Sunshine, Shadows, and SCIENCE!

Submitted by: Melissa Poland, Science
Petros-Joyner School, Oliver Springs, TN

Target Grade: 4th grade science

Time Required: 3 days, 70-minute lessons

Standards

Tennessee Academic State Standards

- 4.ESS1: Use a model to explain how the orbit of the Earth and Sun cause observable patterns: a. day and night; b. changes in length and direction of shadows over a day.
- 4.ETS2: Use appropriate tools and measurements to build a model.
- 4.MD.A.1: Measure and estimate to determine relative sizes of measurement units within a single system of measurement involving length, liquid volume, and mass/weight of objects using customary and metric units.
- 4.MD.C.6: Measure angles in whole-number degrees using a protractor. Sketch angles of specified measure.
- 4.W.PDW.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- 4.SL.CC.1: Prepare for collaborative discussions on 4th grade level topics and texts; engage effectively with varied partners, building on others' ideas and expressing one's own ideas clearly.

Lesson Objectives

Students will:

- Categorize various materials as opaque, translucent, or transparent.
- Correctly measure and mark at least three lengths between 0-100 centimeters using a meter stick.
- Correctly measure and mark at least three angles using a protractor.
- Identify patterns of change in a shadow as it relates to the sun's position in the sky.
- Collaborate with peers to present sundials, data, and findings according to a scoring rubric.

Central Focus

This lesson plan consists of three distinct activities that can be completed separately or as a cohesive unit. The first activity, ***What Makes a Shadow***, serves as a hook to assess students' prior knowledge of shadows and helps build vocabulary by categorizing objects as opaque, translucent, or transparent. In the second activity, ***Patterns in the Sky***, students will construct a tower outside and measure how shadows change throughout the day. The final activity, ***Create a Sundial that Correctly Displays the Time of Day***, is an outdoor STEM project that challenges students to build a functional sundial, helping them understand how the sun's placement in the sky creates observable patterns in Earth science phenomena such as climate changes, weather patterns, and shifts in the planet over time.

Key terms: orbit, angles, makerspace, math, measure, data

Background Information

What Makes a Shadow

Students will work with a small group to investigate different materials to determine which materials make the best shadows. Students will use a flashlight to cast shadows on the items, and then sort them into groups to categorize opaque, transparent, and translucent properties. Different items will cast different types of shadows based on the materials.

Shadows are made when materials block the light that is shining upon it. Some materials allow light to pass through completely, some block the light completely, and some allow partial light to pass through. These properties are classified as being transparent, opaque, and translucent. Because light travels in a straight line, the shadow will align itself in a straight line with the light source as it shines upon the item.

In this activity, students should recognize that some objects create darker, more solid shadows than others and that there is a relationship between the light source and the direction and shape of the shadow based on the properties of the object and the direction of the light.

Prior to the lesson, the teacher can set out different materials students can test. Possible materials would be the following: paper plates, cardboard, pencils, skewers, construction paper, straws, various types of tape, and hot glue.

Patterns in the Sky

Shadows are created when an object blocks a source of light. The shape and size of a shadow depend on the shape and position of the object, as well as the angle and intensity of the light source. As the position of the sun in the sky changes throughout the day, the angle and intensity of sunlight hitting objects on the Earth's surface also change, resulting in changes in the shape and position of shadows.

In general, shadows are longest in the early morning and late afternoon when the sun is closer to the horizon, and shortest around noon when the sun is highest in the sky. The length and direction of shadows can also be influenced by the season, as the Earth's axis tilts towards or away from the sun, changing the angle at which sunlight hits different parts of the planet.

The study of shadows, particularly how they change over time, can be useful in a variety of fields, including architecture, art, and science. For example, measuring the length and position of shadows can help architects and designers understand how sunlight will interact with their creations at different times of day and year. In science, tracking the position and movement of shadows can help scientists understand the Earth's rotation and revolution around the sun, as well as how sunlight affects climate and weather patterns.

Students will observe the phenomena by building small towers and tracking the change of the shadow throughout the day. By building small towers and tracking the change of the shadow throughout the day, students can gain a better understanding of how the position of the sun affects the shape and position of shadows. This can also help them to develop skills in observation, data collection, and analysis.

Prior to this activity it may be helpful to have the following discussion with the whole-group:

- Discuss the cardinal direction the sun was in at the different times of day and what conclusions we can draw about the patterns in the sky. When the sun is low on the horizon, shadows are longer. When it's high in the sky, shadows are shorter. The sun "rises" in the east and "sets" in the west.
- Explain to students that, although the sun appears to move across the sky throughout the day, it does not actually "rise" in the morning and "set" in the evening. The earth rotates on its axis, and because of this our view of the sun changes throughout the day as we experience day and night. It is beneficial to use an earth and sun model to demonstrate this, if desired.
- Reiterate that light travels in straight lines and that when an object blocks the path of light, a shadow is formed. The position and angle of a light source affect the size and shape of a shadow.

Create a Sundial that Correctly Displays the Time of Day

In this activity, students will design and create sundials. Sundials work by casting a shadow onto a surface marked with hours or other units of time. The shadow is created by an object, called a gnomon, which is positioned so that it points towards the celestial pole, which is the point in the sky around which the stars appear to rotate. As the Earth rotates on its axis, the position of the sun in the sky changes, and the shadow cast by the gnomon moves across the marked surface, indicating the time of day.

The angle and position of the gnomon are important in determining the accuracy of a sundial. The angle of the gnomon must be set to match the latitude of the location where the sundial is being used, while the position of the gnomon must be adjusted to account for the Earth's axial tilt and the changing position of the sun in the sky throughout the year.

Students will research the best way to make a sundial on their own, but the general steps are the following:

1. Find a sunny and level outdoor location to place your sundial.
2. Choose a gnomon, which is the object that casts the shadow on the sundial. A gnomon can be made from a variety of materials, such as wood, metal, or plastic. It should be long enough to cast a shadow that can be easily seen, but not so long that it becomes unstable.
3. Determine the latitude of your location. This will help you determine the angle at which the gnomon should be set. You can use an online latitude finder or a compass to determine your location's latitude.
4. Mark the hours on your sundial. Make sure to space the marks evenly and accurately.
5. Position the gnomon on the sundial. The gnomon should be positioned so that it points towards the celestial pole. The angle of the gnomon should be set to match the latitude of your location.
6. Test your sundial. Wait for a sunny day and check that the shadow cast by the gnomon falls accurately on the marked hours of the sundial. If it does not, adjust the angle of the gnomon until it is accurate.

Keep in mind that sundials are not always accurate due to changes in the position of the sun throughout the year and the effects of daylight-saving time.

Key Terms

Throughout the lesson, students will use the following vocabulary:

- Translucent: Not completely see-through, but clear enough for light to pass through the object
- Opaque: Cannot be seen through; does not let light through
- Transparent: Can be clearly seen through; light passes through the object
- Compass: a device that displays the cardinal directions
- Cardinal Directions: North, south, east, and west
- Sundial: A device that shows the time of day by the position of the shadow cast onto a marked plate by an object with a straight edge.
- Latitude: A location marked by its distance from the equator, measured in degrees
- Degree: The unit of measurement for angles
- Protractor: A tool used to measure angles
- Angle: Two rays that meet at a common point

Materials

What Makes a Shadow

- Flashlight (one per group)

- A variety of different materials representing opaque, translucent, and transparent properties - one set of materials per group (examples can include pencils, twigs, paper, magnifying glasses, clear cups, Ziploc bags, wax paper, glass marbles, etc.)
- Vocabulary labels for sorting materials (one set of labels per group)

Patterns in the Sky

- Student notebooks
- Large butcher paper and pencil (one per group)
- Compass (one per group)
- Natural materials found outside (sticks, rocks, leaves, etc.) If these materials are scarce, students can use building materials such as Legos and building blocks instead.
- Meter sticks (one per group)

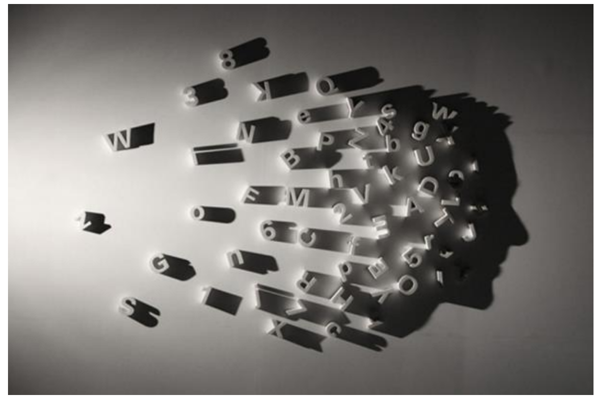
Create a Sundial that Correctly Displays the Time of Day

- Student notebooks
- Compass (one per group)
- Building supplies: At the teacher's discretion, materials can be collected from a STEM lab, makerspace, and/or from natural materials found outdoors. Some examples include paper plates, cardboard, pencils, skewers, construction paper, straws, various types of tape, and hot glue.
- Protractor (one per group)
- Markers or colored pencils

Instruction

What Makes a Shadow

Introduction (15 minutes)



- Show students examples of shadow art.
- Lead a short class discussion over the following questions:
    - What do you notice about this sculpture? What makes it unique?
    - What do you think the artist would need to consider when creating their work?
    - What scientific concepts are needed to create shadow art?
- Instruct students that over the next few days, the class will be observing and investigating the patterns of daily changes in the length and direction of shadows, which can provide valuable information about the movement of the Earth in space.

Engagement (45 minutes)

- Hand out testing materials, flashlights, and vocabulary labels to each group.
- Turn out the lights. Make the room as dark as possible to create the best atmosphere for observing shadows.
- Allow students time to explore the objects and their shadows using the flashlight in the dark room.
    - Circulate and encourage discussions about the properties of the objects and conclusions they can draw from their observations.
- As students discover the relationship between the types of materials and the shadows they cast, have them place lab items under the corresponding vocabulary labels.
    - For example, students should place the pencil and twigs under the opaque label, wax paper and glass marble under the translucent label, and Ziploc bag and clear cup under the transparent label. You can use any materials that you have readily accessible for testing as long as each vocabulary term is represented.
- Lead a class discussion to identify how students sorted each item and why.

Closure (10 minutes)

- Facilitate a whole-group discussion about how groups sorted their materials.
    - What type of materials made the best (darkest, most solid) shadow?
    - Why did some objects make darker or lighter shadows?
    - How does this relate to the real world?
    - What causes shadows?

Patterns in the Sky

Introduction (10 minutes)

- Begin class by showing the students a video of a famous shadow artist: https://www.youtube.com/watch?v=JqQsr57jpN4
- Have students discuss the following:
    - Why might the position of the light be important for shadows?
    - How can shadows be used?
    - What can be inferred by shadows?

Activity (50 minutes)

- Have students prepare their notebooks with a data chart for collecting information during the experiment. The following is a sample data chart heading:

Time of Day	Position of Sun	Length of Shadow	Direction of Shadow	Observations

- Take the class outside to an area that gets full sun.
    - A smooth concrete pad works best, as it gives a solid base on which to build and trace shadows. If one isn't available, any sunny, flat spot will work.
- Hand out a large piece of butcher paper, pencil, and compass to each group.
    - Groups should lay their butcher paper on a flat surface.
- Using the compass, students should mark cardinal directions at the appropriate locations on their butcher paper (north, south, east, west).
- Once papers are labeled, partners will gather materials they find in the outdoors to make a small tower.
- Once groups have gathered materials, they will begin building their towers in the middle of their butcher paper.
    - Towers need to be freestanding.
    - Provide building support as necessary.
    - If outdoor materials are scarce, students can use Legos, blocks, or other building materials.
- Once towers are built, partners will trace the shadow of their towers onto the butcher paper.
- Students should label the tracing with the time of day for reference.
- After tracing the shadow, students will measure the tracing using a meter stick and record the measurement and time of day on a data table in their notebooks.
- After recording the data in their notebooks, students will compare their shadow measurements to the actual height measurement of the towers.

  - Is it shorter, taller, or the same as the actual height of the tower?
  - Note the position of the sun and how it relates to the shadow (Shadows are cast in a straight line from the sun's position, resulting in shadows being cast in the opposite direction of the sun's location).
- Repeat the last two steps at two different times of the day.
  - For example, trace the shadows at 9:00, 12:00, and 2:00 (or times that accommodate your schedule). Do not forget to record data and observations during each visit.
  - If this is not possible in the classroom, have students in other class draw the shadow and write the time of day on the paper for their peers. Begin the following day by measuring and writing data in lab journal.

Closure (10 minutes)

- Allow students to review the data they recorded in their notebooks and reflect on the following questions:
  - Based on your observations, how did the shadow's height change throughout the day?
  - At what point was it shortest? longest?
  - Did the direction of the shadow change?
  - When the sun was positioned in the east, what direction did the tower's shadow point?
  - Were the shadow, tower base, and sun always positioned in a straight line?
  - How did the length of the shadows compare to the actual height of the tower at the different times of observation?

Create a Sundial that Correctly Displays the Time of Day

This activity could be separated into 2 days depending on the amount of time needed for students to research and build.

Introduction (5 minutes)

- Show students the following video on the sundial timelapse: https://www.youtube.com/watch?v=ToxDGva9BLo
- Ask students the following questions:
  - What do you notice in the video?
  - What do you think that video is showing?
  - What details about the device are probably important to its function?

Activity (65 minutes)

- Instruct students that today they will be designing and building sundials.
- Allow students to do a 20-minute research on how to model and design a sundial, by using the guiding question: How do you design and create a sundial?
- Encourage students to write their research in their lab journal.
- In notebooks, students will plan the design for their own sundial.
- Their plan will need to include a blueprint of their idea including labeled materials they plan to use and how they will be attached together.
  - Students should know what materials they will have available to build their sundials, utilizing a STEM lab, makerspace, and/or outdoor materials.
- Once individual plans are complete and approved by the teacher, allow partners or small groups to assemble and share ideas.
- Each student should explain their design ideas and materials to the group.
- Once each student has shared, the group will collaborate to combine the best ideas into one design.
- Students should sketch a new group design plan in notebooks, labeling each part with planned materials.
- The group will share their design with the teacher for approval before acquiring materials.
- Next, groups will work together to build the base of the sundial that they designed together.
- Students should mark 12:00 (noon) on the base of their sundials. This may be easier after they create their base but before they attach any other materials to it.
  - To do this, make a mark in the center of the base. Use a ruler, meter stick, or other straightedge to draw a straight line to the top of the plate. Mark the top of the line as “12” to represent 12:00.
- From here, have students make additional marks around the top of their plates at the following degrees using a protractor to mark their sundials with the times:

Time of Day	Measurement
12:00 (Noon)	0 degrees
11:00 am and 1:00 pm	9 degrees
10:00 am and 2:00 pm	19 degrees
9:00 am and 3:00pm	30 degrees
8:00 am and 4:00 pm	45 degrees
7:00 am and 5:00 pm	66 degrees
6:00	90 degrees

Note: These measurements were calculated based on a latitude of 36°, which will work for east Tennessee locations. If you are in a different location, you can retrieve accurate measurements for your location by checking your latitude on Google and then visiting Sundials.org. Depending on student ability and available class time, students could do this research on their own as an extension activity, or it could be a group member's 'job' if they have different responsibilities within the group setting. Also, you may select only the most pertinent times for students to mark, based on your schedule for testing sundials.

- Students will use available materials to complete their designs.
- Allow students the opportunity to discuss their finished products and improve their designs.
  - Remind students to record the changes they make to their sundials in their notebooks and note any additional materials they use that differ from original designs.
- Students should find a sunny spot with no shaded areas for testing.
- By using a compass students can determine which direction is north, ensuring that the number 12 on their sundials are pointed in that direction.
- Students will observe the shadow being cast by the sun onto their sundials and read the time to see if it is accurate.
  - Be sure students record observations they make about their sundials, the sun, and the shadows in the data chart that they drew in their notebooks.
- Check the sundial at different times of the day to see if the shadows align accurately according to their markings.
  - Students should record their observations in notebooks.
- If time allows, have groups present their sundials, including initial design sketches, materials used, and test results, along with relevant vocabulary and scientific concepts learned. Time will be given for preparation and understanding can be assessed using the rubric attached.

Differentiation

- Assign group roles for students who struggle to stay on task and/or are reluctant to participate in group activities. Be sure each student is clear on his/her specific roles in the group setting.
- Provide sentence stems to encourage discussion amongst all group members.
- Assign groups heterogeneously to allow higher level students to assist lower-level students. This can be advantageous to all types of learners as higher-level students benefit from "teaching" or helping lower-level students, and lower-level students benefit from hearing the concepts being taught by peers from different perspectives.

- Provide images and/or vocabulary cards for ELL students in their home language to enhance understanding of new terms.
- Alter assessments to include multiple choice or word bank options as opposed to open-ended responses to accommodate special needs and/or ELL students.
- Provide prepared, written notes students to accommodate individual needs.
- Allow students additional time to complete assessments, as needed.

Assessment

Summative Assessment:

- Student Presentation, which can be scored with the rubric below.

Formative Assessment:

- Student notebooks (individual and group design sketches, data table including times of day and observations of shadows, and improvement suggestions based on test observations)
- Scientific discourse during small group and whole group should include relevant vocabulary and exhibit an understanding of the observable patterns made by the movement of the earth around the sun and their causes.

Student Presentation Rubric: Summative Assessment

Group:______________________________ Date: ____________________

	4	**3**	**2**	**1**	**Score**
Preparedness	All group members are prepared and presentations have obviously been rehearsed.	All group members are prepared, but presentations may have needed to be rehearsed a little more.	Some group members are not prepared and presentations needed to be rehearsed a little more.	None of the group members are prepared. Presentations were clearly unrehearsed.	
Explanation	Shows full understanding of the topic; Uses appropriate facts and relevant details to explain concepts.	Shows good understanding of the topic; Uses some appropriate facts and relevant details to explain concepts.	Shows good understanding of parts of the topic; Uses some appropriate facts and relevant details to explain concepts but some pertinent information may be missing.	Shows little or no understanding of the topic; Uses mostly irrelevant and/or incorrect facts and details to explain concepts.	
Organization	Ordering of all presented information was coherent and sequencing was accurate and relevant.	Ordering and sequencing of information was mostly accurate, but some information may have been disorganized or irrelevant.	Most information presented lacked accurate sequencing and was confusing, and/or contained irrelevant information.	Order of information presented is illogical; Sequencing was confusing and/or incorrect.	
Participation	All group members participate equally and are able to answer questions.	All group members participate but not equally; All group members are not able to answer questions.	Some group members do not participate in the presentation or answering questions.	Not all group members participate.	
Content	Presentations include all of the following: • Initial design sketch • Materials used for sundials • Summation of observations • Relevant vocabulary terms and scientific concepts relevant to the experiment.	Presentations include 3 of the following: • Initial design sketch • Materials used for sundials • Summation of observations • Relevant vocabulary terms and scientific concepts relevant to the experiment.	Presentations include 2 of the following: • Initial design sketch • Materials used for sundials • Summation of observations • Relevant vocabulary terms and scientific concepts relevant to the experiment.	Presentations include 1 or none of the following: • Initial design sketch • Materials used for sundials • Summation of observations • Relevant vocabulary terms and scientific concepts relevant to the experiment.	

VOCABULARY LABELS FOR SORTING: WHAT MAKES A SHADOW? (2 SETS)
CUT EACH SET APART BEFORE DISTRIBUTING TO GROUPS.

TRANSLUCENT

TRANSPARENT

OPAQUE

TRANSLUCENT

TRANSPARENT

OPAQUE