**Unit Essential Question:** *What forces keep the parts of our solar system together and how can we use this knowledge to plot a telescope route through space?*

**Introduction**

In the task, students learned that the best way to visualize large systems is to create models. They practiced the skill of developing and using models within the context of the smaller Sun-Earth-Moon system. However, in order to chart a route for the new telescope, they must find out where objects are and how they are laid out within the entire solar system. To visualize all this, students need to develop a model of the solar system, using those skills they practiced in the previous task. Unlike in the last task, however, students now focus on the scale aspect of developing models. To construct a scale model, students must first analyze and interpret data to determine scale properties of objects in the solar system. In doing so, they will find that while the solar system is huge, they can use math to model it on a smaller scale, providing the perfect context within which to plot their telescope route.

**Alignment Table**

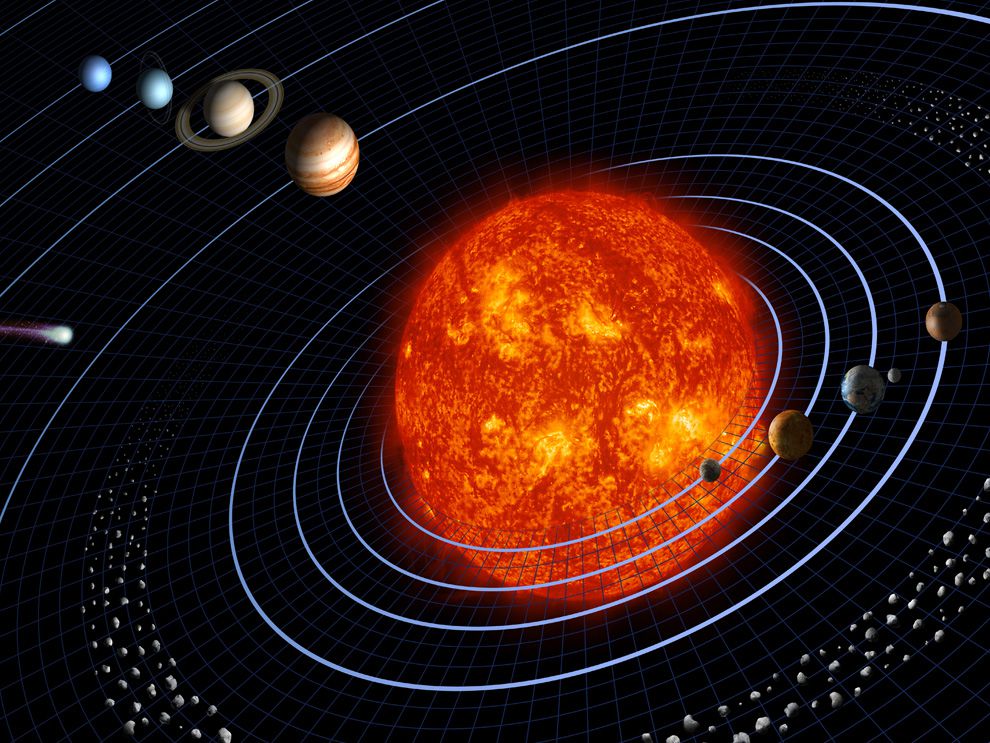
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| --- | --- | --- | --- |
| **Performance Expectations** | **Science and Engineering Practices** | **Disciplinary Core Ideas** | **Crosscutting Concepts** |
| **MS-ESS1-3 Analyze and interpret data to determine scale properties of objects in the solar system.**[Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object’s layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.]  [*Assessment Boundary: Assessment does not include recalling facts about properties of the planets and other solar system bodies.*] | **Analyzing and Interpreting Data**  * Analyze and interpret data to determine similarities and differences in findings. | **ESS1.B: Earth and the Solar System**  * The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids ~~that are held in orbit around the sun by its gravitational pull on them.~~ (The portion of this DCI that is crossed out will be addressed in Task 3). | **Scale, Proportion, and Quantity**  * Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. |
| **Supplementary Science and Engineering Practices**   * Developing and Using Models * Develop and use a model to describe phenomena. * Evaluate limitations of a model for a proposed object or tool. * Using Mathematics and Computational Thinking   + Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems. | | | |
| **Equity and Groupwork**   * Discuss how data can create a full picture of our solar system. * Come to consensus to build an assigned planet model. | | | |
| **Language**   * Use analytical and mathematical terminology to do oral and written analysis of data. * Watch a video and write written conclusions. | | | |

**Learning Goals**

This learning task asks students to analyze and interpret data to determine scale properties of the solar system. More specifically, the purpose is to:

* Explore the idea of scale using a simpler example.
* Analyze and interpret data to determine scale properties of objects in the solar system.
* Use mathematical and computational thinking to scale and build a smaller solar system model.
* Use an example to identify limitations in most solar system models and the importance of scale.
* Apply knowledge of scale properties to explain the layout of the solar system as the backdrop for a telescope route.

**Content Background for Teachers**

**** This task builds on what students have already learned about models and the Sun-Earth-Moon system to look at the solar system as a whole. As stated in the background section of the Lift-Off Task, the solar system is made up of eight planets and their moons, along with other smaller celestial bodies. Most students will be able to identify at least a few of these planets. These planets orbit the largest body in the solar system—the sun. Keep in mind that the sun contains 99% of the solar system’s mass. Because of this size, it is not reasonable for us to use the same scale for the sun as we do for the planets. This is an important point to emphasize to students as they create their classroom solar system models.

As stated in the background section of the Lift-Off Task, it is the gravitational pull of the sun that keeps all the planets in orbit around it. Each planet orbits the sun at a different distance, known as the orbital radii. The orbital radius is defined as a planet’s average difference from the sun. As students will see in the Explore, this distance greatly differs; the greater the orbital radius, the farther it is away from the sun. This is what will allow them to construct a layout of planets in the solar system. Because these distances are so large, scientists use a unit called the Astronomical Unit, or AU, which is approximately 150 million kilometers. It is also important to note that while these numbers tell us of the average distance a planet is from the sun, this does not mean they are all positioned in a straight line. Planets orbit the sun at different speeds, so they will be spread out within the solar system at any given time. This should also be made explicit to students as they develop their classroom models.

Within the same concept of scale properties, students will also learn that planets are different sizes. They will look at data of the diameter of different celestial bodies (including the sun). Some students may need clarification on the term diameter, which measures across the entire center of a sphere, as opposed to radius. Students will find that some planets, like the gas giants Jupiter and Saturn, are much larger than others. And yet, none of these planets come close in size to the sun.

In gaining all this content knowledge through data analysis and development of models, students will better be able to visualize the setting through which they will launch their telescope for their culminating project and truly understand the meaning of a scaled model.

**Academic Vocabulary**

* Sun
* Earth
* All Other Planets
* Orbit
* Radius
* Astronomical Unit
* Relative (Size/Distance)
* Scale
* Ratio
* Proportion
* Diameter

**Time Needed (Based on 45-Minute Periods)**

4 Days

* Engage: 0.5 period
* Explore: 1 period
* Explain: 1 period
* Elaborate: 0.5 period
* Evaluate and Reflection: 1 period

**Materials**

* Unit 2, Task 2 Student Version

Elaborate

* Light source, such as a standing lamp
  + Extension cord, if necessary
* Varied materials to make planet models, such as:
  + Clay
  + Styrofoam spheres
  + Cotton
  + Balloons
  + Construction Paper of different colors
  + Paint and Brushes
* String or Twine
* Rulers (with cm)
* Labels
* Markers

Evaluate

* Project Organizer Handout

**Instructions**

**Engage**

1. Introduce Task 2: In the last task, you made a model of the sub-system of the solar system that we are most familiar with, the Sun-Earth-Moon system. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
   * Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.
2. Transition to Task 2: The type of model we made helped us to understand the science behind many phenomena we experience on Earth. The model you will build in this task serves a different purpose. To prepare to launch the new telescope through space, we need to know the layout of the whole solar system *to scale*. As you know, the solar system is huge! If we want to visualize where things are in the solar system, we are going to have to scale objects down, or reduce them to a much smaller size.

* Now pass out their Task 2 student guide.

1. Before students make a model of the entire solar system to scale, it is important that students understand the idea of scale. This exercise introduces students to the crosscutting concept of **Scale, Proportion, and Quantity**, which they will continue to explore throughout the unit. By introducing the concept within a more familiar context, students will better be able to understand the following idea of scale that is outlined by NGSS: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
2. We recommend students do this individually, as each student will have different examples of locations in their head.

* You may want to first model the procedure on their student guides via a whole-class demonstration on the board.
* After students do this activity on their own, debrief the activity and the implications for modeling and scale. In particular, think about how useful one scale might be for certain purposes and not others.
* Wrap up the activity with the following excerpt from their student guides: Congratulations! You just made your first attempt at a scale model. A scale model shows real objects with all the sizes reduced or enlarged by a certain amount, known as the scale. Today, you will be exploring the real sizes of objects in the solar system so you can reduce them by a certain amount for your scale model.

**Explore**

1. In this Explore, students begin to explore the data that will help them to determine scale properties of objects in the solar system.
   * This gives students practice at **Analyzing and Interpreting Data**, as they look at data on planets’ diameter and orbital radii to determine similarities and differences among solar system objects.
2. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
   * Ask the Materials Manager to handle any resources needed to complete the task.
   * Ask the Facilitator to read the directions, make sure everyone understands the task, and facilitate discussion.
   * Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone’s voice is heard.
   * Ask the Recorder to make sure the group is recording their data analysis in their student guides.
3. Students analyze data showing the diameters of different planets (Part I) and the orbital radii of all the planets (Part II). You may wish to review terms like “diameter” and “orbital radius” before students begin this activity, building off whatever prior knowledge you find most appropriate. Questions are provided on the student guides to facilitate analysis of the data. Some sample student responses are below:

Part I

* 1: This illustration shows the planets in relative size. What do you think relative size means? *Relative size means compared to one another’s size or in relation or proportion to one another’s size.*
* 2: What is the largest and smallest body in the solar system? *The largest body is the sun, but the largest planet is Jupiter. The smallest body is Mercury.*
* 3: What do you notice about the size of the planets? Make some comparisons based on similarities and differences you see. *It looks like the first four planets are much smaller than the 5th and 6th planets. The last two planets are average size.*
* 4:Why does this information matter to create a solar system model and plan a route for the new telescope? *We don’t want our telescope to crash into a planet so it is important to know their size in the model.*

Part II

* 1: The illustration to the right shows the planets in relative distance from the sun. What do you think relative distance means? *Relative distance means compared to one another’s distance or in relation or proportion to one another’s distance.*
* 2: Orbital radius is ultimately the average distance each planet maintains from the sun as it orbits. Why do you think scientists use AU for orbital radii instead of kilometers? *1 AU is 150 million kilometers, so the distance between planets must be huge! That’s why you would use AUs instead.*
* 3:Why does this information matter to create a solar system model and plan a route for the new telescope? *We don’t want our telescope to crash into a planet so it is important to know how far apart they are in order to maneuver around them.*

1. Optional: Conduct a whole-class debrief that brings out the ideas students saw in the data.
   * The use of equity sticks is encouraged for more equitable participation in class-wide discussions like these (See “How To Use This Curriculum” for more details).

**Explain**

1. This section of the task asks students to take data they have analyzed and use it to make a physical model of the solar system. This will help them visualize the solar system so they may figure out possible routes the new telescope may take.
2. We recommend reading the two introductory paragraphs on their student guides aloud, as these will give background for why students are making a solar system model and the justification behind the type of model they will make.
   * This activity allows students to explicitly emphasize the crosscutting concept of **Scale, Proportion, and Quantity** as they create a scale model for the solar system, which is much too large to visualize otherwise. Because of the large difference in planet size and planet distance from the sun, it is not realistic for students to use the same scale. Thus, for the sake of this model, they will be using two different scales—one for planet size and one for orbital radii. They will revisit this reasoning in the Elaborate.
   * Students are also continuing to build their skills in **Developing and Using Models**, which they began in Task 1, but are now usingto describe the phenomena of our solar system as a whole.
3. Again, we recommend use of group roles in this activity. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Reporter.
   * Ask the Facilitator to read the directions and to make sure everyone understands the task.
   * Ask the Materials Manager to handle any resources needed to complete the task.
   * Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone’s voice is heard.
   * Ask the Reporter to make sure the group is reporting their math and labeling their models.
4. Part I: In this section of the task, students use the following ratios to help them figure out the proportions of their solar system model: Size of Body (1000 km = 1 cm) and Distance from Sun (1 AU = 10 cm)
   * This asks students to use the science and engineering practice of **Using** **Mathematics and Computational Thinking.** The math is fairly simple and the focus should be on applying the mathematical concept of ratio throughout to ensure a properly scaled model.
   * Optional scaffold: Model the math for each of the charts with “Mercury” so students know how to start.
5. Part II: Assign each group one of the planets to be in charge of for the class solar system model, which they will return to for the rest of the unit.

* Clear a space in your classroom for a class solar system model, placing a light source, such as a standing lamp, in the center of the room. Explain to students that this will represent the sun in their classroom model. They will not be using the same scale for the sun as their planets because the sun is so huge…it takes up 99% of our solar system’s mass!
* Provide students with the materials outlined in the beginning of this guide and ask them to use the directions in their student guide to create a physical model of the planet and cut a string to signify the actual distance from the sun. These should then be labeled and placed within the class solar system model (\*Note: labeling is essential so the model may be cleared and reassembled for each class period).
* Note: If it doesn’t come out naturally as students place their planets, it is important to emphasize to students that while these numbers tell us of the average distance a planet is from the sun, this does not mean they are all positioned in a straight line. Planets orbit the sun at different speeds, so they will be spread out within the solar system at any given time.

**Elaborate**

1. To drive this idea of *scale* home, students watch the following video detailing the process in creating a truly scaled solar system model: <https://www.youtube.com/watch?v=Kj4524AAZdE>.
2. Once they watch the video, they will use the questions on their student guide to facilitate a discussion about model limitations and the concept of scale, in pairs. This activity emphasizes a different aspect of the Science and Engineering Practice of **Developing and Using Models** as students evaluate the limitations of various models for the solar system and Sun-Earth-Moon system. Again, students are exploring the crosscutting concept of **Scale, Proportion, and Quantity** by observing an example of a solar system model that is at a different, more accurate scale than their own.

* In doing so, students will reflect on the models from Task 1 as very limited in their accuracy to scale. Their class solar system model is also limited for several reasons, as described above. First, the sun is far greater than the other planets, so there is not enough room in a classroom setting for an accurate scale. Second, the distance between planets is far greater than the planet diameters, so again an accurate scale cannot be used in a classroom scale. This is why we don’t often see true scale models of the solar system. However, the individuals in this video were able to do it by using a huge area (7 miles) and very tiny planets (Earth was just a tiny marble).
* Debrief the video as a class, using the themes of some of the questions on their student guide. As usual, the use of equity sticks is encouraged for more equitable participation in class-wide discussions (See “How To Use This Curriculum” for more details).

1. Return to the whole-class concept map from the Lift-Off Task.

* In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See “How To Use This Curriculum” for more details).
  + Some facilitating questions to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
  + Draw circles around each question and boxes around each concept.
  + Write connector words to describe connections between the concept boxes.
  + For this task, students may begin to connect some of their previous question circles to concept boxes about the following: layout of the solar system, size of planets, and scale properties of objects in the solar system.
* Have students analyze the additions to the class concept map for as many examples of this task’s crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
  + **Scale, Proportion, and Quantity**: These could be phrases such as, “is proportional to”, “compared to”, “has a ratio of”, “is bigger/smaller than”, “is longer/shorter than”, etc.
* Once again, the purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

**Evaluate: Connecting to the Culminating Project**

1. Students independently complete the Task 2 section of the Unit 2 Project Organizer in class. Revisions can be done for homework, depending upon student’s needs and/or class scheduling.
2. Students have begun developing a model of the solar system so they can propose the best route a new telescope should take through space. Their prompt is as follows: To plan a route for the new telescope, you will need to know more than just the Sun-Earth-Moon System and more than just a list of total parts; you will need a specific layout. Draw a sketch of your class solar system model, including where the new telescope needs to arrive.

* In captions, explain the scale you used for your assigned planet within the model.
  + - What data did you use?
    - How does it compare to other planets in the solar system model?

**Reflection**

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:

* At the beginning of this task, you were asked to make a scale drawing showing locations around you. Look back at your drawing: how is this similar to the solar system model you made in this task? What makes your solar system model a better scale model than this first drawing?
  + In this task, we focused on the crosscutting concept of **Scale, Proportion, and Quantity**: scaled models can be used to study time, space, or energy systems that are too large or too small. Where did you see examples of **Scale, Proportion, and Quantity** in this task?
  + Now that you have created a class model of our solar system, what questions do you still have?

1. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

**Assessment**

1. You may collect students’ Project Organizer and assess using:
   * *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
   * This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.
2. You may also give students time to make revisions with one of the two options:

* Students may make changes to their Project Organizer according to your comments OR
* Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.