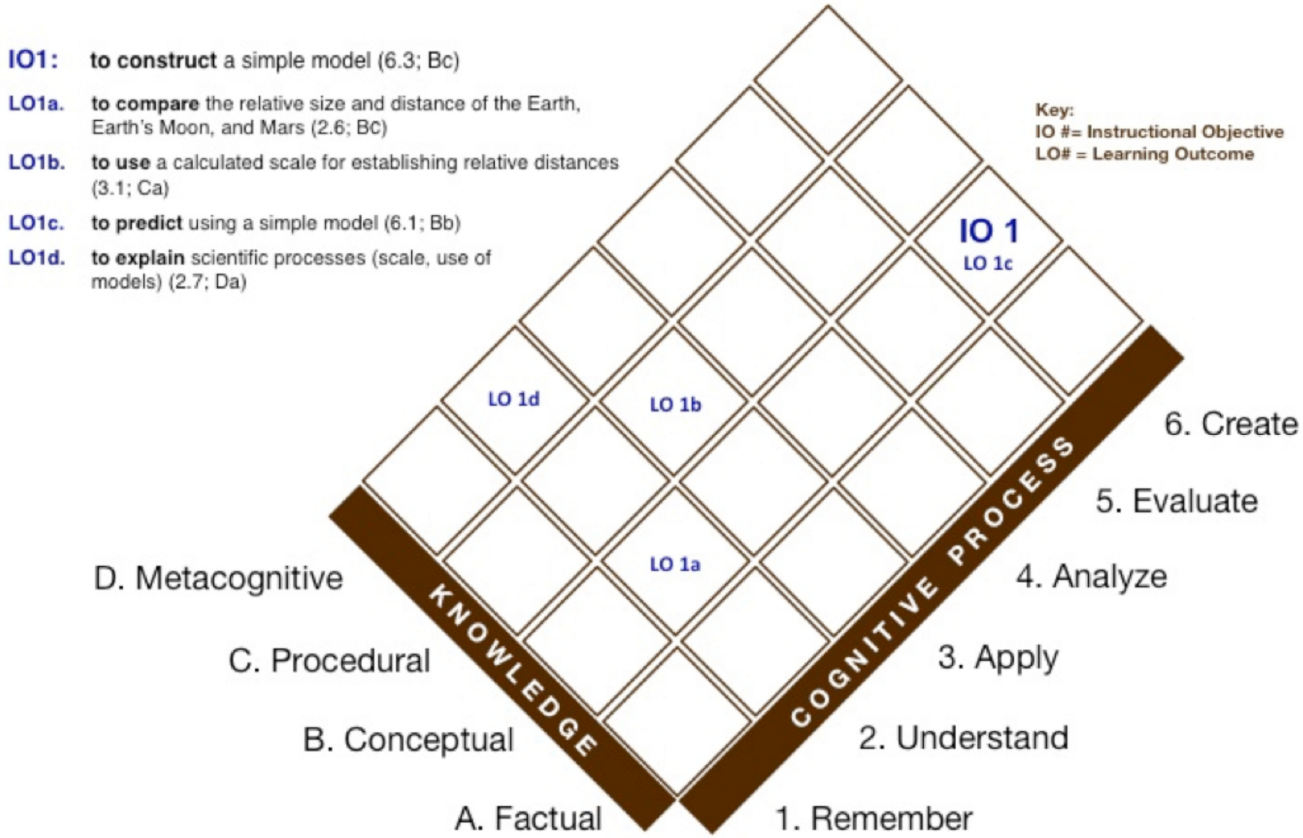
(H) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (2 of 3)

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Pedagogically, it is important to ensure that objectives and outcomes are written to match the knowledge and cognitive process students are intended to acquire.



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(H) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (3 of 3)

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Below are the knowledge and cognitive process types students are intended to acquire per the instructional objective(s) and learning outcomes written for this lesson. The specific, scaffolded 5E steps in this lesson (see 5.0 Procedures) and the formative assessments (worksheets in the Student Guide and rubrics in the Teacher Guide) are written to support those objective(s) and learning outcomes. Refer to (H, 1 of 3) for the full list of categories in the taxonomy from which the following were selected. The prior page (H, 2 of 3) provides a visual description of the placement of learning outcomes that enable the overall instructional objective(s) to be met.

At the end of the lesson, students will be able

IO1: to construct a simple model
- **6.3:** to construct
- **Bc:** knowledge of theories, models, and structures

To meet that instructional objective, students will demonstrate the abilities:

LO1a: to compare size/distance in model
- 2.6: to compare
- Bc: knowledge of theories, models, and structures

LO1b: to use a calculated scale
- 3.1: to use
- Ca: knowledge of subject-specific skills and algorithms

LO1c: to predict using a model
- 6.1: to predict
- Bb: knowledge of principles and generalizations

LO1d: to explain scientific processes
- 2.7: to explain
- Da: strategic knowledge

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