Making the Transition to Three-Dimensional Teaching

An NGSS@NSTA curator and elementary science specialist shares how to evaluate teaching materials using the EQuIP rubric.

By Betsy O'Day

Curriculum and lesson planning require us to consider many things. With a shift to the *Next Generation Science Standards* (*NGSS*), integrating the dimensions of science and engineering practices, disciplinary core ideas, and crosscutting concepts becomes a focus of that planning (NGSS Lead States 2013). While in Chicago for NSTA's National Conference on Science Education, I attended Stephen Pruitt's presentation about the top 10 things he learned in 2014 regarding the *NGSS*. That presentation was the focus of an article in the summer issue of *Science and Children* that I have reread several times (Pruitt 2015). It reminds me that this shift is not easy, and I need to be patient with myself and my students as we make this transition. There will be varying degrees of success as students and teachers together build a three-dimensional culture in our classrooms.

The transition planning can be overwhelming. In my role as elementary science specialist, I teach fourth- and fifth-grade science. Since I teach in a small rural district, I am the person responsible for both grade levels' science curriculums. The question before me is how to plan instruction for both grade levels that is aligned to the *NGSS*. Most of the instructional materials that I have used or found in my search for materials were developed before the *NGSS* was completed. To start, I needed to decide what in my current curriculum will need to be discarded because it is no longer at that grade level or no longer meets the need for instruction under the new standards. The materials and resources I have left would need to be evaluated and adapted for alignment to the *NGSS*, as would any other new resources that I find in a search for instructional materials to meet the need. It is important for me to remember that this process will take time and all of the materials I use in my classroom do not need to be transitioned immediately.

After the *NGSS* were released, I was given the opportunity to serve as an NGSS@NSTA curator. Curators are using the EQuIP (Educators Evaluating the Quality of Instructional Products) rubric developed by Achieve and NSTA (see Internet Resource) to evaluate resources. Using the rubric, curators can examine how a resource might be aligned to the *NGSS* and consider ways to make it more three-dimensional. In my new role, I began to examine materials used for instruction toward building student proficiency in the performance expectations found in grade 5 Space Systems: Stars and the Solar System (Figure 1). Not only would I be evaluating these materials, but in adapting instruction in my classroom, I knew I would also be potentially using them. I began my work by evaluating a lesson that I was very familiar with because I had used it previously in my classroom and in informal settings, the *Kinesthetic Astronomy Sky Time* lesson (Morrow and Zawaski 2004).

The lesson was designed and intended for students from sixth grade to adult. In this lesson, students construct a size-distance scale model for the Sun, Earth, Moon, and stars. In addition, they use their bodies and movements to model the relationship between time and astronomical motions of Earth (rotation on its axis and orbit around the Sun) as well as how these motions affect our view of objects in the sky at various times of day and year. The entire lesson is not appropriate for fifth grade as it includes modeling the reasons for the seasons (something not included in *NGSS* at this grade level), but it can be completed without these sections. In addition to lesson instructions, copies of props to be used and written assessment items are also included. The introductory materials include the prerequisite skills and knowledge, specific learning goals, material preparation, and background and common misconceptions associated with the lesson goals.

Using the EQuIP Rubric

An understanding of *A Framework for K–12 Science Education* (NRC 2012) as well as an understanding of the *NGSS* will be needed to effectively use the EQuIP rubric. When using the rubric, it is important to be cognizant of the critical ideas that are represented in it. First of all, the rubric has a strong focus on explaining phenomena and designing solutions to problems as well as a focus on the opportunities that the materials provide for student engagement in the practices with the core ideas and crosscutting concepts. While it is likely that only elements of dimensions may be present in a lesson, instruction should be building toward a bundle of performance expectations using an integrated, coherent three-dimensional approach. Finally, grade appropriateness of both the practices and crosscutting concepts are also addressed. It is important to be familiar with the specific elements of the practices and crosscutting concepts for your grade band provided in the matrixes of Appendixes F and G in the *NGSS*. The *NGSS* Evidence Statements also provide information about progression throughout the grades for all three dimensions (Ewing 2015).

There are three categories that the EQuIP rubric uses to evaluate resources:

I. Alignment to *NGSS*,

II. Instructional Supports, and

III. Monitoring Student Progress.

Lessons and activities used in instruction should be building toward a bundle of performance expectations. In instruction, students should be engaged in more than the single practice or crosscutting concept identified in each performance expectation. Therefore, it is not expected that the resources being evaluated will align to the specific practice, disciplinary core idea, or crosscutting concept identified in the performance expectation. When evaluating resources for the NSTA@NGSS Hub, the evaluator first identifies the performance expectation or expectations toward which instruction using it builds. They then identify elements of practices, disciplinary core ideas, and crosscutting concepts that may be explicit, implicit, or a suggested component in the lesson. In each section, the evaluator provides tips that might improve the alignment opportunity of each dimension.

The *Kinesthetic Astronomy Sky Time* lesson can be used to build proficiency toward two performance expectations in grade 5. Space Systems: Stars and the Solar System:

- 5-ESS1-1. Support an argument that differences in the apparent brightness of the Sun compared to other stars is due to their relative distances from Earth. [Assessment Boundary: Assessment is limited to relative distances, not sizes, of stars. Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, stage).]
- 5-ESS1-2. 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. [Clarification Statement: Examples of patterns could include the position and motion of Earth with respect to the Sun

FIGURE 1.

A standard from the *NGSS.*

5.Space Systems: Stars and the Solar System

5.Space Systems: Stars and the Solar System

Students who demonstrate understanding can:

5-PS2-1. **Support an argument that the gravitational force exerted by Earth on objects is directed down.** [Clarification Statement: "Down" is a local description of the direction that points toward the center of the spherical Earth.] [Assessment Boundary: Assessment does not include mathematical representation of gravitational force.]

5-ESS1-1. **Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth.** [Assessment Boundary: Assessment is limited to relative distances, not sizes, of stars. Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, stage).]

5-ESS1-2. **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.** [Clarification Statement: Examples of patterns could include the position and motion of Earth with respect to the sun and selected stars that are visible only in particular months.] [Assessment Boundary: Assessment does not include causes of seasons.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used. • Represent data in graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships. (5-ESS1-2) **Engaging in Argument from Evidence** Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s). • Support an argument with evidence, data, or a model. (5-PS2-1),(5-ESS1-1)	**PS2.B: Types of Interactions** • The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. (5-PS2-1) **ESS1.A: The Universe and its Stars** • The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth. (5-ESS1-1) **ESS1.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. (5-ESS1-2)	**Patterns** • Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena. (5-ESS1-2) **Cause and Effect** • Cause and effect relationships are routinely identified and used to explain change. (5-PS2-1) **Scale, Proportion, and Quantity** • Natural objects exist from the very small to the immensely large. (5-ESS1-1)

and selected stars that are visible only in particular months.] [Assessment Boundary: Assessment does not include causes of seasons.]

While *Kinesthetic Astronomy Sky Time* does not explicitly address the three dimensions in an integrated fashion, there are opportunities for a teacher to modify the lesson, bringing out all three dimensions in instruction.

Alignment to *NGSS*

Instruction in the *NGSS* requires a shift in focus of instruction. Rather than being focused on learning content, students should be engaged in making sense of phenomena (Krajcik 2015). There are several phenomena caused by Earth's motions that are explicitly identified in the *Kinesthetic Astronomy Sky Time* lesson—day and night, seasons, and the stars and constellations that are observed at different times during the year, to name a few. These can be directly observed by students in their everyday lives. When using this lesson, an emphasis should be placed on students determining and explaining the causes of these phenomena.

This lesson provides opportunities to use elements of practices to make sense of the phenomena. The most obvious practice addressed in this lesson is Developing and Using Models. The following elements are explicitly addressed in the lesson:

- Identify limitations of models.
- Develop and/or use models to describe and/or predict phenomena

The lesson directs students to use a scale size and distance model with a variety of objects to provide a sense of the relative sizes of the Earth, Sun, and Moon as well as the vast distances between them and the nearest star to our solar system. Students also use a kinesthetic model to show the relationship of time to astronomical motions of Earth. While students are not developing the models, they are using them to describe and can also be asked to predict the phenomena identified. In addition, students are directed to identify the limitations of the kinesthetic model relating it to the scale model they created earlier in the lesson. The lesson asks very explicit questions about the model's limitations. The need for the line of questioning may depend on your students' proficiency and experience in identifying limitations in models. Instead of asking if the setup of Earth-Sun and stars is to scale, the teacher might ask what in this model is not represented accurately and needs to be considered as the model is being used.

There is an opportunity when using this resource for students to also use the practice of Engaging in Argument From Evidence. Students can use this model to support the causal relationship between the astronomical motions of Earth and the phenomena of day and night, daily pattern of shadows, and so on. Teacher strategies here would depend again on students' proficiency and experience. As students spend more years in three-dimensional learning, their proficiency will improve and the strategies used will change. My fifth graders' proficiency is different this year than it will be in three to five years because in the future they will have had more experiences in three-dimensional learning prior to fifth grade.

Elements of the disciplinary core ideas in both performance expectations are addressed explicitly in this lesson. For 5-ESS1-1, this lesson compares the distance between the Sun and Earth to the distance between the Sun and Alpha Centauri. It does not address any other stars compared to the Sun or to each other; therefore, it only partially addresses the second sentence of the disciplinary core idea element: *Stars range greatly in their distance from Earth*. Students will still need to engage in activities that show the varying distances of the many stars visible from Earth. This could be accomplished by constructing 3D scale models of the distances of stars from Earth within constellations. Students will also need to engage in activities that show how distance affects the brightness of luminous objects. The frequently asked question number 4 on page 34 discusses the idea of brightness of the Sun compared to other stars because of distance, but it is not addressed specifically in the model.

FAQ 4: If the Sun is a star, why is it so much brighter than other stars?

Other stars are much farther away than our Sun. The Sun is about 100 million (100,000,000) miles away, but even the nearest star is about 24 trillion (24,000,000,000,000) miles away. The light we receive from a particular star depends on how far away it is (Morrow and Zawaski 2004).

To build toward the disciplinary core idea elements found in 5-ESS1-2, students use the kinesthetic model to describe the patterns of day and night, the position of the Sun at sunrise, midday, and sunset; and how stars and constellations appear to rise and set all caused by Earth's rotation. The lesson also uses the model to show the different positions of stars and constellations as viewed from Earth at different times of the year caused by Earth's orbit around the Sun. While the disciplinary core idea element of daily patterns of change in shadows are not discussed in the lesson, they are an effect of the daily pattern of the apparent motion of the Sun in the sky, which is in turn an effect of Earth's rotation and can be connected to the model. For example, chose to begin instruction with observation of the phenomenon of the daily changes in length and direction of shadows. Students traced the shadow of a golf tee each hour during the school day. After analyzing the data, students explored how the position of a light source affects the length and direction of the shadow of an object in its path. They made further observations of the position of the Sun when tracing the golf tee's shadow. After that, I engaged students in using the kinesthetic model to support the argument that Earth's rotation is the cause of the daily changes observed in both the Sun's position and the resulting shadows.

There are opportunities to address three crosscutting concepts in this lesson: Patterns; Cause and Effect; and Scale, Proportion, and Quantity. All three of these contribute to better student understanding of the disciplinary core ideas. The 3–5 grade band element in Scale, Proportion, and Quantity addressed early in the lesson is *Natural objects exist from the very small to the immensely large*. When comparing the sizes of the Sun and the Earth using a grapefruit Sun, this crosscutting concept is addressed showing the difference in size between the grapefruit and the tip of a ballpoint pen. Students could construct other models using different objects of varying sizes. This model also addresses that within the solar system and universe, the distances are immensely large. The teacher could make sure that students are aware that we use scale size and distance models to make objects and distances that are immensely large more understandable.

There is an opportunity in the lesson to emphasize the grade 3–5 element: *Patterns can be used as evidence to support an explanation* in the crosscutting concept of Patterns. The lesson asks students about patterns of stars that make up constellations but does not explicitly call attention to the patterns in sunrise and sunset and in the appearance of seasonal stars or constellations. There are a variety of patterns that the model explains. Each day repeats after 24 hours. Each day has a sunrise and sunset with a pattern of the Sun beginning low in the sky, getting higher to midday, and getting lower until sunset when it becomes dark. Each night shows the rise and set of varying stars and constellations. Each year repeats after 365 days with the pattern of seasonal constellations viewed repeating each year. As students use the model, the teacher should ask them about the patterns they are observing as well as how they might be used as evidence of Earth's rotation or orbit as a cause.

Finally, the crosscutting concept of Cause and Effect is implicit in the lesson addressing the element: *Events that occur together with regularity might or might not be a cause and effect relationship*. While the lesson focuses on the relationship of rotation to day and night and the position of the Sun relative to the horizon and also orbit to seasonal appearance of stars and constellations, it does not explicitly discuss the causal relationship. When using the model, students need to be made aware of the causal relationship. This may require using other models in addition to this one so they can experience it from a different perspective.

Using the crosscutting concepts of Patterns and Cause and Effect, a teacher has the opportunity to address the Nature of Science with this lesson. When we observe patterns, we generally want to know why those patterns occur. Scientists seek explanations for patterns in their work. We have a record of how this understanding has evolved over time into what we know today about the causal relationship between the phenomena we observe and Earth's astronomical motions.

PHOTO COURTESY OF THE AUTHOR

Students participate in a kinesthetic model.

Instructional Supports

The lesson does not begin with a phenomenon giving students a reason to use the model to explain it. The teacher will need to provide the students with an authentic situation or something in their experiences that will provide them with a purpose for sense making. We spend a day once a month (weather permitting) to trace a golf tee's shadow once every hour. By fifth grade, students understand how a shadow is created and may have experiences with noticing longer or shorter shadows at different times of the day. After a couple of months, they noticed that the daily pattern is similar for each month. This gave me the opportunity to ask students to explain what caused this pattern giving them a purpose to use the model.

There are a variety of "tips" boxes spread throughout the lesson materials to assist students in concept development as well as give answers to questions that students or teachers might have when using the lesson. However, there are not explicit supports in the lesson for differentiated instruction. A teacher would need to consider the obstacles learners might have while using the model or the assessments in the lesson and develop alternative strategies to make the lesson accessible to all learners.

Monitoring Student Progress

This resource has a separate file that has assessment items related to the lesson. The assessments are built around the common misconceptions in the research surrounding these core ideas. Most of the assessments are question-and-answer type or fill-in-the-blank worksheets that assess the core ideas. They do not elicit observable evidence of three-dimensional learning by students. Because these assessments are one-dimensional and not necessarily accessible to all learners, a teacher would need to consider alternative strategies for monitoring student progress.

I found that the *Kinesthetic Astronomy Sky Time* lesson—with modifications—could be used in my classroom as a resource for my curriculum to build toward student proficiency of the performance expectations in grade 5. Space Systems: Stars and the Solar System. This lesson will fit into a group of lessons in which students will use multiple practices and crosscutting concepts to make sense of phenomena. It will not be perfect, but both my students and I will learn along the way. My instruction will be improved, and I will make notes as we work through this together about how to improve it next year. Three-dimensional learning is hard. It will take time, but we will all get better as we work through the challenges. ■

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Internet Resources

EQuIP Rubric

www.nextgenscience.org/sites/ngss/files/EQuIP%20Rubric%20for%20Science 20v2.pdf

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http://ngss.nsta.org