Teacher's Edition

IQWST

Physical Science

Can I Believe My Eyes?

Second Edition

Physical Science 1 (PS1)
Can I Believe My Eyes?
Light Waves, Their Role in Sight, and Interaction with Matter

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About the Publisher

Sangari Active Science Corporation is a mission-driven company that is passionate about STEM education. We make it easy for teachers to teach with quality, investigation-centered science curriculum, tools, and technology. For more information about what we do, please visit our website at http://www.sangariglobaled.com.

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Lesson 2

What Do We Need to See an Object?

PREPARATION

Teacher Background Knowledge

Fair Test

Students might think of the hidden-objects Activity 2.1 as a game like I Spy, or a contest in which they want to answer "yes" more times than their peers. Therefore, you might begin with a discussion of *fair* test in a science experiment. In this experiment, in order to make everyone's test close to the same, the class must agree on what it means to look for an object from their seats. It is possible for students to look in all directions by turning their bodies, leaning, among other things, but turning to look 360° defeats the purpose of the activity. Stress that students should turn their heads but not their bodies and that the purpose is not to be able to see everything but to figure out what they can and cannot see. **No one will be able to see everything**. Also caution students not to talk to one another, nor to reveal to their peers where something is when they have spotted it in the room. This activity is engaging, and the period of revealing its results is fascinating for students and sets up the conditions for seeing that will be used throughout the unit. Thus talking about fair test sets a tone that even as we investigate and enjoy what we are doing, we will follow the practices of science as closely as we can.

Discussion in IQWST

In each lesson, IQWST identifies different discussion types and states their purposes to support teachers in asking the most useful type of questions and knowing when and how to press students' responses. For example, in a brainstorming discussion, whose purpose is to elicit students' prior knowledge so that it can be built upon in the lesson, the only questions typically needed are those meant to clarify what a student is thinking ("Say a little more about that") or to probe reasoning behind a response ("What makes you say that?"). In a summarizing discussion, questions that probe what we know now and how we know it ("What evidence do we have for that?") are more useful. The IQWST Overview has several sections devoted to establishing norms for classroom discourse and to facilitating thoughtful discussion in whole-class or small-group settings. The Overview also offers generic questions that can be asked as written or can be tailored to particular discussions.

Conditions for Seeing

The four conditions may not be the only ones needed to see an object. For example, one might correctly argue that the object's size or the distance between the object and the eye impact whether people can see it or not. The four conditions used in the model in this unit are intended as a starting point, as they are necessary to address standards related to how light (waves) are reflected, absorbed, or transmitted through various materials. The four conditions are not intended to be memorized as a comprehensive list of the only possible conditions.

Wave-Particle Properties of Light

In the activities in this lesson, students might comment on the fact that the diameter of the spot on the wall gets bigger or smaller as a flashlight is moved closer to or farther from it. There is a relationship between the size of the spot and the distance from the wall because light actually travels outward from a source as a wave front. Think of a wave front as the surface of a balloon. As you blow into the balloon, its diameter expands, similar to the size of the circle of light on the wall. Light has the properties of both a wave and a particle. It is not important for students to explore the wave-particle dual properties of light. For the purpose of this unit, the path of light is treated as a straight line. This is called the ray model of light. The spot gets bigger or smaller as the flashlight gets nearer or farther from the wall because light spreads outward from a source. This will be further explored in Lesson 5 when students investigate shadows.

Analyzing Patterns

Data analysis is an important link between observations and claims. Much of the data analysis is qualitative in this unit. For example, it is a qualitative pattern that no student can see the object in the light box when the light flap was closed. It is important for students to learn that observations can be analyzed, and once patterns are found in those observations, the patterns can be used as evidence to support scientific ideas.

Common Student Ideas

The Role of Light and the Eye

Students might not recognize light as something that travels from a source to an object. They often do not recognize that light from an object needs to enter the eye for the object to be seen. Instead, they often think that the eye actively observes an object. As you read students' responses on their activity sheets, there is no need to challenge their responses in the first activity. The following activities in this lesson are designed to provide evidence that light travels in straight lines and must enter the eye.

Some students typically believe that the light needed to see an object is coming from the eye rather than to the eye. Cartoon characters and superheroes that shoot beams from their eyes contribute to this common idea. If students express this, ask them to close the flap of the light box back up and look for the object. Ask: "If the light is coming from your eye, why are you not able to see the object when the light box is completely closed?" With support, they should realize that the light must be coming from the outside of the light box rather than from their eye.

Light as an Entity

Students typically think of light as an entity that fills a space rather than something that moves between points. Sample probing questions aim to help students recognize that light is moving from one area (outside the light box) to another (into the light box) and from the object in the light box to their eyes.

Setup

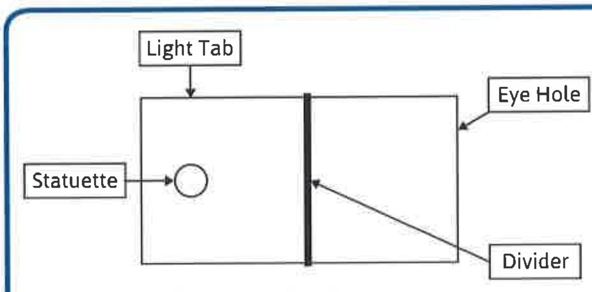
Activity 2.1

Before class, place six to eight easily identifiable objects around the room. Objects should be visible to some students but not others (with some students' view of the object being blocked). Place a stuffed animal, for example, on the floor next to a desk or table so that only students sitting to that side of the table can see it; students on the other side will not be able to do so. Place one object so that no students can see it. Place another so that all students can see it. The placement of objects so that most can be seen by only some students is necessary to establish key concepts about a straight, unblocked path for light to travel from an object to someone's eyes.

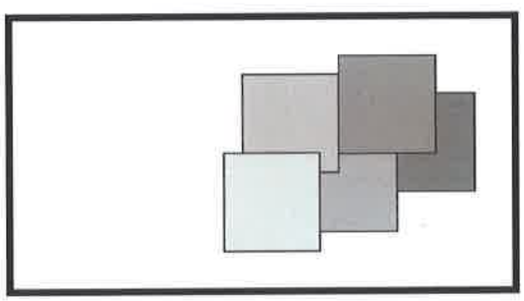
Activity 2.2

Prepare light boxes from shoeboxes with lids. If available, shoeboxes with hinged lids work well because the lids are less likely to fall off as students pass the light boxes around. On the short end of the shoebox, cut a small round hole (about the size of a penny) near the bottom. Label it eyehole. When the light box is held up to the eye, it should look completely dark inside. If there are places where light is coming in, cover them with construction paper or tape to prevent light from entering. On the long side of the box, away from the side where you cut the round hole, cut a square, 1.5" tab that can be folded up to create an opening and then folded down again to seal the opening. This will allow light to enter the box (when needed) by folding up the tab. After cutting, tape a piece of construction paper or cardboard over the tab to prevent light from entering the box (around the slits) when the tab is closed. Label this light tab.

The statuette should be small enough to fit standing up in the light box with the lid completely closed. All the light boxes should contain identical statuettes. They should be asymmetrical, so students cannot guess what the entire statuette looks like if they are able to view only one side of it. Statuettes should also be relatively easy for students to draw. Using glue or tape, fix the statuette in each light box in the same place and the same orientation, so that the light boxes are as close as possible to identical.



Light Box – View from Above



Prepare dividers—pieces of cardboard that fit into the light box—but do not put them in the light boxes until the appropriate point in the lesson. Each divider should have a 2in square hole cut in a different place so that the light boxes will provide different views of the statuette. Dividers can be taped to the sides of the boxes so that they remain upright and in position. See to the drawings and photograph images for reference. The time to add the dividers to the boxes will be specified in the lesson.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Refer to IQWST Overview.

LESSON 2

What Do We Need to See an Object?

TEACHING THE LESSON

Performance Expectation

Students will use, analyze, and interpret data from observations to explain that an object can or cannot be seen depending on whether light from the object enters the eye.

Overview

Activity 2.1

Compare observations to determine patterns in what is needed for people to see an object.

Activity 2.2

Investigate the ability to see an object, and use observations to establish four conditions that need to be met in order to see an object.

Building Coherence

This lesson provides evidence for four conditions (the existence of light, an object, an eye, and a straight path for light to travel between the object and the eye) necessary to answer questions on the DQB related to the question: How Does Light Allow Me to See?

Timeframe

2 Class Periods

Materials – Activity 2.1

For the Teacher

- (1) projector*
- PI: What Affects Sight?
- PI: What Hinders Sight?
- PI: What Can You See?
- (6–8) hidden objects*

For Each Student

- Activity Sheet 2.1

*This item is not included in the kit.

Introducing the Lesson

If you did any regrouping of students' questions on the DQB, explain that and indicate that students will now be addressing the question: How Does Light Allow Me to See?

Have students close their eyes and think about how they would know there is such a thing as light if they were unable to see. *(People are aware of light primarily because they can see, so it makes sense to begin investigating light by investigating how people see and what role light plays in seeing.)*

Discussion – Brainstorming

Purpose

Elicit initial ideas about how people see.

Suggested Prompts

- What do people need to be able to see an object? *(list ideas)*
- What could happen that would keep someone from seeing? *(too dark, something blocks their vision, eyes are closed, blindness)*

Show PI: What Affects Sight? and have students respond to Question #1 on Activity Sheet 2.1. Encourage students not worry if they are unsure, stating that sharing their initial ideas is important to all learning. When students finish, show PI: What Hinders Sight? and have them write responses.

Activity 2.1 – Probing Ideas: Seeing Objects around the Room

Place objects as indicated in Setup. Instruct students that they cannot move in their seats other than turning their heads. The goal is not for everyone to be able to see everything, and in fact, some objects are placed so that they are supposed to be visible only to some students. When they finish, they will be looking for patterns in what people can and cannot see.

Name objects one at a time. Students write the name of the object in the table on Activity Sheet 2.1 and then put a mark in the box for each object they can see.

Show PI: What Can You See? Review the list of objects one at a time. As each is named, students raise hands if they could see the object. Students should look at raised hands and begin to think about what students who could see an object have in common and how they differ from people who could not see it. If time is short and you hurry through some items on the list, take the most time to discuss objects that could be seen by some students but not all. Once students have had a chance to observe who could see the various objects, have them talk in small groups. Then have the whole group discuss patterns and what conclusions they can draw about what is necessary to see an object.

Discussion – Synthesizing

Purpose

Compare data, note patterns, and establish what is needed in order to see an object.

Suggested Prompts

- What patterns did you notice that are related to who could and could not see different objects?
    - o What did the position of objects you could see have in common?
    - o What did the position of objects you could not see have in common?
    - o What did all the people who could see a particular object have in common?
    - o What did all the people who could not see an object have in common?
- What factors affect whether you can see an object or not?

Some students can see an object, while others cannot because of their position in the room. Students may begin to discuss the idea of light's path, which will be more fully developed in Activity 2.2. Students will use Activity Sheet 2.1 again at the end of the next activity.

Materials – Activity 2.2

For the Teacher
- (1) string or ruler
- (1) flashlight
- PI: What Affects Sight?
- PI: What Hinders Sight?

For Each Group
- completed light box* (described in Setup)

For Each Student
- Activity Sheet 2.1
- Activity Sheet 2.2
- Reading 2.2

*This item is not included in the kit.

Activity 2.2 – Determining the Conditions for Sight – The Light Box

In the remainder of this lesson, you will be working with students to generate a list of conditions that need to be met to see an object: an eye, an object, light, and a straight, unblocked path between the object and eye.

Hold a statuette like the one in the light boxes in your hand so students can see it. Ask: "Based on the evidence you have collected so far, what is needed in order to see this object?" *(List ideas students suggest using evidence from Activity 2.1.)*

Provide groups with one shoebox per group. Explain that students are not to look in or open the box until you instruct them to do so. Explain that each group has a light box with an object inside. Students should take turns looking through the eyepiece and record on Activity Sheet 2.2 what they see. *(They will not be able to see the object because it is completely dark inside the light boxes.)* After students have had time to record observations, have them leave the lid closed but open the flap on the side of the light box. They should look again through the eyepiece and describe what they see.

Discussion – Making Sense

Purpose

Compare observations and interpret data to determine what is needed to see *(If light, an eye, an object, or straight, unblocked path between the eye and the object are not already on the list of things needed to be able to see, add them as they come up in discussion.)*

Suggested Prompts

- How was what you observed different when the flap was open compared to when it was closed? *(Students could see and describe the object with the flap open but could not see it with the flap closed.)*
- Why were your observations different? *(With the flap closed, light could not get into the light box, but with it open, light could enter allowing them to see.)*
- Where is the light coming from? *(It comes from outside the box, the lights in the room, or the sun.)*
- Where does that light end up? *(It ends up in the box, on the object, or in the eyes.)*
- How does the light get there? *(This question may cause some confusion. Answers will vary.)*

The Light Box with Divider

Add a divider to each light box. Each group should get a different divider; each should block a different portion of the object. Have students look through the eyepiece again and sketch on their activity sheets what they see. Make sure they sketch only what they see, not what they think might be there. When students finish their sketches, they should compare results with another group without looking inside one another's boxes.

Suggested Prompts

- How was the sketch you made similar or different to the one made by the other group? *(The sketches show different parts of the object. They may also say that it is the same object. Encourage them to describe what they see, rather than making inferences about what they cannot see.)*
- Why are the sketches different? *(They cannot see around the divider, or it blocks their view of part of the object.)*
- Why can you not see around a divider?

If no one raises the idea, suggest that because light travels in straight lines, they see different parts of the object when the divider is in different positions. Ask students for other examples of where a straight, unblocked path might be needed. Answers might include shooting a gun, playing billiards, or playing a video game. The aim is to further establish that there must be an unblocked, straight path along which light moves to the eye. After answers have been shared, add "unblocked, straight path between the object and eye" to the list on the board.

To further develop the idea of light traveling in straight lines, guide students through the following exercise by modeling the procedure. Have students hold their left hands about four inches in front of their left eyes. Have them close their right eye and keep their left eye open. Instruct them to move their right index finger across from the right until they appear to be just behind their left hands. Have students open their right eye and close their left eye.

- What happened when you switched back and forth between eyes? *(It is important that students be able to describe their finger disappearing and reappearing.)*

With a string or straight edge and a volunteer, show students how the path from the finger to the eye is blocked in one situation and not blocked in the other. The path between the left eye and finger was blocked, so they could not see the finger, while the path between the right eye and the finger was not, so they could see it. An object can only be seen if the path between that object and the eye is not blocked by something else, so that light can travel between the two.

The Path

Dim the lights. Turn on a flashlight and shine it on the wall where students can see it. Ask the following questions to prompt discussion.

- Where is the light coming from?
- Where is the light going?
- How did it get there?

Begin moving the flashlight around slowly. Continue the questioning.

- Why is the light on the wall moving the same way the flashlight is moved?
- Why does moving the flashlight cause the light spot to move?

Turn the flashlight off, point it in a new direction, and ask: "Where will the light appear on the wall when the flashlight is turned on? Explain your idea." Turn on the flashlight to show that the students' prediction was (roughly) correct. It is important that students recognize the pattern—that the spot moves when the flashlight moves because light always moves in a straight line away from the flashlight.

At this point, the list on the board should mention all four conditions that need to be met in order to see an object. Ask students the following: Imagine you look out the door right now, just as a friend walks by and waves to you. Using the conditions we have just listed, how would you explain how you can see your friend? What evidence did you discover, or what activity did you do, to support the claim that an eye, an object, light, and an unblocked path are all necessary to be able to see?

- Insert the following on the Scientific Principles list: Four conditions need to be met for an object to be seen—an object, an eye, a source of light, and a direct, unblocked path between the object and the eye (using the students' own language).
- In the last two activities, students used data as evidence to support their ideas. Science is about investigating and making claims that can be supported. This support comes in the form of data derived from observations or measurements and can be used as evidence.
- When students get an idea they want others to concur, encourage them to look for data that will support the idea. For example, if they think an unblocked path is important to being able to see an object, they might talk about the data collected in the last activity that showed only people with nothing blocking their line of sight to an object could see it. That would be evidence.

Return to Activity Sheet 2.1 and PI: What Affects Sight? In groups, give students a couple of minutes to identify the reasons that the girl can see the tree. Next, have students use the list on the board to think again about this situation. How are the four conditions present or not present? When finished, choose one group to report their ideas. Ask for other groups to comment on any differences they had. *(The tree could be seen because the four conditions for seeing were all met: eyes [on the girl], an object to see [the tree], light [from the sun], and a straight path for the light [from the tree to the girl].)*

Use PI: What Hinders Sight? Have students use the list to think again about this situation. What conditions might help explain why the girl cannot see the car? Have a group report their ideas and encourage other groups to comment. Encourage students to use terminology from the list. *(There is no unblocked path in this situation.)*

At the beginning of Lesson 2, students likely explained that the girl could not see the car because of her position or because the wall was blocking her view. These answers imply that the eye plays an active role in seeing objects. In IQWST, it is important that students learn to articulate their ideas. At this point, students should explain how the girl sees the wall using the scientific idea that because the light's path from the wall to her eye is unblocked, she can see the wall, but because the light's path from the car to her eye is blocked by the wall, she cannot see the car.

Wrapping Up the Lesson

Discussion – Synthesizing

Purpose

Address the Driving Question or other questions on the DQB.

Suggested Prompts

- What questions from the DQB are we now able to answer?
- What questions can we add to this part of the DQB?
- How does what we learned help us think about the Driving Question: Can I Believe My Eyes? *(If students struggle to respond to this question, use the following focused prompts.)*
  - o Imagine you are in a room with no light in it . . . would you believe what your eyes are telling you—that there is nothing in the room? Explain your ideas.
  - o Imagine that you are facing a brick wall . . . would you believe what your eyes are telling you—that there is nothing but a wall in front of you? Explain your ideas.

Have students add relevant information and additional questions to the Driving Question Notes near the beginning of the student book.

Introducing Reading 2.2 – Picture This!

The reading explores how it is that people see something that is not really there, such as an image on a television. TV, film images, and art are used as examples to explore how it is that pixilation produces images and enable students to compare this process with how people see objects. To introduce the reading, the Getting Ready section can be done in class, as will often be the case across IQWST. This type of reading extends classroom learning, helping students see the relevance of science to life outside of science class. Sometimes the contexts are unfamiliar (e.g., solar-powered cars) and are used to pique students' interest. IQWST aims to have students understand that science learning is not just for science class—that science applies to events in their everyday experiences and to new opportunities for them in the future.

LESSON 3

Constructing Models of How People See

PREPARATION

Teacher Background Knowledge

The Scientific Practice of Developing and Using Models

A scientific model can be thought of as a representation (or set of rules or relationships) that scientists use to illustrate, explain, and predict phenomena. Scientific models are not all-inclusive; rather, they highlight key components, characteristics of those components, and relationships among the components. (See IQWST Overview for a discussion of models and modeling, as "Using and Developing Models" is one of eight Science and Engineering Practices required by the Next Generation Science Standards.) Models are useful in every scientific discipline. The modeling practices in which students engage in this unit will be revisited and built upon in IQWST units that follow.

Consensus Models

The consensus model of seeing will be revised throughout this unit. At this point, students do not need to think about revision because they have not completed experiments that suggest the need for a revised model. However, some students may anticipate the need to revise the model if they have mentioned transparent objects. In Learning Set 2, students will revise their ideas about the way light interacts with transparent, translucent, and opaque objects. In Learning Set 3, they will revise their idea of the nature of light to include color. In Learning Set 4, the model will be revised to include forms of nonvisible light.

This consensus model, like any model, has certain features, strengths, and weaknesses.

- Features—The consensus model represents the nature of light and how people see. It specifically represents light as rays that propagate outward from the light source, interact with objects and materials (by bouncing off of them), and is detected by the eyes (as it enters and is absorbed by the eyes). There are multiple arrows on each ray to imply that light travels continuously from the light source.
- Strengths—It helps predict and explain simple examples of seeing (ones that involve a single light source, a single object that scatters light, and an eye with a direct path between the object and the eye).
- Weaknesses—The consensus model is two-dimensional and not three-dimensional (like the physical world). It is not a dynamic representation, though scientists know that light travels over time through space. It is a simplified model that includes only one object, one light source, and an eye. It does not explain light as a wave phenomenon. It does not explain how light interacts with objects or the properties of color. Light is actually emitted in all directions from each point of the light source.

The Ray Representation of Light

Straight lines with arrows are used to represent the path of light, with arrows showing the direction in which light is traveling and multiple arrows showing that light travels continuously from the light source in all directions. This way of thinking about light is useful because it describes the path light travels from one place to another and why there are places light cannot reach (e.g., when light is blocked by a tree or building). This representation also has two limitations that do not need to be discussed explicitly with the students:

- Light travels in all directions in three-dimensional space. Two-dimensional diagrams can only depict rays on the plane of the paper.
- Light is emitted in all directions from each point of a light source. Rays are shown to emanate in all directions from the light source in general, not from each point in the light source.

Common Student Ideas

Models

Students often think that a model needs to look like the thing it represents. They are more likely to resonate with the model car example than their drawings. Help students understand that there are many types of models (diagrams, equations, and computer simulations, in addition to physical or material models) and that they all serve to help make sense of scientific ideas and to communicate those ideas. Emphasize that models can help people understand, explain, and predict and that their drawings can help them do that.

Research suggests that when diagrams include both real and symbolized entities, students may misinterpret what is real and what is symbolized. In addition, research suggests that students may not be familiar with conventions that allow one to show invisible entities in a diagram; these conventions need to be taught explicitly. Without explicit discussion of the status of rays, students may interpret them as visible and/or material entities.

Students may also interpret the rays in diagrams as a person's vision. It is important to be clear that the arrows are a convention that will be used for representing light rays. If a student draws light rays from the eye to an object, ask the student what the arrow represents. If they respond that it represents a person's vision, ask them if the rays exist even when the person's eyes are closed.

How Light Travels

A common student conception is that light does not continuously move but instead comes from a source and either fills a room or sits on the walls and ceiling of a room. Students do not think of light as continuously moving away from a source and bouncing off the walls into their eyes. Reading 3.1 introduces students to the speed of light, which explains why light appears to fill a room instantly when a light is turned on. Refer students back to the light box activity and ask them to explain where the light came from when the light flap was opened on the light box. Then ask them what happens to the light inside the light box when they close the flap again. The concept to stress is that the light moves all the time, but it can only move into the light box when its path is not blocked.

Setup

Activity 3.1

Cut two sheets of paper in half. On each half, write one of the conditions needed to see an object—light source, object, eye, and straight path between the eye and the object. Post the sheets on or next to the DQB first quadrant.

Activity 3.2

Students will construct models using materials you make available. A dollar store is a great source for materials. In addition, students may realize through the course of working on their models that they have something from home that would enhance their model. Encourage them to bring these items in the following day. In preparing materials, keep in mind the four things that students are going to need to model and choose objects they might be likely to be able to use. Do not suggest what the items could represent. Simply supply a table of items and let students choose how to represent the components of the model. They will need to model a light source, an eye, an object to see, and a way to show that the light shines on the object and then to the eye. Ideas include yarn and a variety of other craft materials (to show path of light or that light travels), clay or balls (which can be used for the light source, the object, or the eye), animals or dolls (for the object or the eye), markers, and poster board or construction paper (to be cut to represent objects or to use as a base for the group's model).

⚠ Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

This lesson has built-in differentiation in its use of different types of models to represent a shared phenomenon students will experience together. The physical, 3-D modeling activity (3.1) allows students to create models in any way they choose. Some will be very creative, and some will use only objects that look like the thing they are trying to represent. For example, some students will use a ball as an eye, and some students will make the ball look like an eye. Some will use a ball as a light source, and some will sculpt clay to look like a light bulb. You will notice that some students actively engage in this activity and some stay more on the sidelines. Often those that do not readily engage will be much more comfortable with the following activity, in which they are given the components to create a 2-D model. Support all students in moving back and forth to connect the actual phenomena (light travels from a source, to an object, to their eye, so that they can see an object), the physical models as one kind of representation, and the drawings as another kind of representation. Each of the models that they develop can be used to explain how people see an object, even though they are very different ways of representing the phenomenon. Students will develop and use different types of models throughout IQWST to explain and predict phenomena, as called for in NGSS, so helping them to understand modeling as a scientific practice, its purposes in science, and that different models can represent the same phenomenon are all important aspects of these activities. The varied ways in which these ideas are approached are designed to help *all* students understand this practice, as well as the content they are using models to learn.

Lesson 3

Constructing Models of How People See

TEACHING THE LESSON

Performance Expectation

Students will develop and use models to explain the role that light plays in how people see objects.

Overview

Activity 3.1

Create 3-D models of the role light plays in seeing, and share group models as a class.

Activity 3.2

Create 2-D consensus models of the role of light in seeing, and use the model to answer questions about light and its behavior.

Building Coherence

In Lesson 2, students developed a class list of conditions that need to exist for an object to be seen. In Lesson 3, students use that list to develop and use models to demonstrate their understanding of how people see.

Timeframe

2 Class Periods

Materials – Introduction

For Each Group

- (1) color comic strip*
- (1) magnifying glass

*This item is not included in the kit.

Introducing the Lesson

Reading Follow Up

Distribute one color comic strip and one magnifying glass to each group of students. Have students use the magnifying glasses to observe the comic strips and talk about what they see with their group members. Ask: "How does what you see with the magnifying glass relate to what you read about in the last reading?" *(The dots they see in the comic strip under the magnifying glass are like the pixels referred to in the reading.)*

- Explain how, even though the words and characters in the comic strip are just a collection of dots, you see words and characters, not dots. *(The dots are too small to see individually without the magnifying glass, but their brains put them together somehow to see it as a character.)*
- In the reading, you learned that a TV combines two conditions needed for sight into one—the pixels make up both the light source and the object. What were the other two conditions for being able to see? *(The other two conditions are an eye and an unblocked path between eye and object.)*

Students will use the ideas they have evidence for about how people see to construct models of how light works.

Discussion – Brainstorming

Purpose

Express initial understanding of models.

Suggested Prompts

- What do you think of when you hear the word *model* in science?
- What are some different examples of models?
- How is a map different from a globe? How is it different from a computer simulation of Earth?
- What is common for a map, a globe, and computer simulation of Earth? *(They can all show some of the same things but in different ways.)*
- Why do we use different models to represent the same thing? *(Each one has advantages and disadvantages. We use the model that best suits our needs at a given time. When our needs change, we may use a different model.)*

Students will now use different materials to build a model of how people see. Talk about the following ideas:

- The purpose of building the model is to help each other think about how a person sees and to share our best ideas about what is happening.
- There is no one right or best model. Different models have different advantages, and no model is perfect. Scientists revise models when they figure out ways to make them better. Creating models takes creativity and imagination for putting something together in a new kind of way.
- Just like different models represent Earth, different models could represent how we see, but all of them need to be consistent with evidence—they need to represent the ideas learned from the investigations. An important aspect of a good scientific model is that it is consistent, meaning it can account for all the existing evidence. *(Use the terms consistency and consistent to help students begin to recognize this as an important aspect of models.)*
- We have evidence of four conditions that need to be represented in the model—a light source, an object, an eye, and an unblocked path between the eye and the object.
- Explain that data may be gathered later about other conditions, but for now, these four conditions, based on the evidence, need to be part of the model.

You might choose to make a chart about the features of models. Record important ideas about modeling as they come up throughout the lesson. Use the chart to remind students about what they have learned. So far, students know that models do not need to look exactly like the thing they represent, but they do need to be consistent with evidence.

Materials – Activity 3.1

For the Teacher
- (2) sheets of paper*
- (1) small light bulb
- (1) small light bulb base
- (1) D-cell battery holder with wires
- (1) D-cell battery
- modeling clay
- (6–8) toy cars
- (1) digital camera* (for photographing group models)

For Each Group
- modeling clay
- small toy cars
- miscellaneous materials* (for students to use to build models)
- rulers*
- paper*
- scissors*
- pens*
- tape*

For Each Student
- Activity Sheet 3.1
- Reading 3.1

*This item is not included in the kit.

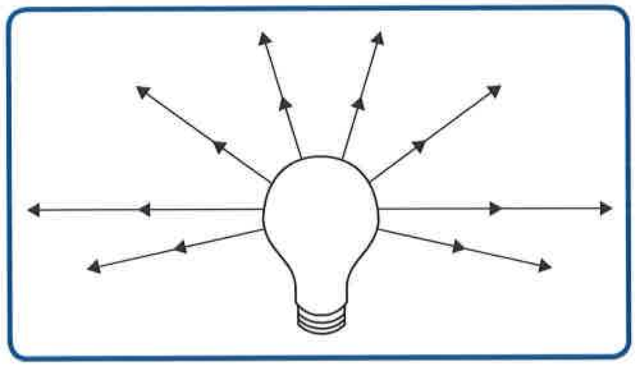
Activity 3.1 – Preparing to Develop Models

In a place that all students can see, turn on the small, uncovered light bulb. (Note: This light source will be referred to as a bulb throughout the lesson.) Ask the following questions.

- How would you describe the behavior of the light coming out of this bulb? *(Light is traveling away from or out of the bulb in straight lines in all except for the bottom or base, and that light is being continuously emitted.)*
- What ideas about light did the flashlight in Lesson 2 provide evidence of? *(Light travels in a straight line.)*
- How is the light coming out of the bulb different from light coming out of the flash-light? *(Light from the flashlight went in more or less one direction, but light from the bulb goes in almost all directions.)*
- How would you describe the way in which light is coming out of the bulb? Continuously, like a stream of water, or a bit at a time? *(It is continuously emitted.)*

Talk with Students about Models
- Students have some ideas to help explain how light from a bulb behaves. When we use words, drawings, objects, equations, or computers to illustrate or explain ideas about how a phenomenon works, it is called a model.

- There are different ways to illustrate or explain things, and so different models have different advantages and limitations in terms of how they show ideas. Show two different models, and ask students to talk about how they show different ideas more or less clearly.
- Draw on the board a two-dimensional picture of the light bulb with light rays coming out of it in multiple directions.



Next, show students an example of a physical 3-D model of light shining from a light bulb. Use the modeling clay to represent the light bulb and position small toy cars coming out in multiple directions (see picture). The cars represent the light leaving the light bulb in all directions. If available, it may be helpful to put the model on a projector. When you project the model, note that the projection is two-dimensional while the model was three-dimensional. Ask students to relate what they see on the screen to the physical model.

Give students a minute or two to record their ideas on the first part of their activity sheet. Explain that light comes out of a bulb continuously in straight lines in all directions.

- How do these two models do a better or worse job of communicating those ideas? *(Students should identify the following: The drawing shows light coming out in more than one direction but not in three dimensions; it shows light coming out continuously with continuous lines and multiple arrows; it shows that light travels in straight lines but does not show that it is moving. The physical model also shows light coming out in more than one direction, but not in three dimensions; it does not show light coming out continuously, as there is only one car for each light ray; and it can show light's movement in straight lines.)*
- If students struggle to respond to all or part of this question, ask them to evaluate the models in relation to specific ideas. For example, we said that light is coming out of the bulb in all directions. How well does the drawing show this idea? How well does the physical model show this idea?
- Since neither model shows that light spreads out in all directions, how might we create a model that does a good job of showing this idea? *(Answers will vary; students might suggest sticking toothpicks in the ball to represent light rays, or fixing lengths of yarn or string to a bulb, or crumpling yellow paper around the model bulb.)*

As students answer this question, a Think-Pair-Share cooperative learning structure might be useful for eliciting students' ideas. During the Think, have students reflect on the question silently and individually. You may want them to write their ideas in notebooks. During the Pair, have students discuss their answers with a partner. Let students know that each pair will be sharing with the class the ideas they have generated with the rest of the class. During the Share, have pairs report their ideas to the class.

Creating Physical Models of How People See

Now that students have had a chance to look at different models, they are going to build their own physical models of how light helps people see based on the investigations and the evidence.

Refer to the Driving Question Board and the four conditions the class has identified that are necessary to see an object. Students will need to include the four conditions in their models. They will need to make decisions about how to show them in a way that will explain how light helps people see.

Show students the materials available. Groups should decide how they will represent the conditions in a model using the materials available and how they will work together to build a model. The process of identifying important ideas, thinking and talking about how you will represent them, and creating the model is called model construction.

Circulate and ask questions about what students are trying to accomplish. Remind them that the purpose of this activity is to construct the models to demonstrate their understanding (to others) of how they are able to see objects based on the evidence from Lesson 2.

Students require scaffolding when deciding which characteristics of things need to be represented in a model. It will not be apparent at the start if the colors, texture, form, and location of these things are important in explaining how we see. A model should be simple and include only the relevant characteristics to the phenomenon being modeled.

Students need to complete the activity sheet, including a description of the strengths of their model—the ways in which it does a good job of accounting for the data they have collected and the ideas they have developed—and its weaknesses, like any ideas that it does not show as well, or evidence it might not account for.

The purpose of building the model is to provide students an opportunity to represent in a nonverbal manner their explanation of how people see. In this process, they clarify their ideas for themselves. Students' models should show light as follows: (a) in constant motion, (b) traveling in straight lines away from the light source in a variety of directions, (c) traveling in straight lines from the object being seen, and (d) entering the eye. Students' written explanations should include the evidence supporting how the model represents the process of seeing.

You might create an assessment rubric to share with students, or co-create a checklist for evaluating models that you will use and build on as students learn more about modeling.

When groups have finished, have groups briefly share their models with the class. Let them know that they are using models in a way that scientists do—to communicate ideas to others. Communicating will help them clarify their own ideas, learn from others, and practice expressing their ideas.

Suggested Prompts

- How are the four conditions needed for sight incorporated in your model? *(The model should include the light source, the object, an eye, as well as a direct path between the object and the eye.)*
- What are some advantages and disadvantages of the different models? What ideas do the different models show well or less well?
    - The flashlight provided evidence of the idea that light travels in straight lines. How does your model show that idea?
    - The light bulb provided evidence for the idea that light travels out in all directions. How does your model show that idea?
    - The flashlight provided evidence of the idea that light moves from one place to another. How does your model show that light moves?
- The object hunt activity in Lesson 2 provided evidence of the idea that objects can be seen from different locations. How does your model show why you can see the object from several different locations?
- Which parts of your model represent each condition of how people see?

Take photographs of the models. Post them on the DQB or elsewhere in the room along with students' written explanations.

Introducing Reading 3.1 – Modeling

Give students a minute or two to complete the Getting Ready section. For each statement, ask students to raise their hands if they agree or disagree. Have one student with a raised hand and one without talk about why they agreed or disagreed with the statement. It is important that students articulate their reasoning. Follow up the reading in next class period.

Materials – Activity 3.2

For the Teacher

- Use the icons of the eye and light source; prepare two copies of the eye and icon of a triangle*
- (1) object large enough to be seen by the entire class*
- (1) small light bulb and small light bulb base
- (1) D-cell battery holder with wires and D-cell battery
- poster paper*
- copies of Icons for Written Models*

For Each Group

- copies of Icons for Written Models*
- scissors*
- tape or glue*
- sheet of paper or cardstock*

For Each Student

- Activity Sheet 3.1
- Activity Sheet 3.2
- Reading 3.2

*This item is not included in the kit.

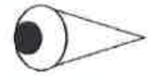
Activity 3.2 – Building the Consensus Model

Reading Follow Up

Have students revisit the statements in the Getting Ready section. Ask: "What changed the way you responded to one of the statements? What in the reading led you to think differently about the statement?" (*It is important that students recognize that [1] models can change, [2] there can be more than one way to model a phenomenon, and [3] all models have advantages and disadvantages. If students are struggling with these ideas, have them revisit specific sections of the reading, looking for support for each of these ideas one at a time.)*

To spark discussion, ask: "What did you think were the best parts of other students' models from the last lesson? What made those parts strong?" *(Answers will vary; it is important that students support their ideas about what was good in relation to the features of models—that they account for important evidence and ideas and communicate ideas and explanations clearly to others without extraneous information.)*

Since physical models are harder to keep and work with, students will now translate their physical models into drawings. Have students use a set of common symbols to represent the four conditions they have established so far. Keep in mind that these symbols are not the only ones that could be used and that they represent a range of things. For example, we could use a light bulb instead of a sun to represent the light source. The coffee cup represents any object that could be seen that is not a light source. Use the symbols in the chart to represent the parts of the model.

Light Source	
Eyes	
Object	
Light Path	→

Give each group a copy of Icons for Written Models and a piece of paper or cardstock. Instruct each group to cut out the symbols and glue or tape the symbols to the cardstock to represent the model they created. (They may need to draw in more lines for the light path.) Give groups time to work and as much guidance as needed, especially revisiting the probing questions (such as "Does your model show X?")

Have students post completed models without their names on them, so everyone can discuss the ideas and not the people who made them.

Discussion – Synthesizing and Pressing for Understanding

Purpose

Evaluate models and refine understanding of what the models must do.

Suggested Prompts

- Ask: "How do the different models show the ideas for explaining how light helps people see based on the evidence we have so far?" Evaluation involves comparing to think about what ideas are shown and which are not, and how different models show particular ideas more or less clearly.
- Ask students questions about individual models and what they show or do not show.
- Ask: "What patterns do you see in how different groups constructed their models?"

  Always refer to the evidence that supports a particular part of a model—if some aspect of a model cannot be supported with evidence the class has so far, it may have to be left out, even if it makes sense.

Once students have talked about what ideas are important and how they can be clearly represented, create one model with which everyone can agree. This kind of model is called a consensus model. As students agree on parts of the model and ways to represent them, use their ideas to construct a consensus model. It is important that the final drawn model looks similar to the Sample Consensus Model, because the model will be used and modified repeatedly throughout the unit.

Discussion – Summarizing

Purpose

Refine the consensus model.

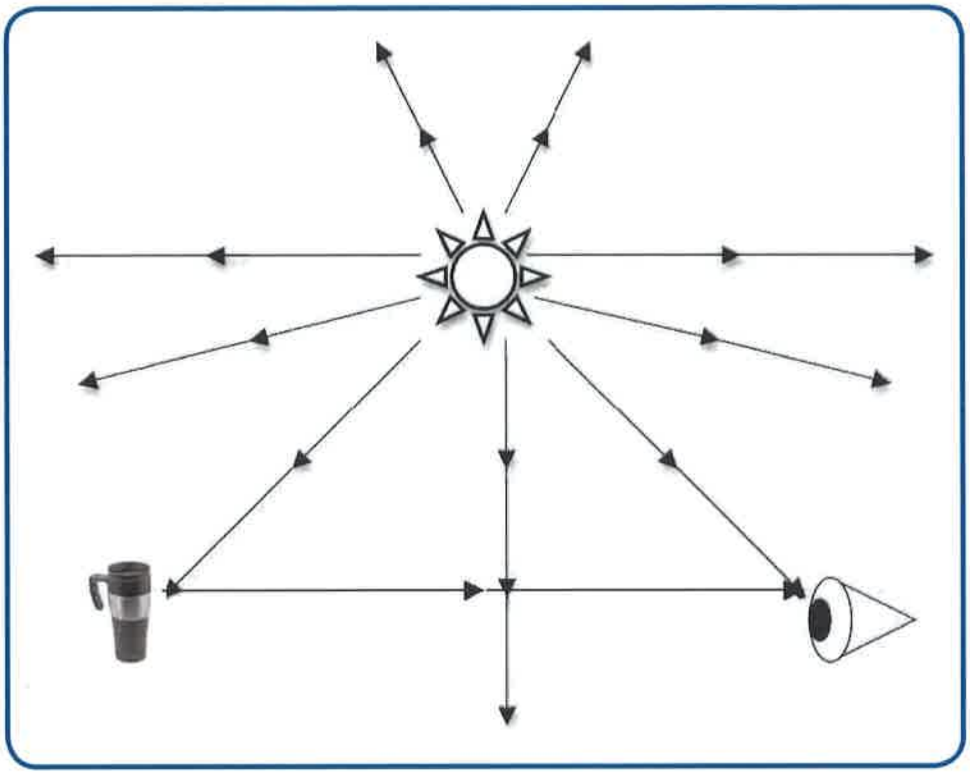
Suggested Prompts

- What do all the models have in common? What are their key components?
- What are differences that you notice between the models? What evidence would support one approach or the other? How should we represent that in our consensus model?
- What ideas do multiple models show? How should we represent that in our consensus model?
- Does anyone disagree with any part of the consensus model so far? How do you think it should be changed? What evidence supports that idea?
- We talked about models having tradeoffs—different models show different ideas more or less clearly. How does our drawn model show important ideas more or less clearly than our physical model?
- How does the consensus model help to explain the first question on the Driving Question Board? It is important that the consensus model represent several key ideas that are based on gathered evidence summarized in the table.

IDEAS	EVIDENCE
Light is continuously emitted in all directions from a light source and travels in straight lines.	uncovered light bulb, flashlight
Some light travels directly to the eye if there is an unblocked path.	light box, "disappearing" finger
Some light bounces off an object and travels to the eye, if there is an unblocked path.	light boxes

Note: In the Sample Consensus Model, light is continuously emitted from the light source. The light source has arrows coming out in all directions. The multiple arrowheads on each line show that light is moving continuously outward from the light source. Some of that light reaches the object. Some of the light that reaches the object bounces off the object and enters the eye. This model can help explain how people see the object. The model also shows light from the light source entering your eyes directly. That is why we can see both the object and the light source. We can see each other, and we can all see the sun or the overhead lights in the classroom.

Sample Consensus Model



Using the Consensus Model

Ask: "How could you use the consensus model to explain why you cannot see the teacher in the other room?" *(There is no path for light to travel between the object [person] and the eye because it is blocked by walls.)* "Now that we have this model to explain how light helps people see, what do you still need or want to know?" *(Students may ask for more details about what happens to light when it reaches the object and how it bounces into their eyes. Respond with a statement like the following: You are practicing an important modeling skill using the model to ask new questions. Your questions will help direct our next investigations into how light interacts with objects.)*

Discussion – Summarizing

Purpose

Bring together ideas about modeling as a scientific practice and about the model itself.

Suggested Prompts

- How were models used to help think about and understand how people see?
- How does the consensus model relate to a camera taking a picture? *(A camera taking a picture operates in much the same way as my eye does. There is light that bounces off objects and then enters the camera just as it would enter my eye.)*

- When it is dark at night, you can still see some things a little bit. How does the consensus model help explain this situation? *(Because it is almost never completely dark, there is almost always some light from stars or buildings that is bounced off objects and enters the eye.)*
- How does our model help us explain how we see things in a television even though the things are not there? *(The television generates light in certain ways that make it look like the object is in the television. The eye detects the light from the television and thinks that the object is there even though it is not, because the light generated looks similar to the light that might have been bounced off the objects had they been there.)*

Wrapping Up the Lesson

- Models can be used to illustrate and explain what happens in a situation; they can be used to predict what will happen, and they can be used to communicate your thinking to others.
- Students should use the consensus model of light to predict what happens in some new situations. So far, they have used models in two different ways: first, to help communicate their ideas to each other, and second, to explain new phenomena.

Attach one of each of the icons to the board, as shown in shown in section 1 of the following figure.

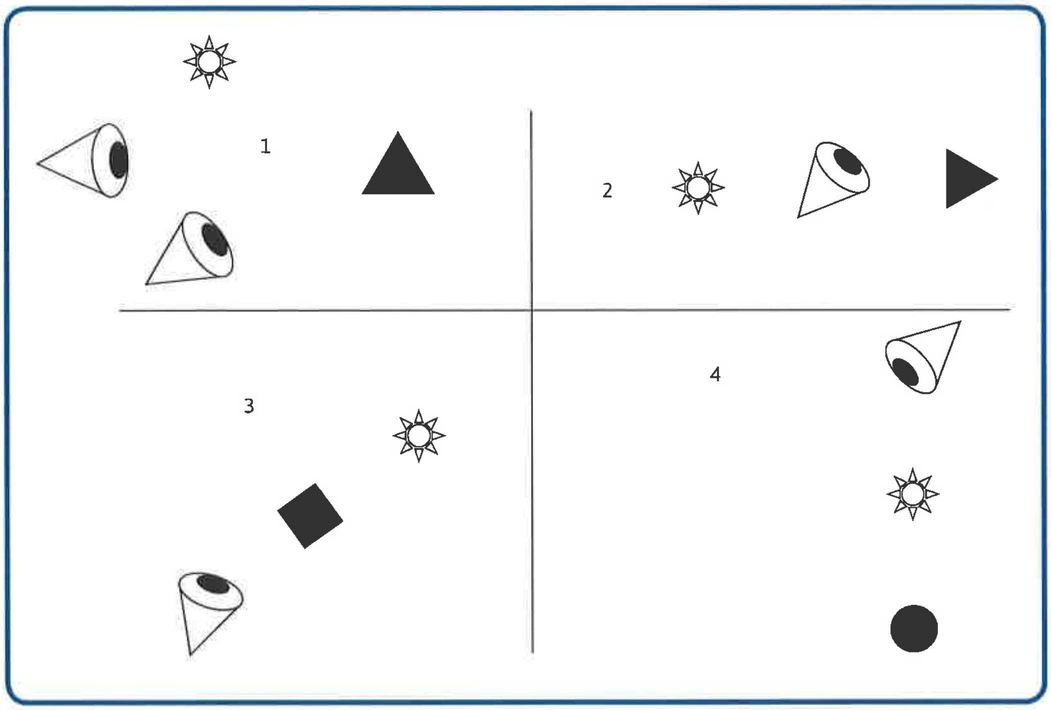
- Will the person (the eye) be able to see the triangle? Why?

Have a student come to the board and add arrows to describe the student's response. Add another eye in a different position (the dashed eye in section 1 of the following figure).

- Will this person see the same thing as the first one? What will they see and why? Have another student add arrows to the diagram to explain the student's response. Rearrange the icons again, as shown in section 2 of the following figure.
- Will this person be able to see the triangle? Why?

Have another student come to the board and explain the student's response. Students can use the object and light source to demonstrate the arrangement.

- Does everyone agree with this arrangement? If not, show us how you would arrange it differently based on the diagram. Repeat this sequence with the arrangements shown in sections 3 and 4 of the following figure.



This activity can be used as an assessment to determine whether students still have the alternative conception that sight involves light leaving the eye and to check their understanding of the consensus model. Another possible assessment is to show the consensus model and ask the students to use the model to explain why, if the object had eyes, it could see the eye as well.

Introducing Reading 3.2 – Faster than a Speeding Bullet

One of the reasons people have difficulty understanding that light is moving all the time is because light moves so fast, it seems to go from source to object to their eyes instantaneously. When you turn on the lights in a room, the room seems to brighten immediately with no lag time. Light is the fastest moving thing known to scientists. To help students think about how fast different things move, have them complete the Getting Ready section in class. Have a few students share their ideas and on what they are basing their ideas. (Students may know information about some of these, so it is important for them to be able to share.)
Icons for Written Models