Using Reflective Thinking to Learn About Relative Distances of Solar System Objects

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Middle school students are naturally curious about our solar system. When given the opportunity, students will use their creativity, imagination, and prior knowledge to discuss the solar system just as scientists use their creativity, imagination, and prior knowledge when they explore the natural world. Although there is a natural level of curiosity and enthusiasm for space science, one issue that can arise when learning about a popular topic is when students hold inaccurate ideas and views about natural phenomena (Sadler et al. 2010). These inaccurate views can be derived from previous experiences, personal ideas, media representations, misinterpreted conclusions, or other encounters. The issue with these inaccurate views is that students can hold on to these views and be resistant to modifying them toward more accurate representations.

Even though it can be challenging, it is important that we provide opportunities for students to modify what they know based on reliable data and evidence via authentic tasks by thinking about what they know and why they know it. One way to address this, and to inspire conceptual change, is to have students practice reflective thinking, which includes contemplating about how we think, what we think, and why we know what we know. Reflective thinking is an important component of metacognition or “thinking about one’s own thinking” (Cooper and Sandi-Urena 2009, p. 240). Therefore, reflection and reflective thinking is critical to developing deeper understandings about our own learning processes (see Reflective Teaching links in Online Resources).

According to Song et al. (2006), to provide a classroom environment conducive to reflective thinking, a teacher should:

- provide ample wait time for reflection
- provide supportive environments that encourage reevaluation of findings
- provide authentic tasks and data for students to analyze and engage in reflective thinking
- review learning experiences and situations, and model reflective thinking during instruction
- ask questions that prompt for reasons and evidence
- provide less-structured environments to promote exploration of important concepts
- provide social-learning opportunities that foster collaboration between peers, teachers, and experts
- provide opportunities to write about thinking, positions, and evaluation of strengths and weaknesses in thinking

In this sixth-grade lesson, students are asked to think about what they know regarding the solar system prior to completing an activity, and then compare their prior knowledge with the new knowledge after completing the activity based on data.

Engage

Begin this lesson by starting a KWHL chart and asking students
open-ended and guided questions to probe their prior knowledge about the solar system. A KWHL chart, versus a KWL chart, is especially relevant for science teaching. K stands for what students know at the start of a lesson, W is for what they want to learn or what questions they have, H is for how students will explore and investigate their question, and L is to collect what students have learned after the lesson. Write down responses from the class under the “K” section of the KWHL chart. Ask questions such as: What do you know about our solar system? What is in our solar system? What is at the center of our solar system? What are some differences between the Sun (star) and planets? Where are the Sun and planets placed in our solar system?

Next, ask students what they want to know about the solar system. Note the questions under the “W” section of the KWHL chart. Guide students to question the placement of space objects in our solar system. Give each student a strip of receipt paper about one meter long. Ask students to color the very left edge of the paper and label it as the edge of the Sun. On the opposite edge, ask students to draw a dot and label it Pluto. Let students know that the strip of paper is a model of the solar system and represents the space between the edge of the Sun and where Pluto is located in our solar system. Ask students to independently draw in and label the remaining solar system objects that were listed together during engage. They are to draw these objects on the paper as they are placed in our solar system to generate a model of where the Sun, planets, Pluto, and the Kuiper belt are in our solar system. At this point, do not correct students as this is part of the activity that provides a visual representation of students’ prior knowledge of the solar system. Ask students to write “before” on the lower left-hand corner so they can differentiate this model from the one they will generate on the other side of the paper (see Figure 1).

**Explore**

Have students work on the next part of the lesson in small groups of three to four. Provide each person with a copy of the Pocket Solar System from the Astronomical Society of the Pacific (see link to PDF handout in Online Resources). Have students turn their receipt paper over to the blank side, then follow the directions from the handout starting with the section titled Making Your Pocket Solar System. This activity provides easy-to-follow directions for marking the planets and Kuiper Belt by relative distance by providing step-by-step instructions on how to fold the paper in ways that help locate and mark, more accurately, where the planets can be found between the Sun and Pluto. If needed, a differentiation strategy to consider is grouping students that speak the same second language together, so students can collaborate in their home languages. Another differentiation strategy may be to group students by various reading skills so that students can assist one another as they work through this part of the lesson. For visually impaired students, have a partner assist the student to fold and mark the paper strip with stickers or something that helps indicate the locations of the

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**CONTENT AREA**

Space science

**GRADE LEVEL**

6

**BIG IDEA/UNIT**

Activity illustrates the relative distances between space objects in our solar system, and students reflect on their thinking before and after activity.

**ESSENTIAL PRE-EXISTING KNOWLEDGE**

Our solar system consists of space objects including the sun, planets, a dwarf planet, and Kuiper belt.

**TIME REQUIRED**

Two 50-minute class sessions

**COST**

None.

**SAFETY**

No concerns.
planets on the paper. As students finish, ask them to write “after” on this side of the paper so they know this model was created after the first drawing (see Figure 2).

After each student is done, have them compare their models from the start of class with the model they generated with instructions. Ask students to reflect on their thinking about the two models by writing their thoughts, ideas, and questions in their science notebooks. The teacher can help students reflect on the activity by implementing a free write, or provide prompts such as: What do you think about your drawings or models of the solar system? What are some of the differences between your first model and the second model? Do you think your second model accurately represents our solar system? Why?

After students have had time to reflect on their drawings, ask them to discuss their reflections with members of their small groups and collect ideas about how the initial drawings compared with the second drawings. If needed, provide prompts for students to ask each other. Some examples include: How do our drawings from before compare to one another? Why did you think the planets were spaced as such? What do you think influenced the way we think about the position of the planets in our solar system? Why is Pluto included even though it is no longer considered a planet?

Having students question one another after they think on their own can provide opportunities for deeper reflection. For a differentiation strategy, prepare some prompts that may guide students to reflect on the topic of this lesson if needed, or pair students so they can challenge one another to think about additional questions or insights.

**Explain**

Have each small group generate their own way to present their findings and reflections to the class. As students show their drawings, ensure each group thoroughly shares the ideas and thoughts and provide time for classmates to ask questions or compare their own work with the presenters’ work.

As the class presentations occur, write down the main points that you want your students to know and formatively assess for developing understanding. For example, make sure your students understand:

- the Sun is the center of our solar system
- the correct order of the planets
- what the Kuiper belt is and what it consists of
- there are more objects in our solar system

**FIGURE 1:** Student examples of solar system before activity.
solar system than represented in our model, and this model only includes the main objects from the Sun to Pluto

- some solar system objects, like comets, are not included in their models, but may be found within this space at certain times
- the planets are not lined up in a straight row as the model represents
- the planet sizes are not accurate as the model represents

Next, prompt students to think reflectively about the activity and their knowledge about the solar system. Ask them questions such as: Why do you think your drawings differ? Why did you think that all planets were evenly spaced throughout the solar system? What might have influenced your preconceptions? What do you think about the relative distances of the planets in the solar system now? Do you think it will be easy for you to change your ideas about what the solar system looks like now that you have completed this activity? Why?

Finally, have students add any additional reflective thoughts in their science notebooks comparing their model drawings with the actual solar system. Ask students why scientists create models and review the importance of models in science. They can then create a pocket in their science notebooks to place the Pocket Solar System for future reference.

**Elaborate**

Have students refer to the chart with the distances of the solar system objects listed in the Pocket Solar System (see link in Online Resources). Let students know they will work in their small groups to model the distances outside the classroom on a larger scale. In other words, students will need to figure out ways to model the distances provided in kilometers and astronomical units in the schoolyard. Point out that this time, they will need to include Eris in their model, which is another dwarf planet in our solar system. Have them reflect on what they know about dwarf planets, prompt students to think about their thinking, what they think they know, and if appropriate, think about ways they can discover more information on the topic at a later time.

As the small groups brainstorm ideas on how they will work together to model kilometers and astronomical units into feasible distances outside, write down each group’s ideas as they are generated under “H” on the KWHL chart. Check that students’ ideas are correct to ensure that they will demonstrate an accurate model of the relative distances of space objects. Also, make sure the ideas are feasible by the comparing groups’ plans with the available outdoor space the activity will take place in. After the groups have developed their plan and the teacher has checked that the plans are accurate and feasible, remind students of the rules and expectations of working outside the classroom to safeguard students during the activity, such as staying within a predetermined area and...
notifying the teacher if anything is of concern. Next, have students go outside and model the major objects in our solar system so they can experience a different representation of the relative distances of the major planetary bodies in our solar system. After students return to the classroom, ask them what they learned from the lesson thus far about relative planetary distances. Add the student comments under “L” on the KWHL chart.

**Evaluate**

Begin this section by asking students to share thoughts about what they learned during this lesson. After the class has shared what they have learned about the relative distances of planets and dwarf planets from the Sun, ask students how they spaced the planets at the start of class on the “before” model. (Typically, students will space out the planets evenly on the receipt paper.) Have students brainstorm why most of them thought the planets are evenly spaced. After the discussion, ask students if they have seen models of the solar system before and where they have seen these models. After a brief discussion, use an internet search engine and search for solar system images. Most images will show the planets evenly distanced from the Sun. Discuss with students the images they see and why images from the internet may have impacted their knowledge about the relative distances. Share that often these drawings are done to include all the major planetary bodies in a limited space and discuss the limitations of scientific models. Also discuss the importance of thinking about what we think we know and using evidence and data to modify our knowledge to more accurate views of science.

To evaluate, provide an image of the solar system from a source on the internet that represents the solar system as evenly spaced planets from the Sun. As the evaluation component, ask students to identify five things that are inaccurate about the image.

Students should also include a brief reflection on what they know about the solar system at the end of the lesson and compare it with what they knew about the solar system at the start of the lesson. Prompt students to recognize that their new understandings are data driven and are more aligned to accurate scientific views on the relative distances of planets and dwarf planets in our solar system.

**Conclusion**

Reflective thinking provides students opportunities to think about what they know and how they know it, and to make judgments about experiences. Practicing reflective thinking also fosters students’ ability to modify their knowledge based on data and evidence, which is important to the development of scientific knowledge over time. Additionally, reflective thinking is part of critical thinking, an essential part of developing scientific literacy and becoming consumers of information as world citizens. It is important that students be reflective as learners to promote conceptual change toward more accurate views of scientific phenomena.

**REFERENCES**


**ONLINE RESOURCES**

Pocket Solar System—https://bit.ly/3aNgWIs


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