COOLER IN THE SHADOWS

DESIGNING TO STAY COOL

LESSON OVERVIEW

LESSON SUMMARY

Students will make inferences about the cause of shadows, by observing and making their own shadows in the sun. Many properties of shadows (such as heat and brightness of light) will also be identified firsthand as the students conduct simple experiments to observe changes that are comparable to those experienced by the MESSENGER spacecraft in its voyage to and around Mercury.

GRADE LEVEL
Pre-K - 1

DURATION
1-2 hours

ESSENTIAL QUESTION

How does the amount of sunlight and heat change in areas that are shaded?

OBJECTIVES

Students will be able to:

- discover patterns in the behavior of sunlight, temperature, and shadows
- gain an understanding of how shadows form and the factors that influence the shape and size of a shadow
- explain the difference between a shadow and a reflection
- understand that light travels in a straight line
- begin to understand why shadows outdoors are different at different times of the year

Concepts

- Sunlight and other types of light form shadows.
- Shadows form because light travels in straight lines.
- Light cannot pass through some materials and this leads to the formation of shadows.
- Shadows can change position and shape and size depending on the position of the object in relation to the position of the light source.
- Darkness is the absence of light.

MESSENGER Mission Connection

The generation of heat by sunlight is also why shadows are important for the MESSENGER mission to Mercury. Because the spacecraft will be very close to the Sun, it will receive much more intense sunlight than we get on Earth. To reduce the temperatures in the probes, a sunshade is included on the craft.

The spacecraft is oriented so that the shade always faces the Sun, and the sensitive instruments used to make observations of Mercury are always in shadow.

WARNING

Do *not* look directly at the Sun!

This lesson is about the Sun and sunlight, but be sure to remind students frequently ***never* to look directly at the Sun!** Looking for even a few seconds can cause permanent damage to the eyes, and longer exposure can cause blindness. Note that sunglasses do *not* provide an adequate safeguard against looking directly at the Sun.

Standards & Benchmarks

National Science Education Standards

K-4 Standard D2b Objects in the Sky

- The sun provides the light and heat necessary to maintain the temperature of the Earth.
  (From the narrative: "As they [students] observe changes, such as the movement of an object's shadow during the course of a day, and the positions of the sun and moon, they will find patterns in these movements.")

K-4 Standard B31 Light, Heat, Electricity, and Magnetism

- Light travels in a straight line until it strikes an object.

Benchmarks for Scientific Literacy (AAAS Project 2061)

4E (K-2)
The sun warms the land, air and water.

Science Overview

The Nature of Shadows

Shadows are evidence that light travels in straight lines from its source. If the path of light is blocked by an object, then the light cannot reach the surface behind the object, so it remains (relatively) un-illuminated, in contrast to the more brightly lit area around it. Thus a shadow may be defined as the lack of illumination rather than an object in its own right.

Nevertheless, common phrases and stories, as well as repeated experience, lead us to think of shadows as things. For example, we talk of 'casting a shadow', or of 'our shadow following us', while shadows take on a separate identity in cartoons and stories such as Peter Pan. Even for those who have a scientific understanding of shadow production, the appearance of shadows makes them seem like objects. For children who have not formed an understanding of light travel, this appearance can overwhelm any attempt to teach the scientific explanation.

Shadows are important in our daily lives. It is, after all, what separates night from day: night comes in an area when the Earth rotates around its axis so that the area in question is not facing the Sun but is in the shaded side of the Earth.

The Relationship Between Light, Heat and Shadows

Sunlight heats the objects it illuminates. Because there is less light in the shadows and in the shaded parts of objects, the heat generated by the light in these areas is also less. That is why it is cooler at night than it is during the day, and why the temperatures in the shade are lower than in sunlight during the day.

Young students require many different experiences in various contexts to successfully form a conceptual knowledge of light. Take into account the children's own ideas, not only at the beginning of each experience but also at intervals during an activity. It is important to plan investigations with the children, using their ideas as a starting point. For instance if children believe that shadows can only be produced by the Sun, have them test this idea. For example, by shining a flashlight and/or a candle on a toy figure, a child can see that a shadow is indeed produced by other kinds of light as well as by the Sun.

Generally children are more aware of their own shadows than the shadows of objects. Some children confuse shadows with reflections and draw a colored shadow detached from the object casting the shadow. Many youngsters know that shadows can be produced by sunlight, but very few can explain what happens to light when a shadow is formed.

Lesson Plan: Activity 1: Shadows

In this activity, students will explore making and tracking shadows of different objects over the course of the day to discover patterns in the behavior of sunlight, temperature and shadows.

Teaching Tip

Do this activity when the sun is relatively high in the sky, either near the beginning or the end of the school year. You'll also want to measure sun shadows at least twice and perhaps three or four times during the day to see how they vary.

It is best to conduct this shadow activity a day or two before reading the book, Bear Shadow, (Activity 2 of the Cooler in the Shadows lesson) and making the map of Bear's neighborhood (Activity 3).

Preparation

Assemble the needed materials [e.g. in the center of each table, on each student's desk, etc.]. If the students are working in groups it is useful to provide the materials for each group in a bucket, tub or plastic bag so that the materials are easily carried outdoors.

Materials

Per class:

- Two large classroom thermometers or temperature strips
- yardstick
- large coffee can of soil or stones holding a 12-14" stick

Per group:

- large pieces of paper
- chalk
- an umbrella
- pencils
- markers
- paints
- various objects such as hoops, lace, balls, toy figures etc.
- large, flat sheet of cardboard, poster board, or other heavy paper (at least 2' x 3')
- compass

Warm-up & Pre-assessment

Find out from the children what they think or know about the nature and origin of shadows. Use some of the following questions to spark the conversation:

- What are shadows?
- Can you pick up a shadow?
- Can your shadow become detached from you? If so, how?
- If your shadow is detached from you, could it be sewn back on, like Wendy did with Peter Pan's shadow?
- When do you have a shadow? What needs to be true before you have a shadow?
- Why does there have to be a bright light? What does the light do?
- Where does your shadow appear? Is there any connection to where the light is coming from?
- Can you ever have more than one shadow? How?
- If a shadow forms because you block the light, how is it that you can still see something that is in the shadow?

Teaching Tip

This exercise (or something similar) can be used when children disagree about the properties of shadows, such as their size and shape. It is best if such an exercise (or small scale experiment) arises from the children's discussion and/or specific predictions, statements or disagreements. The children might well devise similar experiments involving, say, themselves and the sun or a flashlight and toy figure. It is equally important to follow the experiments with a discussion of what was discovered. The basic pattern here is the well-known POE - Predict, Observe, Explain. This method is most likely to be effective, however, when the children co-construct both the prediction and explanation through discussion, rather than by mandate from the teacher.

Procedures

1. Divide the class into 2 teams: The Shadow-Makers and the Shadow-Trackers. (You may want to have 2 trackers per maker, so that they can compare observations.)
2. Explain the roles to be played, and how important it is that everyone participate.
3. Set up a system so you can record the temperatures on a summary chart on the board to show all the students at the end of the activity.
4. Have the Shadow-Makers lay down a piece of poster board, on which they place some objects in the sun, either outside or on a window sill.
5. Have some Shadow-Trackers trace the objects' patterns on the poster board every hour.
6. Have other Shadow-Trackers measure the temperature of the stationary objects and the shadow they create every hour, and record it, with the time of day, next to the tracing on the poster board.
7. Have the Shadow-Trackers try to draw what the objects and their shadows would look like if they could take a "snapshot" that would freeze the moment in time, like a photograph does.
8. Outside in the sunlight, mark a place in chalk for a Shadow-Maker to stand and hold at arm's length one of the objects that was placed on the ground in the first part of the investigation. Have a Shadow-Tracker trace the shadow below on to a sheet of poster board or card stock. (Later in the classroom you will compare the traced images of the objects.)

Teaching Tip

When actual temperatures are not possible to measure, have the students place their hand on the object and see if they can compare how it feels in or out of the sunlight, or compared to another object in or out of the sunlight. Use "hotter" or "cooler" to describe the different surfaces of the objects, in or out of direct sunlight.

You may also want to have the students place a small object in the shade, keeping it there by moving it with the moving shadows through the day, measuring its temperature (which should remain steadily cooler than the surface of the larger object in direct sun).

Discussion & Reflection

Summarize the students' observations on a chart set up for the whole class to see. Ask what kinds of conclusions they can make about the nature and behavior of shadows, and of objects found within those shadows.

Using the traced shadows of the objects you used both on the ground and suspended in the air, ask if there are any differences. Then have the students imagine sitting in a basket under a big tree. Would there be shade? In the tree's shadow, would it be hot or cool? Now have them imagine sitting in that basket suspended high in the air. Is there any shade? Would it be hotter or cooler there than under the tree?

Point out that when objects (such as airplanes and space rockets) move up very high into the sky, they don't have shade anymore from the Sun, so we have to keep them – and any people inside -– from getting too hot from being in the sunlight all the time.

Tell the students that we are sending up a rocket into space with a little spacecraft called MESSENGER, and that since it won't have any shadows to rest in when it gets too hot, we had to build something to give it a shadow all the time.

Ask the students if they can show you one of the objects they used in the activity that would be a good shade for a small spacecraft. If necessary, stand under the umbrella and ask them if you are in the light or in the shade. If using a lamp, let a student move the lamp. Move the umbrella to keep your faced shaded. If outside, show how you can easily keep up with the movement of the sun to keep your face out of the light. Tell them that this is exactly how they're going to keep MESSENGER from getting too hot while it's up in space.

Lesson Adaptations

- For students with hand-eye coordination problems, have them work as a team to trace shadows on for the Shadow Trackers, or give them Shadow-Making roles.
- For non-readers of letters or numbers, have them mark the thermometer's level with a post-it or a crayon, so that the teacher can then read it and record it for them. See also Teaching Tip about using the hand to compare warmer or cooler temperatures.

Curriculum Connections

- *Math / Measurement:* Reading thermometers
- *English:* New vocabulary words to introduce into daily usage : shadow, shaded, sunshade, attached/detached, light intensity, temperature, exposure, illumination etc.
- *Art:* Tracing images, drawing in details or color after outlining, drawing an object with its shadow when illuminated from different directions

Assessment

Have students describe (orally or in writing as appropriate) the experiment, report data, and come to a conclusion about how shadows form and how the temperature varies in sunny or shaded areas.

Lesson Plan: Activity 2: Bear Shadow

In this activity students learn about shadows using literature-based discussion and experiences.

Materials

- *Bear Shadow* by Frank Asch

Warm-up & Pre-assessment

Review what students may have learned about shadows in the previous lesson or prompt a brief discussion based on some of the following questions:

- What are shadows?
- What does a shadow do?
- When do you have a shadow? Give some examples.
- If a shadow forms when you block light, why can you still see something in a shadow?

Procedures

1. Organize the students into a reading area
2. Read *Bear Shadow* by Frank Asch, either individually or as a participatory exercise. In this story, a bear attempts to escape a shadow that seems to be chasing him. You might guide this discussion by asking questions based on the Warm-up, such as:
   - What did we just discuss about shadows that makes the book funny?
   - Why did Bear's shadow disappear when he hid behind a tree?
   - Why did the shadow disappear when Bear buried it? What do you think about that?
   - What makes a sun shadow fall one direction at one time and another direction at a different time of day?
   - What else do you have to say about shadows?
3. Use the responses to help the children shape activities through which they will discover the answers to their questions.

Teaching Tip

If you have already begun the study of shadows and have measured sun shadows (Activity 1-Shadows above) at least once, your discussion of Bear Shadow will be more specific. In addition to the kinds of questions above, you can, for example, discuss the time of day when the various events occur and the direction Bear's shadow will fall at these times.

Discussion & Reflection

- Is your shadow always the same size (and/or shape) as you?
- Under what conditions does the size/shape of your shadow change?
- What factors might affect the size or shape of your shadow? How would it be affected?
- How could you test if your answer is right? (Alternatively, if several class members are offering different answers: How could we decide whose idea produces a better explanation?)
- Remember the MESSENGER spacecraft we talked about? (If you did not do Day 1, tell the students that we are sending up a rocket into space with a little spacecraft called MESSENGER. Since it won't have any shadows to rest in when it gets too hot, we had to build something to give it a shadow all the time; it look likes an umbrella and is called a sunshade.)
- Well, we're putting all sorts of cameras on MESSENGER to take pictures up in space! We don't want any of the cameras to get damaged by all the hot sunlight, so when do you think is the safest, best time to use the cameras?

Assessment

Use the answers to the questions above as the basis of your assessment.

Curriculum Connections

- *Reading and Listening:* **find other books, both fiction and non-fiction which feature shadows**
- *Reasoning and Logic Development*
- *Art:* **Have the students draw a variety of objects with the shadows they cast when illuminated from different directions**

Lesson Adaptations

Encourage students to experiment for a minute or two to test out some of their theories and ideas during discussions. Then have them return to the group and decide if they want to maintain their original comments, or change them to reflect what they discovered in their mini-experiments.

Lesson Plan: Activity 3: Making a Model of Bear's Neighborhood

In this lesson, students will construct a model neighborhood to demonstrate their understanding of shadows. Many questions and suggestions for varying the activities are presented to allow you to tailor this lesson to your particular needs. It is best to make the model of Bear's neighborhood when the sun is relatively high in the sky, either near the beginning or the end of the school year. You'll want to measure the sun shadows with students at least twice, and perhaps three or four times during the year, to see how they vary over time.

Preparation

Ideally, you will have completed Activity 1: Shadows, or have measured sun shadows in some other context, so that your discussion can be more directed. You may, for example, discuss the time of day when the various events in the book occur, and the direction in which the Bear's shadow will fall at these times.

Organize the materials for the activity. Clear a space in the room if you cannot construct your model neighborhood outdoors, or identify and reserve, if necessary, a place on the playground to build the model.

Teaching Tip

When you construct Bear's imaginary neighborhood on the playground or in a field, do it away from the potential shadow of the school building! For young children, it's best to construct the model outdoors where the relative position of the Sun is determined by the Earth's rotation, tilt, and location in its yearly revolution around the Sun.

Materials

For small 3-D model:

- some appropriate area in the classroom, art room or other available space, large enough to build a model of the neighborhood (about 5x5 feet)
- cardboard
- scissors
- glue
- cardboard boxes of various sizes to represent buildings in Bear's neighborhood
- foil to make the pond and brook
- Model trees, potted plants or small pieces of shrubs to represent the trees
- tape
- pencils, crayons, and markers
- a bright lamp

Warm-up & Pre-assessment

- Re-read Bear Shadow by Frank Asch (See Activity 2) and briefly discuss.
- Be sure the students know their compass directions. If necessary, teach them beforehand how to find North on a compass.

Procedures

1. Divide students into groups of 3-4.
2. Explain to the students that the class will make a 3-D model of the neighborhood where Bear lives. Use a compass (teacher or students can do this) to find North. The model should show clearly which direction is North, either with an arrow or by orienting a three-dimensional model correctly with respect to the actual directions. Tell them to be sure the map/model includes:
   - Bear's house
   - the pond where he went fishing
   - the brook he jumped over
   - the tree he hid behind
   - the cliff he climbed
   - the place where he tried to nail the shadow to the ground
   - the place where he dug the hole to bury the shadow
3. Start making the model by asking the students to select a place for the pond. Once they have made that decision, assign each group a feature to place on the model. Have each group explain the reasoning that led to each placement. There may be disagreements, but the criterion for "correctness" is whether the placement parallels the pictures in the book.

Materials cont'd:

For large 3-D map/model to be built outdoors:

- an appropriate place on the school grounds
- six or seven different-sized large cardboard boxes
- scissors
- glue
- duct tape
- pencils, crayons, and markers
- any additional material (e.g. fallen branches, a broom, a tarp, plastic sheeting) students can use to create landmarks like the tree, the pond, and so on
- A Teddy Bear of appropriate size to represent Bear
- compass

Teaching Tip

Some questions might be posed to all students, or to groups, either to answer "immediately" or to direct their thinking during model construction. Some questions may also be used for assessment of the children's understanding, their attentiveness to the story details, and their reasoning. In all cases, the response to a question should contain an explanation of how the answer was obtained, not just the answer itself.

4. When the model is complete, the students will use the thermometers to measure the temperature in the sunlit areas and the shaded areas. Record the temperatures at each location in a chart so that the students can easily see any differences. Ask the students to explain why some areas are warmer or cooler. Help the children conclude that it's hotter in light than it is in shadow.

   Discussion questions may include:

   - At what time of the year does the story happen?
   - At what time of day did Bear go out to fish?
   - At what time of day did Bear try to nail his shadow to the ground?
   - At what time of day did Bear try to bury the shadow?
   - How long did Bear nap?
   - How many windows are there in Bear's house?
   - Which direction does the door of Bear's house face?

Assessment

Sample assessment questions:

- Could Bear see his shadow when he faced the Sun? What about when he turned the other way? If you're not sure of the answer, can you find a way to test it and show me?
- When did Bear lose his shadow? Could you ever lose your shadow? If so, how? If not, why not?
- Why was Bear afraid of his shadow? Are you afraid of your shadow? Why or why not?
- Can your shadow do something without you? Can you do something without your shadow? How?
- Name three places where Bear could not see his shadow. Name three places where YOU can not see your own shadow!
- Could Bear see his shadow on the pond? If so, when? If not, why not? What else could he see in the pond when he looked down into it? Encourage the students to discuss the differences between shadows and reflections.

Curriculum Connections

Science:

- Add toy figures and flashlights to the block corner or science area, to allow youngsters the freedom to try out ideas about shadows.
- On a sunny day, set out two or three prisms of different sizes and shapes and let the children explore the effect of sunlight passing through the prism.
- Have students draw and measure each other's shadows with string at different times during the day in order to observe and describe changes in the size of the shadow.

Art: Have the students color cardboard cutouts of Bear's model neighborhood, and then shine a light on them to prove that different colored-shadows will not appear. Explain and show how light is needed to see color, and that the less light that is available, the less one is able to see color. A good demonstration of this is to use a dimmer switch on a stage in the auditorium. Lower the lights until only faint images are visible, then raise the lights to show how colors become more intense with increased light (up to the optimal point), and then can get bleached out when the light becomes too intense.

Lesson Adaptations

Have students set up a dollhouse, accessories and a lamp as the Sun. Hold the lamp at different angles, and ask students to speculate on such questions as:

- What time of day is it for the dolls?
- Where would they want to plant their garden so it gets the most light?
- Where is the coolest part of the house to rest in the middle of summer (assuming they have no air conditioning?
- In the coldest winter months, where could they sit inside to be warmed by the Sun? What time of day or night would that be?

Lesson Plan: Activity 4: Creating Shadows of a Model Earth

Students experiment with making shadows of a three-dimensional object, including a globe, to see how they can alter the size, shape and position of their shadows.

Teaching Tip

Remove the lampshade if the light is not strong enough, or if you cannot darken the room sufficiently to make shadows

Warm-up & Pre-assessment

- How can you "make" a shadow?
- Can you make more than one shadow?
- How can you change the size, shape, or position of your shadow?
- Where does the light come from that makes the shadow?
- Can light get around the corner to make a shadow?

Materials

- Lamp with 75-100 watt bulb; thermomaters or temperature strips
- a 12" diameter sphere (e.g. ideally a world globe but any ball of this approximate size will do)
- A sheet of 36" white poster board
- 1 toy (1"-2") "Matchbox-style" car or truck, and other models of real objects, larger and smaller than the toy car

Procedures

1. Have the children sit in a large circle. Darken the room.
2. Place the lamp on a stool or a file cabinet inside the circle.
3. Hand one ball to a child and have him or her stand in the circle near the lamp, holding the ball at arm's length. During this time, ask the children to predict what they will see.
4. Ask questions about what the children observe.
   - Is the ball making a shadow? If so how do you know? Where is the shadow?
   - If there is no shadow, why not? Where do you think it should be?
5. Hold a piece of poster board right behind the ball and have students observe its shadow. Discuss with them how they needed something on which to see the shadow. (They may have noticed it on the floor or on the classroom wall before this).
6. Hand a small toy car to another child and have him or her stand about a foot behind the first child and further from the lamp, with the car extended at arm's length. Ask what the children observe. (NOTE: The first ball should be making a visible shadow on the toy car behind it; adjust the children's distance if necessary, and use the poster board to emphasize the light difference.)

Teaching Tip

If you want to convey the straight line of light concept, use a string to pull between the lamp and the ball, then behind it to the toy car. Have students observe that the light does not turn left and right and cannot reach behind the solid ball)

Procedures

7. Exchange the toy car with other objects of different sizes. Ask the children:

   - What happens when the object is much smaller than the ball? Larger?
   - How can theobjects get out of the shadow?
   - Have the children predict: If you were in the car in the shadow, would you be cold or hot?

     If you then went into the light, how would you feel?

8. Place the thermometers in the light near the lamp and in the shadow behind the ball. Record the temperatures.

9. Tell the students now to pretend that the ball is the Earth, and that they are standing on it! Remind them that we are sending a little spacecraft called MESSENGER to the planet Mercury. It will be very far away from Earth and much closer to the Sun. Since it won't have any shadows to rest in when it gets too hot, we had to build something to give it a shadow all the time; that something looks like an umbrella and is called a sunshade.

   - Use a toy car or spacecraft and move it towards the lamp and far from the ball, to show how it gets no shade anymore from the large planet Earth.
   - If this model MESSENGER got too close to the lamp, and were left overnight there, how hot would it get?
   - Discuss how MESSENGER's sunshade is like an umbrella, that it keeps most of the light and heat away, so that the cameras under it will stay cooler than if they were out in the sun. Use the temperatures from their experiment to prove this.

10. Record the temperatures on the board. See if the children can identify hotter temperatures by their numbers. Help the children conclude that it's hotter in the light than in shadow.

Discussion & Reflection

Discussion and reflection questions are embedded in the procedures above.

Assessment

Reread Bear Shadow. As a class, identify those aspects of the story that are purely fictional and those that "could happen," paying particular attention to how shadows change during the day. Ask students to discuss how they notice temperatures changing during the day, too. Help them make correlations where appropriate.

For example, ask:

- Where would you want to sit to be coolest when it's a summer day: in the shadow of a big building or in full sunlight in the middle of a baseball field?
- When it's freezing outside and there's snow everywhere, where can you warm up most: in the shadow of a big building or in full sunlight in the middle of a baseball field?

Compare the shadows in Bear Shadow to those students made and tracked in Activity 1. Revisit the discussion questions from the Warm-up and Pre-assessment activity, especially focusing on the last one, "What other questions do you have about shadows?" You could spend time answering the students' questions, as well as generating ones to be answered in the other lessons of this series.

As a class, create a nonfiction version of the story.

Curriculum Connections

Art: Have students trace each other's shadows on the ground at different times of day. Mark the footprints of a child so that he or she stands in exactly the same place at three or four different times. Have another student trace the shadow in a different color each time. Write the exact time in the same color chalk (or draw a clock with the hands pointing to that time). Discuss the movement of the shadows, time of day and the placement of the Sun. Have the students speculate as to what will happen as the Sun sets in the evening. Point out the importance of sunlight when artists decide to paint something outside, and how objects can look different when placed in different lights.

Music: Teach the students the song "Me and My Shadow," and use it as part of a presentation to parents about what they have learned about shadows and sunlight.

Internet Resources & References

http://www.sciencenetlinks.com/matrix.cfm

http://hea-www.harvard.edu/ECT/the_book/index.html

Acknowledgments

AAAS /Marco Polo Science NetLinks