**How Do We Study the Sun from Earth?**

**by Thomas N. Tomas**

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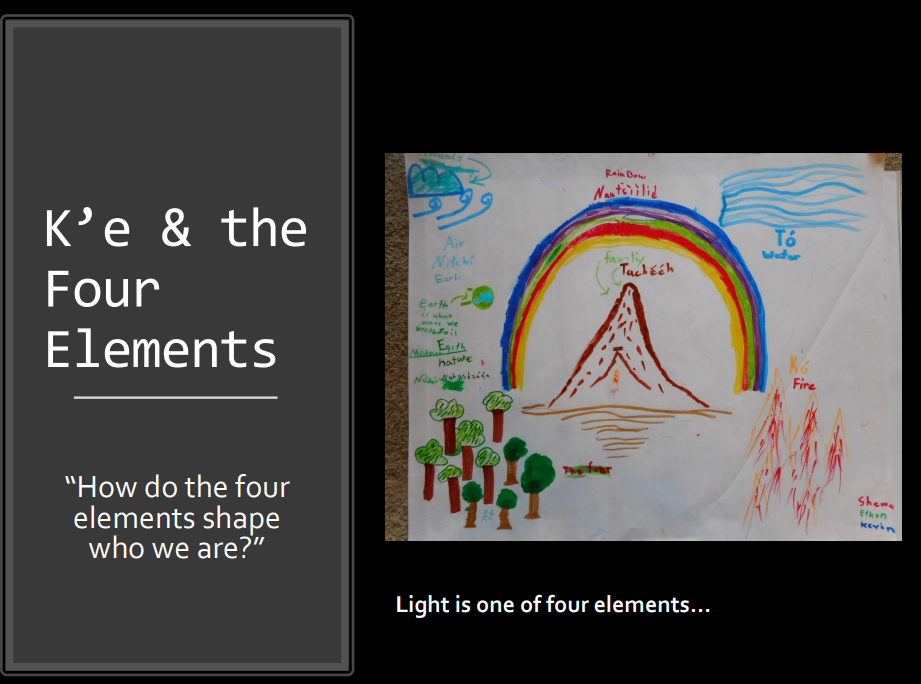
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Level: Grades 5 and 6 Time: Ten 60-minutes class periods



Note: This lesson was designed for Navajo students but is included in the HEAT collection to inspire and support all educators to incorporate indigenous knowledge.

**Lesson Overview**

Students will learn about the heliophysics associated with our closest star, the Sun. They begin with the relationships between the Sun, Earth, Self, and one’s shadow, then use a meter stick to measure length and angle of the shadow at the same time each day for two weeks. Students then construct and use a sundial to tell the time. Students will work in small groups to identify how the Sun is a natural system, beginning with a KWL chart. Then students will research, create a graphic organizer with the Sun as a natural system, and deliver a whole group presentation. Next, students will do a KWL chart pertaining to the two solar probes (Parker and Soho), followed by research and a draft of a graphic organizer concentrating on the probes as human-designed systems.

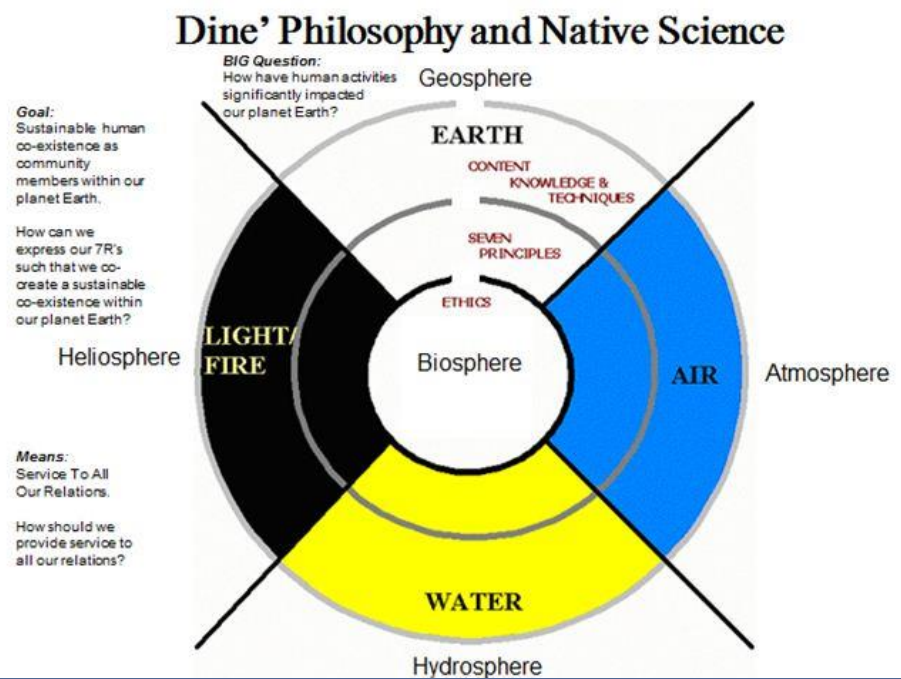
**Educator Background Knowledge**

The Sun takes about a month to rotate 360 degrees which can be seen using a Dobsonian telescope. As seen from the surface of Earth, the Sun has a diurnal path (daily, determined by rotation of Earth) and a seasonal path (quarterly, determined by the orbit of Earth around the Sun). A sundial can be used to track both. Shadows can be used to track how the Sun rises later and later each day as we approach the autumn solstice and in the days following. Seasonal changes caused by the orbit of Earth and tilt can be observed by noting where on the western horizon the Sun sets from their home perspective, for two weeks, providing dates and times.

Teachers may share the role of the Sun in Native Science: in the four elements that are part of the Dine’ or Navajo culture: The four elements shape who we are. The Heliosphere: One of four systems that comprise our biosphere. K’e as a relationship between Earth, Sun, Moon, Self and one’s shadow.

**Guiding Questions:**

* How do NASA missions contribute to Dine’ science?
* How does Dine’ science contribute to NASA missions?

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**Learning Goals**

Students will be able to answer these questions and the focal question:

* How does when and where we live shape who we are?
* How can we provide **service to all our relations** in ways that help us understand and address climate change?
* Focal Question: What is the Sun-Earth relationship and how do we know?

**Learning Objectives**

1. Students will describe the Sun-Earth relationship as a natural system.
2. Students will be able to support an argument that differences in the apparent brightness of the Sun compared to other stars is due to their relative distances from Earth.

**Framework for Heliophysics Education**

NASA Question: What are the impacts of the Sun on humanity? Big Idea: [The Sun is really big and its gravity influences all objects in the solar system.](https://solarsystem.nasa.gov/heat/big-ideas/big-idea-1-1/)

NASA Question: What causes the Sun to vary? Big Idea: The Sun is made of churning plasma, causing the surface to be made of complex, tangled magnetic fields.

**NGSS Performance Expectations**

* 5-ESS-1.1: Earth’s Place in the Universe: Support an argument that differences in the apparent brightness of the Sun compared to other stars is due to their relative distances from Earth.
* 5-ESS-1.2: Earth’s Place in the Universe: 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.
* 5-ESS-2: Earth’s Place in the Universe: Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
* MS-ESS1-1: Earth’s Place in the Universe: Develop and use a model of the Earth-Sun-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons.
* MS-ESS1-2: Earth’s Place in the Universe: Develop and use a model to describe
* the role of gravity in the motions within galaxies and the solar system.
* MS-ESS1-3: Earth’s Place in the Universe: Analyze and interpret data to determine scale properties of objects in the solar system.

**Common Core Standards for Mathematical Practice**

* MP.2: Reason abstractly and quantitatively. (MS-PS1-2), (MS-PS1-5)
* MP.4: Model with mathematics. (MS-PS1-5)
* 6.RP.A.3: Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS1-2), (MS-PS1-5)
* 6.SP.B.4: Display numerical data in plots on a number line, including dot plots, histograms, and box plots. (MS-PS1-2)
* 6.SP.B.5: Summarize numerical data sets in relation to their context (MS-PS1-2)

**Common Core Standards for ELA Literacy**

* RI.5.1: Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
* RI.5.7: Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.(5-ESS3-1)
* RI.5.9: Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (5-ESS3-1)
* W.5.8: Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources. (5-ESS3-1)
* W.5.9: Draw evidence from literary or informational texts to support analysis, reflection, and research. (5-ESS3-1)

**Crosscutting Concepts**

* Systems and System Models: A system can be described in terms of its components and their interactions. (5-ESS-2), (MS-ESS-2)

**Targeted STEM Skills**

* 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)

**Materials**

* 10” Newtonian telescope on a Dobsonian mount.
* [Hero Twins (book)](https://www.amazon.com/Hero-Twins-Navajo-English-Monster-Slayers/dp/0826355331/ref=sr_1_2?crid=22Y9MY8WDBW0V&keywords=Hero+Twins&qid=1686174005&sprefix=hero+twins%2Caps%2C2102&sr=8-2)
  + A video of the story is available at: <https://www.youtube.com/watch?v=YyZn7dfi8DI>
* [Monster Slayer: A Navajo Folktale](https://www.amazon.com/Monster-Slayer-Folktale-Vee-Browne/dp/0873585259/ref=sr_1_1?crid=2U30ROAQII9HB&keywords=Monster+Slayer+Navajo&qid=1686174227&sprefix=monster+slayer+navajo%2Caps%2C221&sr=8-1) (book)
* [Jo’hanna’ei, Bringer of Dawn (book)](https://www.amazon.com/Johonaaei-Bringer-Dawn-Veronica-Tsinajinnie/dp/1893354547)
* [National Geographic, July 2004](https://nationalgeographicbackissues.com/product/national-geographic-july-2004/) article: “Hot News From Our Stormy Star”
* Space weather activity: Measuring how many days for the Sun to spin 360 degrees on its axis: <https://spacemath.gsfc.nasa.gov/weekly/4Page1.pdf>
* Estimating the Sun’s Rotation Period (Stanford): <http://solar-center.stanford.edu/spin-sun/estimate.html>
* Making a Sundial (globe.gov): https://www.globe.gov/documents/348614/41018820-9356-4929-a750-11391bf646ae

**Bullet point: Students learn about who they are through the clanship system
Sub-bullets: Learn about their 4 basic clans, how they are related to other clans, relationship to non natives, relationship to the natural elements (home, fire, water, earth, sky, etc.)

Bullet point: This establishes a sense of belonging and security
Sub-bullet point: Oral stories about the origins of Dine: Language comes from nature and animals, language is who we are, getting rid of "monsters" of today and continuance of protecting and nurturing, construction of home (tachee, alchi'adeez'ah, sacred mountains, songs, teachings, etc.)**

**Handouts**

* KWL Chart (see Handouts)
* Making a Sundial
* Systems: 5 Features
* Native Science Connections — Systems Thinking and Mother Earth, Father Sky

**Links to Digital Resources for Students**

* Sun 101 | National Geographic: <https://www.youtube.com/watch?v=2HoTK_Gqi2Q>
* The Sun: Crash Course Astronomy #10: <https://www.youtube.com/watch?v=b22HKFMIfWo>
* Sun and Earth size relationships: [https://helioviewer.org](https://helioviewer.org/)
* Student Helioviewer: <https://student.helioviewer.org/>
* Heliophysics Missions<https://science.nasa.gov/learn/heat/missions/>
* Real World: Earth's Energy Balance — Energy In and Energy Out

<https://nasaeclips.arc.nasa.gov/video/realworld/real-world-earths-energy-balance-energy-in-and-energy-out>

* Gravity and Orbits Interactive: <https://phet.colorado.edu/sims/html/gravity-and-orbits/latest/gravity-and-orbits_en.html>
* We’re All Made of Stardust: Here’s How (Smithsonian Channel) video: <https://www.youtube.com/watch?v=xIV-k39Kukw>
* A Total Solar Eclipse Revealed Solar Storms 100 Years Before Satellites: [https://www.youtube.com/watch?v=9oHhO2xA6e](https://www.youtube.com/watch?v=9oHhO2xA6e4)

**Key Vocabulary**

Characteristics of a system: inputs/outputs, interactions, boundaries, components, properties

**Material Preparation**

* Use a collimator to align mirrors within the Newtonian telescope.
* Make certain that the sundial is designed for your school’s latitude.
* Have models of the Earth, Moon, Sun, and measuring tape to help students experience scaled relationships between sizes and distances of each object.

**5E Steps**

**Engage**

Students will study sunspots using a 10” Newtonian telescope on a Dobsonian mount.

Watch the video: We are all made of stardust. Here's how! <https://www.youtube.com/watch?v=xIV-k39Kukw>

We are made of CHNOPS (carbon, hydrogen, nitrogen, oxygen, phosphorus, sulphur).

Students will learn about the significance of one’s shadow within the Navajo culture. Students will trace their shadows on the sidewalk and chart the changes in length and angle over two weeks.

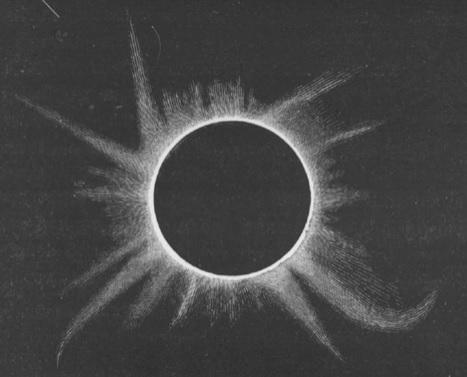
**Explore**

Students will work in small groups to explore the relationships between our closest star (the Sun) and the [Parker Solar Probe](https://www.nasa.gov/content/goddard/parker-solar-probe/) and [Solar Orbiter](https://www.nasa.gov/solar-orbiter) using the [Merge Cube](https://mergeedu.com/cube) (a free educational trial is available).

Students will use a KWL chart to explain what they know about the Sun. Next, students will research and chart the qualities of the Sun as a natural system.

**Explain**

Students will work in small groups to research the links provided, collaboratively create models of the Sun, and then present their graphic organizers to the whole group and explain how the Sun is a natural system. Students will explain relationships between the Sun, Moon, Earth and Self: Lunar eclipses, solar eclipses, Earth’s elliptical orbit, solstices and equinoxes, etc.



The NASA video [A Total Solar Eclipse Revealed Solar Storms 100 Years Before Satellites](https://www.youtube.com/watch?v=9oHhO2xA6e4) shows images drawn by astronomers from around the world. Look back to an historic 1860 total solar eclipse, which many think gave humanity our first glimpse of solar storms, called coronal mass ejections, 100 years before scientists first understood what they were. Scientists observed these eruptions in the 1970s during the beginning of the modern satellite era, when satellites in space were able to capture thousands of images of solar activity that had never been seen before. But in hindsight, scientists realized their satellite images might not be the first record of these solar storms. Hand-drawn records of an 1860 total solar eclipse bore surprising resemblance to these groundbreaking satellite images.

**Extend**

Students will create multimedia presentations and present to the following audiences:

1. Peers at school
2. STEM Family Literacy Nights for family and community members
3. Sister Schools via video conferencing
4. An e-portfolio entry that provides each young scientist and engineer with an opportunity to tell her or his story as a learner.
5. Students will consider how the human-designed (engineered) systems were constructed with the natural system in mind, i.e., compatibility.

**Evaluate**

Students will keep a *Science and Engineering Notebook* as well as an electronic notebook to be kept within their e-portfolio (e.g., Google Drive) located within their classroom website with access granted via each student’s email account.

Students’ work in their notebooks will serve as Common Formative Assessment opportunities. The teacher will seek out students’ on-track thinking as well as misconceptions, and then modify and differentiate instruction accordingly. Additional evaluation strategies will include quizzes, online discussion boards, and online forms.

**Resources**

* KWL Chart
* Making a Sundial (NASA)
* Systems: 5 Features
* Native Science Connections — Systems Thinking and Mother Earth, Father Sky

**Links to Digital Resources for Students**

* Sun 101 | National Geographic: <https://www.youtube.com/watch?v=2HoTK_Gqi2Q>
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* Sun and Earth size relationships: [https://helioviewer.org](https://helioviewer.org/)
* Student Helioviewer: <https://student.helioviewer.org/>
* Sun-Earth: <https://www.nasa.gov/mission_pages/sunearth/index.html>
* Real World: Earth's Energy Balance — Energy In and Energy Out

<https://nasaeclips.arc.nasa.gov/video/realworld/real-world-earths-energy-balance-energy-in-and-energy-out>

* Gravity and Orbits Interactive: <https://phet.colorado.edu/sims/html/gravity-and-orbits/latest/gravity-and-orbits_en.html>
* We’re All Made of Stardust: Here’s How (Smithsonian Channel) video: <https://www.youtube.com/watch?v=xIV-k39Kukw>
* A Total Solar Eclipse Revealed Solar Storms 100 Years Before Satellites: [https://www.youtube.com/watch?v=9oHhO2xA6e](https://www.youtube.com/watch?v=9oHhO2xA6e4)

**Handouts**

These begin on the next page.

**K-W-L Chart**

**TOPIC:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

| What I **K**now | What I **W**ant to Know | What I **L**earned |
| --- | --- | --- |
|  |  |  |

Purpose: Investigate the movement of the sun through the day and determine the time of local solar
noon.

Overview: Students construct a sundial and use it to observe the movement of the sun through the sky over the course of a day by marking changes in the position of a shadow once each hour. Students determine the approximate time of solar noon at their school as indicated by the time of the shortest shadow. Students revisit the site on a subsequent day to estimate the time of day using their sundial.

Student Outcomes: Students will gain an understanding of the daily movement of the sun across the sky and experience conducting a set of simple, quantitative observations.

Science Concepts:
Earth and Space Science: The diurnal and seasonal motion of the sun across the sky can be observed and described.

Geography: The physical characteristics of a location depends on its latitude and relation to incident solar radiation.

Scientific Inquiry Abilities: Identify answerable questions. Design and conduct scientific investigations. Construct a scientific instrument. Develop explanations and predictions using evidence. Communicate results and explanations.

Time: Hourly measurements lasting 5 minutes during one sunny school day, 15 minutes to revisit the sundial on subsequent days; time for classroom discussion

Level: Primary and Middle

Materials and Tools: Wooden dowel or similar pole at least 50 cm long, Shadow markers (flags, rocks, sticks, nails, etc.), Meter stick

Preparation: None

Prerequisites: None

Background: Students may have noticed that when they arrive at school in the morning the sun is shining on one side of the school and when they leave in the afternoon it is shining on the other side. This occurs because the sun appears to travel across the sky each day. Before the invention of clocks, people used this motion of the sun to determine the time by making sundials. Sundials are simply stationary vertical objects, such as a pole, placed on a flat surface. The pole is known as a gnomon (NO-mon) and the flat surface as a dial. As the sun travels through the sky. the length and position of the shadow cast on the dial by the gnomon change. The shadow is longest at sunrise and sunset and is shortest at local solar noon.
In this activity students will make a sundial by marking the position of the shadow cast by a gnomon every hour for one school day. They will return to their dial on a subsequent day to see if they can predict the time of day from the sundial they made.What To Do and How To Do It:
1. Select a day that will be sunny for at least seven hours starting when school begins.
2. Take the students outside to a relatively flat spot on school grounds that will be out of the shadow of buildings and trees until the end of the school day. Place the pole in the ground making certa that it is perpendicular to the ground using a plumb bob (a piece of string with a weight on it) or a level. Measure and record the height from the ground to the top of the pole.
3. Have the students put a #1 on the first object (rock, flag, etc.) they will use to mark the position of the shadows. Ask the students to place the marker on the ground at the end of the shadow and to record the time from their watches. 
4. The students should measure and
record the distance from the base of the gnomon to the end of the shadow in the table provided. (Optional: have the students measure the angle as well using a compass.)
5. Have a few students visit the gnomon at least once an hour for the remainder of the school day. The students should measure the length of the shadow (and the optional angle), place a new numbered marker at the end of the shadow and record the time of day.
6. Ask the students to use the table to determine which marker is closest to the pole. This is the time of the shortest shadow and is the observation closest to solar noon. If you have the time, you could have the students take more frequent measurements around the time of this observation on the following day to get a better estimate of solar noon.7. Visit the sundial on another day in the same week. The students should bring their completed tables. Have the students look at the shadow being cast by the pole and estimate from their tables what the time on their watches will be. Ask each student to write down his or her estimate. Have the students look at their watches to find out how close their estimates were.

Questions
1. What is the path of the sun as it moves across the sky?
2. Does the path of the sun across the sky and the pattern of the shadows from the gnomon on the dial change during the year? (The answer could form the basis for a hypothesis that the students could test experimentally.)

Adaptations for Older Students: Older students can observe the changing angle of the sun above the horizon. By measuring the height of the gnomon and the distance from the top of the pole to the end of the shadow (the hypotenuse of the triangle). students can determine the angle of the sun using simple geometry for similar triangles. Have the students add a column to the table and fill in the solar elevation angle for each time they placed a marker. When is the solar elevation the greatest? the smallest? Could they have predicted this from the length of the shadows?

