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How Does a Camera Work?

A two-part visual arts integrated science lesson for 5th graders with optional lesson extensions

Lesson 1: Investigating the Pinhole Camera

Objectives:

- **Science TEKS 5.2: Scientific investigation and reasoning.** The student uses scientific practices during laboratory and outdoor investigations. The student is expected to:
  - **(A)** Describe, plan, and implement simple experimental investigations testing one variable;
  - **(B)** Ask well defined questions, formulate testable hypotheses, and select and use appropriate equipment and technology;
  - **(C)** Collect and record information using detailed observations and accurate measuring
  - **(D)** Analyze and interpret information to construct reasonable explanations from direct (observable) and indirect (inferred) evidence

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Time: 45 minutes - 1 hour

Materials Needed Per Student:

1 cardboard tube (ex.: paper towel roll, toilet paper roll, or oatmeal container)
1 sheet of black or dark colored 9" x 12" construction paper (brown paper grocery sacks can work if student does not have construction paper)
1 small sheet of aluminum foil (approx. 5" x 5")
1 small sheet of wax/parchment/tracing paper (approx. 5" x 5")
2 rubber bands
Tape
Pushpin/Safety pin/Paper clip/Tip of pen or pencil (used to poke hole in foil)
Scissors
Ruler (optional)

1. **Introduction (5 – 10 minutes):** Let students know that today they will begin an investigation into how a camera works at its most basic level.
    a. Ask students what they already know about cameras. Where do they see cameras? Do they have a camera, and if so, how do they use their camera?
    b. Explain that while digital cameras and smartphone cameras today can create digital images instantly, cameras in the past had to rely on light sensitive materials to create photographs, and the development process could take several hours. At their most basic level, however, both our digital cameras today and the cameras of the past share the same basic structure – they are dark containers with a hole in one side to let in light. Have students identify the hole/lens on a contemporary or smartphone camera where the light enters the camera.
    c. Let students know that they will create their own basic cameras today, called pinhole cameras, using common household items. They are called pinhole cameras because the hole to let in the light will be the size of the tip of a pin.

2. **Activity (25 – 30 minutes):** Guide students step by step in how to create a pinhole camera with their cardboard tube and other materials, or show them this video which illustrates the various steps. After they complete their pinhole camera, have the students look through them inside and outside under different lighting conditions. Last, have them look through their camera with different size holes.
    a. Cover one end of the cardboard tube with the sheet of foil, so that the foil completely covers the end of the tube and it is smooth and flat like a drum. Wrap a rubber band around the foil and tube to keep the foil in place. Be careful not to tear the foil as it is fragile!
    b. Cover the other end of the cardboard tube with the sheet of wax/parchment/tracing paper in the same way as the foil. Make sure the end is completely covered by the paper and that it is smooth and flat like a drum. Wrap the other rubber band around the paper so that it stays in place. Again, be careful not to tear the paper as it is fragile!

c. Wrap the entire tube with the black or dark construction paper, making sure 1) the paper is oriented so that the 12" side aligns with the length of the tube, 2) one edge of the paper is flush with the end of the tube covered in foil, and 3) you tape the paper to the tube prior to rolling the paper around the tube so that it is securely fastened.
d. Use the pushpin/safety pin/paper clip/pencil to poke a small hole in the center of the foil end. Hole should be no larger than a few millimeters in diameter. Your pinhole camera is now complete!
e. Look through the wax/parchment/tracing paper end of the camera, pointing the hole and foil covered end at a light source. Use your hands to cup around your eyes to block out all other light. (This step works best
outside on a sunny, clear day or indoors with the lights turned off and the blinds open to let in natural light or by moving a flash light around for students to look at).
f. Use a ruler to measure the diameter of the original size of the hole and record the diameter and the quality of the picture you can see. Using the push pin/safety pin/paper clip/pencil, gradually make the hole a little bit larger in increments, measuring the hole each time, and recording your observation of the quality of the picture each time.

3. **Conclusion (10 – 15 minutes):** Have students share their observations of looking through their pinhole cameras and formulate hypotheses of how they were able to view an image inside their cameras. Record their responses. Suggested questions: What did you notice when you were looking through your camera? What happened when you made the hole in the foil larger? What questions do you have about the pinhole camera? How do you think this camera works? How are you able to see a picture on the inside? Why is the picture inverted (upside down and backwards)?

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Lesson 2: Analyzing How Reflected Light Creates Images in a Camera

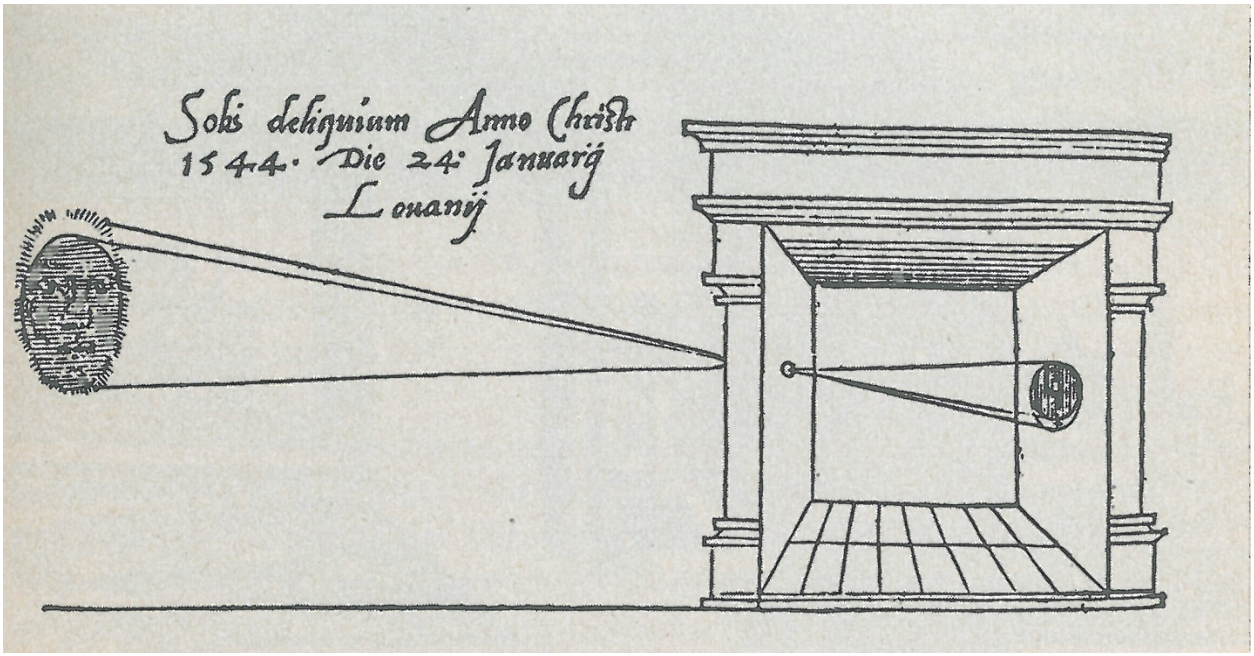

Diagram of a camera obscura drawn by Leonardo da Vinci

Objectives:

- **Science TEKS 5.3: Scientific investigation and reasoning.** The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:
  (B) Draw or develop a model that represents how something that cannot be seen such as the Sun, Earth, and Moon system and formation of sedimentary rock works or looks

- **Science TEKS 5.6: Force, motion, and energy.** The student knows that energy occurs in many forms and can be observed in cycles, patterns, and systems. The student is expected to:
  (C) Demonstrate that light travels in a straight line until it strikes an object and is reflected or travels through one medium to another and is refracted

Time: 45 minutes - 1 hour

Materials Needed Per Student:

Pencil
Blank paper
Light Waves Worksheet (Getty Museum)

1. **Introduction (10 minutes):** Review the recorded observations and hypotheses that the students shared during the last lesson. Explain to students that today they will learn about the history of the camera and how reflected light creates images in a camera.

2. **Activities (30 – 35 minutes):** Let students know that they will learn about the earliest known camera, the "camera obscura," and analyze diagrams of the camera obscura to see how reflected light creates images in a camera.
    a. Define "camera obscura" while looking at Image 1 (attached): This is a diagram of a camera obscura. "Camera obscura" is a Latin phrase that translates in English to "dark room." A camera obscura is a historical optical device that has been studied for at least 2,500 years by scientists, philosophers, and artists from various cultures and times, including the Ancient Chinese, the Ancient Greeks, Middle Easterners
    during the Middle Ages, and Europeans during the Renaissance, including Italian artist and inventor Leonardo da Vinci, who is well known for painting the *Mona Lisa* and other realistic paintings.
    b. Analyzing diagrams:
        i. Have the students describe what they see in Image 1 (attached). Have them identify the dark room, the hole that is letting in light, the source of the light, the path of the light, and the projected image made of light. Have them consider different kinds of light sources and how they all travel in a straight line (ex.: straight beam from a flashlight).
        ii. While looking at Image 2 (attached), have the students identify again the dark room, the hole that is letting in light, the source of the light, the path of the light, and the projected image made of light. Have them also identify how the paths of light are in a straight line until they hit the tree, then they reflect in a different direction but in a straight line towards the camera obscura. Have them consider why the image of the tree is inverted.
        iii. While looking at Image 3 (attached), explain that everything we can see with our eyes is because of sunlight or other light sources bouncing off or reflecting off of surfaces, such as someone else's face or the table, and entering our eyes to make a picture of reflected light that our brain recognizes. Show them how the straight red lines, which represent light, connect the same parts of the tree, and so when light bounces off of the leaves, it forms an image of the leaves, and when light bounces off of the

roots, it forms an image of the roots. Because reflected light travels in a straight line, the image ends up becoming inverted.

c. Draw your own diagram:
    i. Have students complete the Light Waves Worksheet (Getty Museum) by filling in the missing lines of reflected light.
    ii. Then have students draw a diagram of their own pinhole camera to show how reflected light enters their camera in a straight line to form an image of something they have seen with their camera.

3. **Conclusion (5 – 10 minutes):** Have students share their diagrams with each other and summarize what they learned today about reflected light and cameras.

Image 1

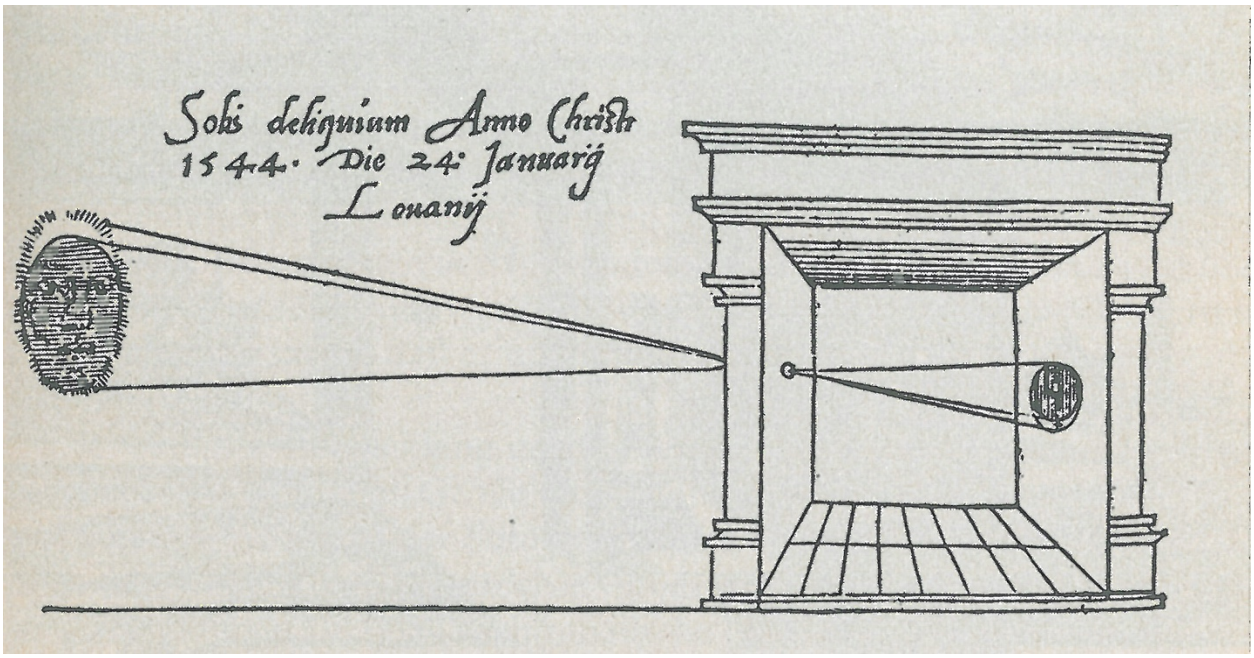

Image 1: Diagram of a camera obscura drawn by Leonardo da Vinci

Image 2

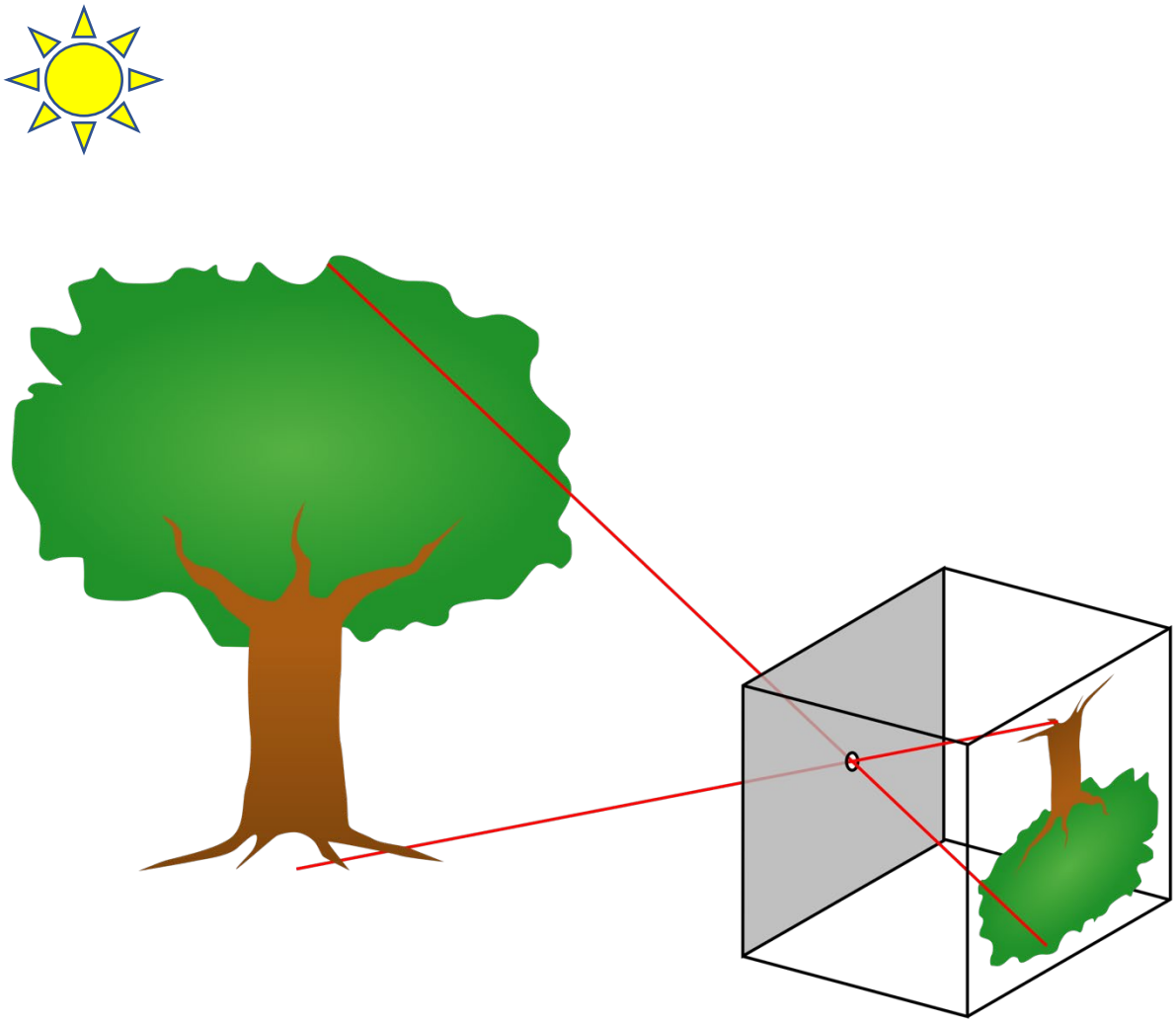

Image 2: Diagram of a camera obscura facing a tree

Image 3

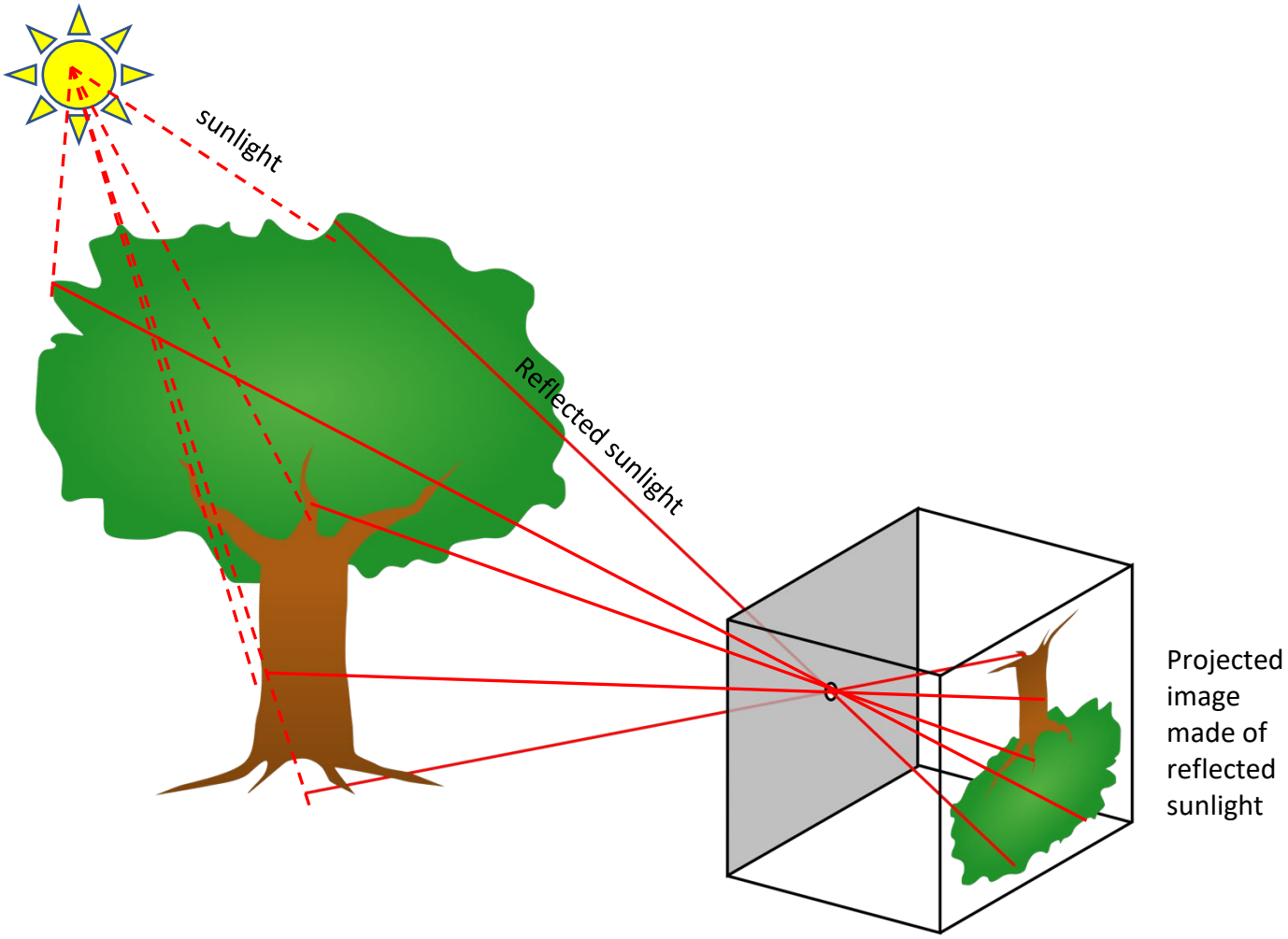

Image 3: Diagram of a camera obscura facing a tree with additional lines of light

Optional Lesson Extensions

1. **Conducting Investigations of Different Variables**

   Objectives:

   - **Science TEKS 5.2) Scientific investigation and reasoning.** The student uses scientific practices during laboratory and outdoor investigations. The student is expected to:
     (A) describe, plan, and implement simple experimental investigations testing one variable;
     (C) collect and record information using detailed observations and accurate measuring

   Activity: Have students identify the different parts of the pinhole camera they made during the first lesson and explain how these are all variables that could be adjusted to possibly achieve different results. Have students adjust each of the following variables while keeping the remaining variables the same. Explain that it is important to only test one variable at a time in order to get consistent results, and that they should keep their original pinhole camera as an example to compare the adjusted versions against.
   a. **Additional Variable #1:** Adjusting the color of the paper wrapped around the tube. Instead of using black paper, wrap your pinhole camera with other colors of paper, including white. Record each time what color paper you use, and what you notice about the picture.
   b. **Additional Variable #2:** Adjusting the diameter of the tube. Instead of using a paper towel roll or tube with a similar diameter, create a pinhole camera with a wider tube, such as an oatmeal container. Record what you notice about the picture when looking through the pinhole cameras with different diameters.
   c. **Additional Variable #3:** Adjusting the length of the tube. Instead of using a paper towel roll or tube with a similar length, create a pinhole camera with a shorter tube, such as a toilet paper roll. Then, create a pinhole camera with a longer tube, such as a wrapping paper roll. Record what you notice about the picture when looking through the pinhole cameras with different lengths.
   d. Have students consider other variables they can investigate.

2. **Create a New Pinhole Camera**

   Objectives:

   - **Science TEKS 5.3 Scientific investigation and reasoning.** The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

(C) connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.

- **Art TEKS 5.3 Historical and cultural relevance.** The student demonstrates an understanding of art history and culture by analyzing artistic styles, historical periods, and a variety of cultures. The student develops global awareness and respect for the traditions and contributions of diverse cultures. The student is expected to:
  (D) investigate connections of visual art concepts to other disciplines.

Activity: Using the principles learned from the first pinhole camera, have students design and create a new pinhole camera using a material other than a cardboard tube, such as a box. Extra challenge: have students incorporate a lens into their design, such as a magnifying glass.

3. **Turn the Classroom into a Camera Obscura**

Objectives:

- **Science TEKS 5.3 Scientific investigation and reasoning.** The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:
  (C) connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.
- **Art TEKS 5.3 Historical and cultural relevance.** The student demonstrates an understanding of art history and culture by analyzing artistic styles, historical periods, and a variety of cultures. The student develops global awareness and respect for the traditions and contributions of diverse cultures. The student is expected to:
  (D) investigate connections of visual art concepts to other disciplines.

Activity: Have students examine the "Camera Obscura" project by contemporary artist Abelardo Morell on his website here. Learn about his artistic process by watching this video. With his process in mind, have students create a camera obscura out of the classroom or their own room at home. Extra challenge: Have students photograph the projected image using a long exposure.

4. **Research the Impact of the Camera Obscura on the Fields of Art and Science**

Objectives:

- **Science TEKS 5.3 Scientific investigation and reasoning.** The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

(C) connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.

- **Art TEKS 5.3 Historical and cultural relevance.** The student demonstrates an understanding of art history and culture by analyzing artistic styles, historical periods, and a variety of cultures. The student develops global awareness and respect for the traditions and contributions of diverse cultures. The student is expected to:
  (D) investigate connections of visual art concepts to other disciplines.

Activity: Have students research how the following historical artists and scientists may have used the camera obscura and what may have prompted them to use the camera obscura for their work:

a. Johannes Kepler, astronomer
b. Ibn al-Haytham (Also known as Alhazen), mathematician, astronomer, and physicist
c. Leonardo da Vinci, artist, scientist, and engineer
d. Johannes Vermeer, painter