TOTALITY2017

Countdown to the Great American Eclipse

How to prepare students for the August 2017 total solar eclipse in the context of the *Next Generation Science Standards*

By Charles Fulco

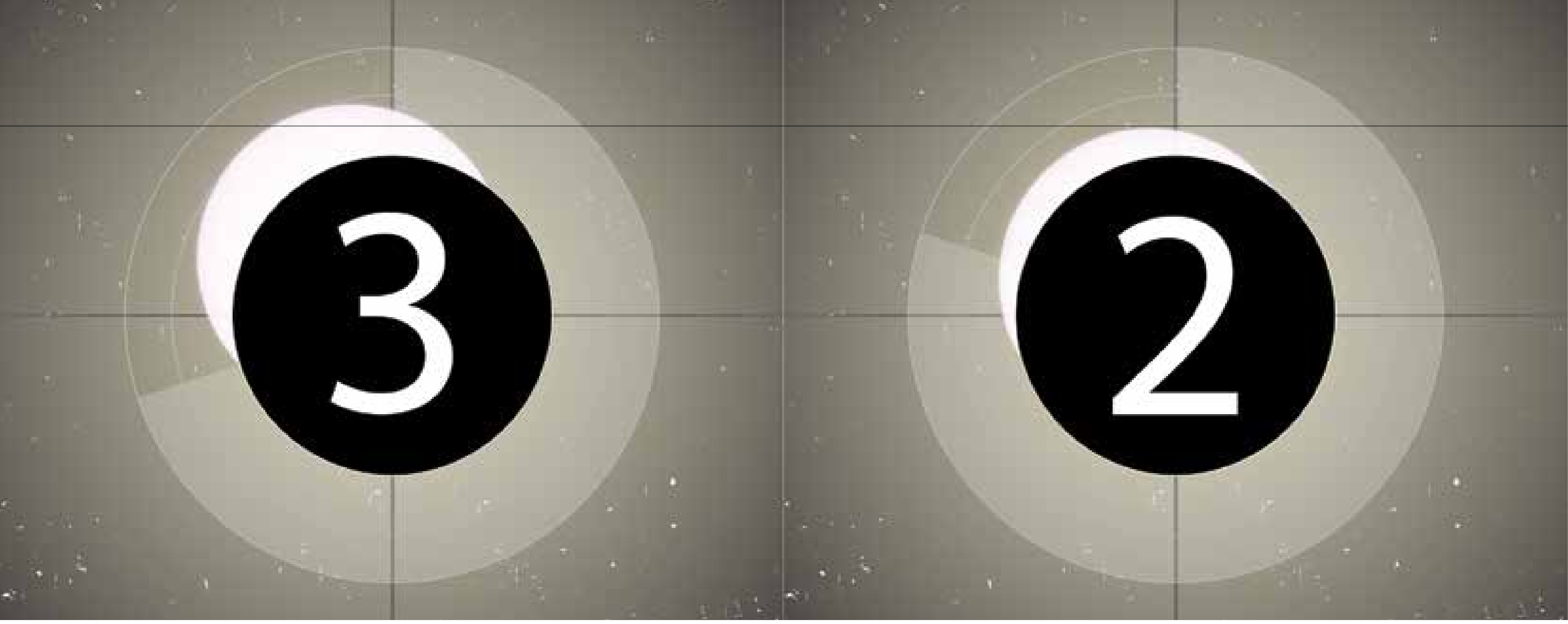
As discussed in the January issue of *Science & Children* (Fulco 2017), the Great American Total Solar Eclipse (TSE2017) will occur on August 21 this year—the first total solar eclipse in the continental United States since 1979. It will also be the first coast-to-coast totality since 1918. For many reasons, this is a scientific and educational milestone event of the highest magnitude that should not be missed by any teacher and student whether or not their school is in session on "Eclipse Day" this year.

For the teacher who wishes to include TSE2017 instruction in his or her elementary science curriculum, it is important to have an instructional timeline for lessons, remembering that summer vacation will put your classroom instruction on hiatus for at least a couple months just prior to the eclipse. Some schools will be returning their students *on the day* of the eclipse. In other cases (notably the Northeastern United States), most schools will still be closed for the summer, so any formal eclipse instruction and preparation will have ended in June.

Having a timeline for instruction should be a part of every teacher's *modus operandi*. The classic model for this is *Understanding by Design* (Wiggins et al. 1998), which states that having clear end-objectives and assessments inherently guides the instruction leading up to them (see Internet Resources).

Planning "Backward" for TSE2017

Recent interviews show "time constraints" and "teaching to standards" as the two most-mentioned concerns within elementary level science instruction. Understanding by Design (UbD), also known as "Backward Design," addresses both these issues, along with the idea that the primary goal of education should be the development and deepening of student understanding. Students should be provided with complex, authentic opportunities to engage in science, echoing the similar educational goals of the *Next Generation Science Standards* (*NGSS*), STEM, and other science-based learning models. Teaching effective and authentic science curriculum (with TSE2017 having an integral role this year) should employ an instructional model with teachers designing lessons, activities, and investigations *after* specific goals have been clarified and assessments designed. This "backward" process helps to avoid instruction in which no clear priorities and purpose of instruction are apparent, things which hinder achieve-



ment of objectives. This may sound like the oft-dreaded "teaching to the test," but with defined instructional goals in sight and effective and purposeful inquiry-based activities developed, it is anything but!

A realistic timeframe for this year's eclipse instruction begins when you read this article. Understandably, the most difficult logistical obstacle for a teacher to overcome might very well be: "Where do I find the time to teach TSE2017 lessons when eclipses aren't part of my science curriculum this year?" and "How do I convince my principal to let me teach these lessons since my colleagues and I barely have time to teach the regular curriculum?"

This is where you approach the problem with your backward design solutions already in hand—in this case, an instructional timeline and *NGSS*-aligned learning objectives and lessons, all demonstrating how you *can* include segments on eclipses without interfering with the required instruction. Just the fact that a total eclipse is such a rare, special, and wonderfully appropriate event for teachers and students should be reason enough for it to be encouraged to be part of every elementary teacher's curriculum.

Designing an Eclipse Unit

There is no reason not to include units on eclipses as part of at least one of your 2016–17 elementary curricula. A series of lesson plans, investigations, and other inquiry-based activities will assist the teacher in reaching learning objectives and science literacy with a decidedly unique focus. Especially for those elementary teachers who don't have a way to realistically work the eclipse into their science curriculum, a cross-content unit lets the class explore TSE2017 through the subject(s) of the teacher's choice, be it social studies, math, ELA, technology—virtually any content area. Remember, these units may be stretched across a good portion of the school year, as long as you keep your student engagement, motivation, and interest at a high level, with reinforcement and brief reviews of prior lessons, outdoor lessons (if possible), and of course, formative and summative assessment lessons bookending each unit.

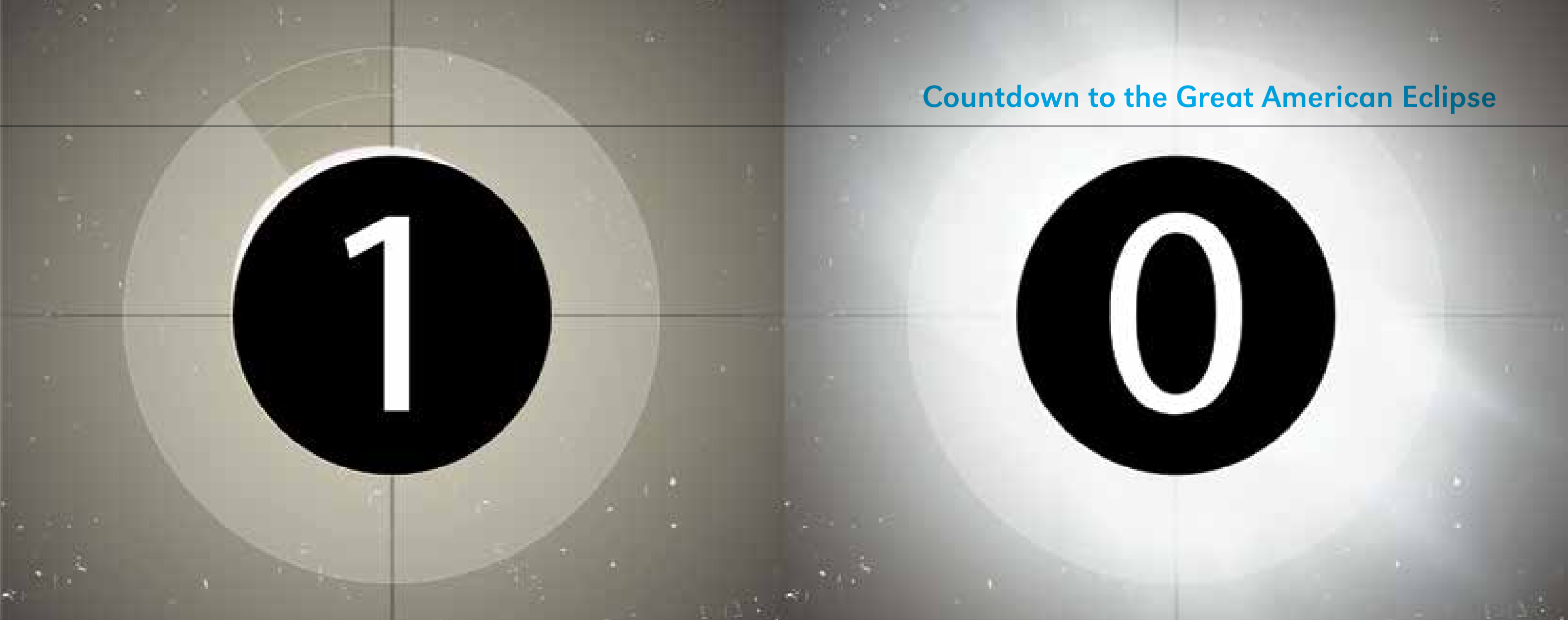
As an example, let's take a look at how a grade 1 and a grade 5 classroom teacher can implement instruction in different ways while addressing their respective *NGSS* Foundation Boxes. No matter which grade you teach, you can use these examples as guides for your own grade level as well.

Grade 1

Selecting the *NGSS* grade 1 performance expectation (PE) that states: *Use observations of the Sun, Moon, and stars to describe patterns that can be predicted (1-ESS1-1)*, students are directed to make connections between celestial motion and pattern recognition (Figure 1). The obvious patterns in the sky are the daily motion of the Sun, the monthly motion of the Moon, and the yearly (annual) motion of the stars, which should be examined and understood. But we can include eclipses in this unit as well, since they follow very regular and predictable patterns of occurrence.

The grade 1 PE is typically achieved using solar shadow recording, lunar phase observation logs, and star maps. It states that students will "use observations…to describe patterns that can be predicted," but it does not necessarily require them to use their own direct observations—they may access this data from media, so long as the sites are valid, such as NASA's International Observe the Moon Night or its dedicated TSE2017 site (see Internet Resources). Of course, you will want to physically demonstrate with a model how the Moon orbits the Earth and can sometimes come exactly between the Sun and Earth to cause a solar eclipse. The important thing is that students recognize and understand that the Moon moves in a very predictable pattern, allowing scientists to accurately predict when eclipses will occur, thereby fulfilling the PE's objective.

Next, you'll need to align your lessons to the most appropriate science and engineering practice (SEP): *Planning and carrying out investigations to answer questions or test so-*



lutions to problems…make observations (firsthand or from media) to collect data…; and Analyzing and interpreting data… collecting, recording, and sharing observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions. In this case, you may address both SEPs, as they have relevant criteria for eclipse studies and address the need for students to observe phenomena to obtain data (either from direct observation or from other sources) and describe and share observations—another good reason to include TSE2017 in your unit.

The disciplinary core idea (DCI) ESS1.A *The Universe and Its Stars, Patterns of the motion of the Sun, Moon, and stars in the sky can be observed, described, and predicted* is, like the SEP above, most usually satisfied through more common observations of the motions of those celestial bodies. But again, I believe this DCI is also quite relevant to TSE2017 and eclipses in general, as these celestial events recur in observable and predictable cycles. And since eclipses aren't frequently observed by students, information from trusted media can be successfully substituted in place of direct observation.

DCIs are synonymous with what we used to call "content instruction," so information on why eclipses happen should take place here, with simple activities demonstrating how eclipses occur. Again, get your students involved: one student holding a light source (the Sun), another holding a smaller sphere (the Moon), and a third holding a larger sphere (the Earth), with the students simulating the orbit of the Moon around the Earth is a simple yet highly kinetic and visual way of showing the dynamics of eclipses that textbooks simply can't convey. It doesn't have to be highly sophisticated at this age—just the idea that the Moon moves around the Earth and can sometimes "get in the way" of the Sun is good enough for now!

Last, an appropriate crosscutting concept (CC), *Patterns in the natural world can be observed, used to describe phenomena, and used as evidence*, should be included as a way to add a holistic dimension to your unit on eclipses. An ELA segment here, perhaps a read-aloud followed by verbal assessment, describing how Christopher Columbus used his knowledge of the pattern of eclipses to save himself and his crew from certain death (see Internet Resources), can show that knowledge of patterns and cycles allows for fairly accurate predictions, which can be very useful in the real world—just ask Columbus!

Grade 5

One grade 5 *NGSS* performance expectation requires that students *Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost,* and another requires students to *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* (Figure 2).

Integrating a lesson on eclipses might not immediately come to mind when reading this PE, but when one realizes the most pressing problem of solar eclipse observation is eye safety, it makes sense. As you may be aware, even today teachers and students are routinely directed to remain indoors (with blinds closed) during eclipses, the fear being that they will become blinded by the eclipsed Sun's light. This is an unacceptable educational practice, but it can be resolved using a very simple, inexpensive and easy-to-construct device known as a solar viewer (see NSTA Connection for solar viewer instructions). Building a viewer solves the problem of safe solar observation while reinforcing fine-motor, instruction-reading, and sequencing skills (not to mention bolstering a student's confidence level upon completion of his/her device).

As discussed in a future installment in this series, crosscutting concepts are a convenient method for introducing a variety of lessons. One CC within the "Earth's Place in the Universe" DCI states: *Similarities and differences in patterns can be used to sort, classify, communicate*

FIGURE 1.

NGSS example for a grade 1 lesson (NGSS Lead States 2013).

Students who demonstrate understanding can:

1-ESS1-1. **Use observations of the sun, moon, and stars to describe patterns that can be predicted.** [Clarification Statement: Examples of patterns could include that the sun and moon appear to rise in one part of the sky, move across the sky, and set; and stars other than our sun are visible at night but not during the day.] [*Assessment Boundary: Assessment of star patterns is limited to stars being seen at night and not during the day.*]

1-ESS1-2. **Make observations at different times of year to relate the amount of daylight to the time of year.** [Clarification Statement: Emphasis is on relative comparisons of the amount of daylight in the winter to the amount in the spring or fall.] [*Assessment Boundary: Assessment is limited to relative amounts of daylight, not quantifying the hours or time of daylight.*]

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
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. • Make observations (firsthand or from media) to collect data that can be used to make comparisons. (1-ESS1-2) **Analyzing and Interpreting Data** Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations. • Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions. (1-ESS1-1)	**ESS1.A: The Universe and its Stars** • Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. (1-ESS1-1) **ESS1.B: Earth and the Solar System** • Seasonal patterns of sunrise and sunset can be observed, described, and predicted. (1-ESS1-2)	**Patterns** • Patterns in the natural world can be observed, used to describe phenomena, and used as evidence. (1-ESS1-1),(1-ESS1-2) *Connections to Nature of Science* **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes natural events happen today as they happened in the past. (1-ESS1-1) • Many events are repeated. (1-ESS1-1)

Connections to other DCIs in first grade: N/A

Articulation of DCIs across grade-levels:

3.PS2.A (1-ESS1-1); **5.PS2.B** (1-ESS1-1),(1-ESS1-2); **5.ESS1.B** (1-ESS1-1),(1-ESS1-2)

Common Core State Standards Connections:

ELA /Literacy -

W.1.7	Participate in shared research and writing projects (e.g., explore a number of "how-to" books on a given topic and use them to write a sequence of instructions). (1-ESS1-1),(1-ESS1-2)
W.1.8	With guidance and support from adults, recall information from experiences or gather information from provided sources to answer a question. (1-ESS1-1),(1-ESS1-2)

Mathematics —

MP.2	Reason abstractly and quantitatively. *(1-ESS1-2)*
MP.4	Model with mathematics. *(1-ESS1-2)*
MP.5	Use appropriate tools strategically. *(1-ESS1-2)*
1.OA.A.1	Use addition and subtraction within 20 to solve word problems involving situations of adding to, taking from, putting together, taking apart, and comparing, with unknowns in all positions, e.g., by using objects, drawings, and equations to represent the problem. *(1-ESS1-2)*
1.MD.C.4	Organize, represent, and interpret data with up to three categories; ask and answer questions about the total number of data points, how many in each category, and how many more or less are in one category than in another. *(1-ESS1-2)*

and analyze simple rates of change for natural phenomena. A lesson on eclipses that satisfies this can highlight the Saros Cycle (see Internet Resources), a pattern of eclipse repetition that was discovered centuries ago: that dates of similar eclipse paths and durations ("families") recur in a period of just over 18 years, making it relatively easy to predict the next event in the series, based on prior observations. A simple device (I call it a "Saros Calculator") can be constructed by writing various Saros family numbers at the top of strips of heavy card stock and their corresponding years of eclipses below, then sliding one at a time into a card stock sleeve with cut-out windows to show as much information as you like your students to see in order to make predictions. To get a feel for the Saros pattern, have students study the dates of past and future solar eclipses (see Internet Resources). Students can note that there were total eclipses in 1927, 1945, 1963, 1981 and 1999. Therefore, through pattern recognition and simple math, students should confidently predict that there should be another in 2017—and of course, there is!

Again, these are just two grade-level examples of integrating TSE2017 into your standards-based science curriculum. But my wish is that *every* elementary teacher will find time to integrate this rare and spectacular event into his or her instruction during the remainder of this school year. Remember that the *NGSS* crosscutting concepts option gives you the flexibility to do this!

In Summary

Don't worry if your elementary grade–level science curriculum doesn't include *NGSS*-based lessons that can be easily applied to TSE2017, because other content areas you (or another team member) teach can easily and suc-

FIGURE 2.

NGSS example for a grade 5 lesson (NGSS Lead States 2013).

Students who demonstrate understanding can:

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 the 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-ESS1-1)	**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) **Scale, Proportion, and Quantity** • Natural objects exist from the very small to the immensely large. (5-ESS1-1)

Connections to other DCIs in fifth grade: N/A

Articulation of DCIs across grade-levels:
1.ESS1.A (5-ESS1-2); **1.ESS1.B** (5-ESS1-2); **3.PS2.A** (5-ESS1-2); **MS.ESS1.A** (5-ESS1-1),(5-ESS1-2); **MS.ESS1.B** (5-ESS1-1),(5-ESS1-2)

cessfully satisfy this requirement (this will be discussed later in this series of articles). However you decide to prepare your students for the 2017 Great American Eclipse, the result will be instructing your students on real-life science, with the goal of seeing a once-in-a-lifetime event (if you are lucky enough to be within the path of totality). Even if you do not experience totality, there are many opportunities that a partial event provides, and you'll be doing them within a manageable timeframe. See future articles in *S&C* for more TSE2017 lesson suggestions. ■

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References

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NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press. *www.nextgenscience.org*

Internet Resources

Eclipses and the Saros
https://eclipse.gsfc.nasa.gov/SEsaros/SEsaros.html

The Eclipse That Saved Columbus
www.sciencenews.org/article/eclipse-saved-columbus

GreatAmericanEclipse
www.GreatAmericanEclipse.com

Mr. Eclipse
www.MrEclipse.com/Special/SEprimer.html

NASA's Experience the 2017 Eclipse Across America
https://eclipse2017.nasa.gov

NASA's Space Place
http://spaceplace.nasa.gov/science-standards/en

Understanding By Design
www.ascd.org/ASCD/pdf/siteASCD/publications/UbD_WhitePaper0312.pdf

NSTA Connection

Download instructions for building a solar viewer at *www.nsta.org/SC1702*.