EMBODYING EARTH'S PLACE IN THE SOLAR SYSTEM

Upper elementary students investigate seasonal constellations using software and model them with their bodies.

By Julia Plummer

E lementary students find it difficult to connect the apparent motion of objects in the sky with how celestial objects actually move in the solar system. As a university astronomy education researcher, I have been investigating methods to help children learn astronomy through workshops and summer camps at science museums and planetariums. In this article, I share an investigation of the seasonal constellations that uses embodied learning strategies to help students with this complex spatial thinking. Students make observations of constellations using a computer program called *Stellarium*, develop evidence-based claims that describe the pattern of change in the seasonal constellations, and make sense of their observations by modeling their own bodies as the Earth while it orbits the Sun.

As the Earth Orbits the Sun...

A goal of the Next Generation Science Standards (NGSS Lead States 2013) is for students to demonstrate their

understanding of how the Earth's place in the solar system can be used to explain patterns of change in our observations of celestial phenomena. Even earlier, A Framework for K-12 Science Education (NRC 2012) asked the following question to organize student learning about astronomy across elementary grades levels: What are the predictable patterns caused by Earth's movement in the solar system? The question points to the existence of a broad range of astronomical phenomena that students could investigate as they learn how objects appear to move as observed from the Earth's surface, including the seasonal change in the constellations. At midnight, when we look into the sky, we face toward a certain set of constellations. But as the Earth orbits the Sun, the direction we face at midnight slowly changes throughout the year; thus, the constellations we observe at midnight slowly change until we return to the same point in space-one vear later—and observe the same constellations again.

Some educators believe we should not teach children about the Sun rising and setting or the constellations

FIGURE 1.

Materials and setup.

Materials

- Projector
- Computer (with Stellarium installed)
- Printouts for each month
- Printouts for each zodiac constellation
- Lamp or yellow ball

Tips for getting started with Stellarium:

- After installing and opening Stellarium on your computer, move your cursor to the far left of the screen where a panel will appear. Open the Location Window and click on the map to select a location near where you live; it does not need to be exact. Click on "Use Current Location as Default."
- Move your cursor to the bottom of the screen. A new panel will appear revealing three buttons controlling the appearance of the constellations (images and labels). Turn labels and either art or line figures on.
- Move the cursor back to the left-hand panel and open the Date-and-Time window. Practice changing the time
 to midnight and then the month and date. This can be done by clicking on the arrows above and below the
 numbers or highlighting the numbers and inputting new values.
- To change the direction you are facing, click on the screen then drag the cursor right or left. You will see the letter "S" on the horizon move. This indicates you are moving away from the direction south.

Setup the day of the lesson

- Project Stellarium showing the current evening sky at midnight, facing south.
- Tape the name of each month in a circle around the classroom, counterclockwise.

changing seasonally because it is "actually" the Earth moving and not the Sun moving or the stars moving (Shen and Confrey 2010). Astronomy curricula often ignore the apparent patterns of motion to focus only on how objects move in space. However, without having a solid understanding of the change over time in astronomical phenomena, as seen from the Earth, students will not learn how astronomers develop and support scientific models.

Using Embodied Learning Strategies

I wanted to help students learn how to make sense of what they can observe in the sky from the Earth using the motion of the Earth in the solar system. With this in mind, I have been developing and testing instructional strategies that will help elementary students learn to explain these spatially complex astronomical phenomena.

Instructional strategies that take advantage of the body's involvement in how we learn can help scaffold the complexities of spatial thinking while studying astronomy (Plummer, Kocareli, and Slagle 2014). Embodied cognition explains how learning takes place: not just by observing and listening but also by physically engaging with our environment (Wilson 2002). Using embodied learning strategies may help children use their bodies in specific ways to focus on key ideas and communicate concepts they may not yet have the vocabulary to express (e.g., Plummer, Kocareli, and Slagle 2014). For example, when doing a preassessment, I asked my students, "Can you show me how you think the Earth moves using your body?" Engaging children physically can help them take on new perspectives that would otherwise be difficult to imagine. I used this idea to create the seasonal constellation investigation in which students used their own bodies as the Earth to observe how their perspective changes as they orbit the Sun throughout the year.

Investigating Seasonal Constellations

I most recently taught the seasonal constellations investigation during summer astronomy programs at a children's science museum for students entering grades 2–5. I taught the investigation as one of a sequence of astronomy and space exploration lessons the students experienced during the programs. I recommend that this investigation may be most appropriate for children in grades 3–5, especially those who have learned to explain the day/night cycle and that stars are outside of our solar system, not moving about near the Earth and Moon (an alternative idea I often hear from my students, prior to instruction). This investigation addresses the grade 5 NGSS standard (5-ESS1-2). Although the framework described in this investigation is appropriate for children in grades 3–5, you may be able to place more responsibility on fifth-grade students for recording observations, developing claims that answer the investigation question, and writing more extensive reasoning in their notebooks. For the younger students, I provided more verbal support throughout to help them develop an appropriate claim from their observations and did more to help them make sense of how the model explained their observations before they made an entry in their science notebooks.

I used a claims-evidence-reasoning framework for developing explanations in the investigation (Zembal-Saul, McNeill, and Hershberger 2012). Using this framework meant that in Part 1 of the investigation (20–25 minutes), we collected data and used that to make a claim that answered our investigation question. In Part 2 (20–25 minutes), we used a model to construct the reasoning for the students' evidence-based claims followed by recording this in their science notebooks. Materials and set-up information are provided in Figure 1, p. 53.

Part 1: Finding the Pattern of Change

I began by asking, "How do the constellations we see at night appear to change over time?" to elicit students' initial ideas. My students' answers usually suggest they think we see different constellations over time. Some specific answers have included "They'd probably go in different directions than last time you saw them. In different places" (third grade) "Orion the Hunter would be there [in the sky] instead of the Scorpion. Because Orion comes out in the winter and the Scorpion comes out in the summer (fourth grade)" and "The stars will move far across the sky and new stars will come in so they're new constellations (fourth grade)." However, students rarely describe the full pattern of how the constellations change over time. To begin answering the investigation question, I had the students make observations using the software Stellarium. I projected and navigated Stellarium from my computer on the classroom overhead projector throughout the investigation. Figure 2 shows the shift in constellations observed at midnight in May and June from Pennsylvania. Other computer-based planetarium software can be used for this investigation (e.g., Starry Night); I recommend Stellarium because it is free and can be used on both Macs and PCs (see Internet Resources).

To help the students make observations, I asked them to focus on a subset of constellations: the 12



constellations of the zodiac. Typically, I do not explain the concept of zodiac constellations to my students, as it is not important for completing this investigation. Zodiac constellations are those in which the Sun appears to pass through over the course of the year because of the Earth's orbit around the Sun. I gave each student or pair of students a sign showing one of the 12 zodiac constellations to focus on during data collection. We made each observation on the same day and time for each month over the course of 14 months. This allowed the students to observe that the constellations they observed in the South begin to repeat after one year's worth of observations. At any given time, a handful of zodiac constellations may be visible across the southern horizon. Therefore, I asked my students to report which of the 12 zodiac constellations was just over the southern horizon. I recorded the

zodiac constellations they observed in the southern sky at midnight on various dates on a chart for the group, though individual students could have made their own records in their science notebooks. See NSTA Connection for an example data table with sample constellation observations.

After recording their observations, I asked my students to identify a claim that answers the investigation guestion, "How do the constellations we see at night appear to change over time?" and to say how their observations support that claim. Initially, some students made claims about how they continued to notice zodiac constellations to the West and to the East even when they were not visible in the South. Another student compared the seasonal change in constellations to the notion of a flipbook, where you could observe the change of constellations over time in a continuous manner. I work toward developing the following type of claim with the students after we have discussed all of their ideas and answers to the investigation question: "From one month to the next, we see the same constellations in the southern sky. Over many months, we see different constellations. But by the same month in the next year, we see the same constellations in the South and the cycle repeats."

FIGURE 3.

Classroom illustration with a ball representing the Sun.



Part 2: Explaining the Pattern of Change

I continued the investigation by asking, "Why do the constellations we see at night appear to change over time?" I have found that some students believe this change is because of the Earth's rotation. This is true if you only consider the change over one night; as the Earth rotates, we see many different stars and constellations appear to rise and set. However, over the course of the year, the stars we see at the same time at night will change because Earth is orbiting the Sun and shifting the direction we are facing in space. The time we call "midnight" is in relation to the Sun, but our location in space is changing with respect to the Sun. Other students believe that we see different constellations because, as we orbit the Sun, we move too far away to see constellations on the other side of the orbit. This explanation suggests that the students do not understand that the distance between one side of our orbit and the other is small compared to the distance to the stars that make up the constellations.

Next, I led the whole class in building a model of the location of constellations with respect to the Earth's orbit

around the Sun. I began by placing a representation of the Sun (a lamp) in the center of the classroom and putting up wall signs for the 12 months of the year, in counterclockwise order, in a ring around the classroom (Figure 3). I asked for a volunteer to demonstrate their ideas about how the Earth moves in the solar system. Sometimes the volunteer only shows rotation or revolution, so I will ask for another student to add onto the first student's idea with additional ways in which the Earth moves. Once a student demonstrates the Earth's orbit, I also point to the month signs on the wall to help the students connect the simulated Earth motion in this model to our notion of the year.

Next, I asked the students, "If you are the Earth, and that is the Sun, where would you need to be in the Earth's orbit to see your constellation at midnight?" A student suggested that if they observed Pisces in October then they would need to be wherever the Earth is in October. I asked that student to tape Pisces on the wall beneath the October sign. I would then move on to the November sign and asked who had the constellation observed at midnight on that month; that student or pair would tape their constellation on the wall below the corresponding month sign and we would continue along, using the data table as needed.

Next we moved to having students make sense of their observations using the embodied model to construct an explanation for seasonal constellations. I began this part of the model by having students stand in a circle around the Sun next to their constellation, explaining to them that they each represent the Earth at a different point in its orbit. I told them to slowly spin in a counterclockwise rotation (I had them turn toward their left hand). This allowed the students to notice that they can see their constellation when they face away from the Sun (midnight) but that other constellations are visible if they look to their left (East) or right (West). To encourage them to understand the full, three-dimensional view, I told them to rotate to face the Sun and asked, "What time is it?" (Daytime; noon.) "What constellation is opposite you? Would you be able to observe this constellation?" (No, the Sun is too bright.)

Then, I asked the students, "What would we have to do to see different constellations than the ones we saw at night?" Students responded that we needed to move around in our orbit. I had the students walk halfway around in the orbit (six months). For safety reasons, I recommend not having students both rotate and revolve at the same time as this could cause tripping and collisions. When asked, "What constellation can you see at midnight?" students stated, "the one that was not visible during the daytime, six months ago." Last, I asked, "What constellation is not visible when it is noon, as you face the Sun?" Their reply was "the constellation I originally saw at midnight; my constellation."



Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013):

5-ESS1 Space Systems

www.nextgenscience.org/5ss-space-systems-stars-solar-system

The materials/lessons/activities outlined in this article are just one step toward reaching the Performance Expectations listed below. Additional supporting materials/lessons/activities will be required.

Performance Expectation	Connections to Classroom Activity Students:				
5-ESS 1-2. Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.	 collect and analyze data on the change in the seasonal appearance of some stars and constellations in the night sky and represent this seasonal change in the stars' appearance through the creation of a physical and embodied model. 				
Science and Engineering Practices					
Analyzing and Interpreting Data Developing and Using Models Constructing Explanations	 develop claims about the change in some constellations over the course of the year by analyzing data. participate in using a model to construct an explanation for why we observe different constellations at different times of the year. 				
Disciplinary Core Idea					
 ESS 1.B: Earth and the Solar System The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the Sun, Moon, and stars at different times of the day, month, and year. 	 observe changes in the stars and constellations over the course of the year and use a model of the orbit of the Earth around the Sun to explain this phenomenon. 				
Crosscutting Concepts					
Patterns Cause and Effect	 develop an explanation for the repeating yearly pattern of our observation of seasonal constellations using the orbit of the Earth around the Sun. use a model of the Earth and Sun to show that our position in the solar system causes us to observe some constellations at night while others are not visible during the day. 				

FIGURE 4.

Second- and third-grade students' science notebook entries.

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TABLE 1.

Rubric for evaluating students' reasoning.

	Full use of scientific reasoning	Partial understanding of scientific reasoning	Emerging understanding	No evidence of understanding
Description of criteria for written and/ or drawn explanation	 The student includes in his or her reasoning: We face toward different constellations at night at different times of the year because we are in different places in our orbit. After a year, we orbit back to the same place and so we see the same constellations. The student may also describe how we do not see some constellations because the Sun blocks them during the ductions 	The student includes the Earth orbiting the Sun in their reasoning for why we see different constellations but does not show why this changes the constellations we can observe.	The student indicates that the Earth moves but is not clear on how it moves (orbits and/or rotates) or describes the Earth's motion inaccurately.	The student uses alternative ideas to explain seasonal constellations, such as suggesting that the constellations are too far away to be observed or that they actually move around in space.

Note: Each of these written elements can be replaced or enhanced by the addition of elements in a drawn representation by the student.

Finally, we discussed how all of the pieces fit together in the model to explain the changing appearance of the constellations over the course of the year. Here is an example of the type of reasoning I aimed for after the whole-class discussion, though I did not expect this exact wording from any one elementary student:

"The constellations we see at midnight appear to change from month to month because the Earth is orbiting the Sun. This causes us to face a different direction in space, toward new constellations, when the Earth is facing away from the Sun. But after an entire year, the Earth has orbited back to its original point in space so we are facing toward the same constellations at midnight."

Notebooking the Pattern

Following this, the students wrote the reasoning portion of their explanation in their science notebooks. I encouraged them to also draw pictures because I have found they often have an easier time expressing their ideas about these relative positions through drawings than the written word (Figure 4, p. 59). A rubric for assessing student reasoning about why we observe different constellations throughout the year is provided in Table 1.

The students' notebook entries showed me that my students were beginning to express their thinking about how the Earth's movement in the solar system changes our observations of the constellations. The students seemed to have more difficulty expressing their understanding



of how the direction we face in space is important to this explanation in writing and drawings than they did when we discussed these ideas in class. I recommend asking children, once they identify the importance of the Earth's orbit in their science notebooks, to answer the question "How does the Earth orbiting the Sun help us see different constellations at different times of the year?" If they have drawn a picture of the Earth's orbit, ask them to draw an arrow pointing to when we would see two different constellations at different times of the year.

Conclusion

These embodied learning strategies can be used to support children in describing and explaining other celestial motion phenomena. All of the strategies involve learning to describe patterns seen from the Earth and a model to explain what these observations look like from space. Prior to engaging students in the seasonal constellation investigation, teachers can use embodied learning strategies to investigate "How and why does the Sun appear to move throughout the day?" by having the students use their bodies to model the Earth's rotation. Investigating the Sun's apparent motion is appropriate for younger students or as an introduction to this investigation (grades 2–4). Investigating both the Sun's apparent motion and change in seasonal constellations prepares students to investigate more complex celestial motion questions in middle or high school. \blacksquare

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Internet Resources

About Constellations

www.lpi.usra.edu/education/skytellers/constellations/about. shtml

- **Kinesthetic Astronomy**
 - www.spacescience.org/education/extra/kinesthetic_

astronomy

Stellarium

http://stellarium.org

What are constellations?

www.astro.wisc.edu/~dolan/constellations/extra/ constellations.html

NSTA Connection

To see a data table with sample observations, visit *www.nsta.org/SC1512*.