Unit 6.1 Light and Matter

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Essential Questions

Why do we sometimes see different things when looking at the same object?

- Lesson 1: How can something act like a mirror and a window at the same time?
- Lesson 2: What happens if we change the light?
- Lesson 3: What happens when light shines on the one-way mirror?
- Lesson 4: How do similar amounts of light transmit through and reflect off the one-way mirror?
- Lesson 5: How do light and the one-way mirror interact to cause the one-way mirror phenomenon?
- Lesson 6: Why does the music student not see the teacher?
- Lesson 7: Why do the music student and the teacher see the music student but the music student can't see the teacher?
- Lesson 8: Why do we sometimes see different things when looking at the same object?

Big Ideas

Unit Summary and Storyline

How does a one-way mirror work? Though most everyone knows that one-way mirrors exist, having students model how they work turns out to be a very effective way to develop their thinking about how visible light travels and how we see images. Initial student models in this 6th grade light and matter science unit reveal a wide variety of ideas and explanations that motivate the unit investigations that help students figure out what is going on and lead them to a deeper understanding of the world around them.

A video of an experience with a one-way mirror, gets students to organize and write down their initial ideas and then they dig in to test those ideas and figure out what is really happening. Students build a scaled box model of what they saw in the video to test out their ideas. Using two boxes combined together with a one-way mirror in between the two, students vary the presence of light in the two boxes to figure out how a one-way mirror works and improve their initial models so they accurately explain how light is reflected and transmitted through materials and the basics of how these behaviors of light result in the images we see.

As the first 6th grade science unit in the OpenSciEd program, during the course of this unit, students also develop the foundation for classroom norms for collaboration that will be important across the whole program while answering several questions.

The anchoring phenomenon for this unit is a material that acts as a mirror from one side and a window from the other side. This material, called one-way mirror, is commonly used in exterior building windows, interrogation rooms, research and medical offices, and exterior house windows. One-way mirrors are made by placing a layer of one-way mirror film onto transparent glass or plastic. While a regular mirror includes a thick layer of reflective material layered onto glass (which makes the mirror opaque), a one-way mirror has a very thin layer of reflective material, like silver, aluminum, nickel, or tin. This thin layer is added to the front of the glass or plastic film. Applying a thin layer creates a “half-silvered” material. Some parts of the glass or plastic film are covered with the reflective coating. However, because the coating is so thin, this leaves some parts of the glass or plastic film still exposed. The result is a material that has some transparent surfaces and some reflective surfaces. Due to its structure, a one-way mirror will reflect slightly more of the light that shines on it than it transmits. When the one-way mirror film is used in a situation where light is shining from both sides, the material looks a lot like a tinted film because light is reflecting and transmitting from both sides. When light shines from only one side, the material acts like a mirror from the light side and acts like a window from the dark side. This is the puzzling aspect of the phenomenon used to motivate students’ learning in the unit.

This phenomenon is an ideal context to develop an understanding of how light interacts with reflective and transparent materials and travels in straight lines between objects (PS4.B). This phenomenon also facilitates the integration with life science to develop an understanding of how our eyes sense and process light entering them (LS1.D).

Enduring Understandings

NGSS Performance Expectations

MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
MS-LS1-8: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

Disciplinary Core Ideas

The unit expands students’ understanding of particle models and energy transfer, which include these Grade 6–8 DCI elements:

PS4.B. When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object’s material and the frequency (color) of the light. Students investigate using the box model, readings, videos, and data collected with light sensors to develop a robust model and explanation for how light interacts with an object’s material. This unit does not address absorption of light, which is taken up in the Cup Design Unit. Should you teach Cup Design Unit next, Lesson 8 in this unit offers a bridge in the form of a related phenomenon. The phenomena in this unit can be explained using a ray model for light, thus a wave model and different frequencies of light are not developed until 8th grade in the OpenSciEd Scope and Sequence. This is a notable omission given the overarching Performance Expectation for the unit. Until students develop a deep understanding of waves, including frequency and amplitude, they are at a disadvantage for developing a wave model for light. Students will engage deeply with wave models in the Sound Unit unit. Thus, expanding the wave model from sound to light in the Space Unit makes sense. The Space Unit is also an ideal placement for these DCI elements as students to develop a wave model of light which has more explanatory power in the study of space-related phenomena.

PS4.B. The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. This unit engages students using the idea that light travels in straight lines to model the one-way mirror phenomenon. There are Building Prerequisite Understandings offered in Lesson 2 to support students further with this concept. Students develop an understanding of refraction of light in Lesson 6 as they notice the bending of light through the lens of the eye to focus light on the retina. Students model how light bends at the surface of the lenses. Extension Opportunities are provided to enhance your students' experiences with refraction at surfaces between air, water, and glass.

LS1.D. Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories. In lesson 6 students develop an understanding of how eyes sense light inputs and transmit them as signals to the brain. Due to the different amounts of light entering the eye, some signals register as stronger or weaker ones. The unit does not address nerve cells because cells will be investigated later in the 6th grade sequence. Instead, students learn about the "optic nerve" connecting eyes to the brain. Students will not figure out how the brain responds in terms of reflex or memories.

Crosscutting Concepts

System and System Models: This unit intentionally develops this crosscutting concept. In this unit, students analyze the phenomenon to consider the components, interactions, and processes of the system, and how changes to light and changes to the material affect what is seen. Students zoom into different parts of the whole system to investigate subsystems (e.g., the one-way mirror material; the eye and brain system). By the conclusion of the unit, students will have a better understanding of what constitutes a system and will have iteratively developed a systems model that describes how light interacts with objects and how reflected light is an input into the eye.

Structure and Function: This unit intentionally develops this crosscutting concept. Students consider how the shape and composition of key components in the system (e.g., one-way mirror material, eye lens) help determine the function of those components. Students investigate the microscale composition (structure) of the one-way mirror, and figure out that the one-way mirror is designed with half-silvering, which affects the amount of light transmitted and reflected. Students explore the shapes and components of the human eye to understand how light inputs are processed into what we see. Students learn that the lens of the eye, because of its structure (shape and composition), refracts light to a point on the retina, where light signals are changed into electrical signals that are sent to the brain along the optic nerve.

This crosscutting concept is also key to the sensemaking in this unit: Cause and Effect

Cross-Curricular Integration

Additional Mathematics and ELA integration can be found within each lesson plan.

Mathematics Integration

In Lesson 3 students will collect light sensor data under very specific measurement conditions in which any deviation from the protocol could result in measurement error. Even given the detailed protocol students follow, the light sensor will not consistently report a single value, so students will need to determine a range that seems as accurate as possible given the measurement conditions. When they rank order the materials by transmissivity and reflectivity, they will use ranges that could overlap for some materials, and students may need to estimate the central tendency within the range of values to help them determine their rankings. This work is largely done as a whole group and can be more or less guided by you. However, the following math concept may be helpful:

CCSS.Math.Content.6.SP.A.2: Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape. Additionally, students collect these data using base tens (x10 lux).
The following math concept will be useful in explaining why they are selecting this setting on the light sensors.

CCSS.Math.Content.5.NBT.A.1: Recognize that in a multi-digit number, a digit in one place represents 10 times as much as it represents in the place to its right and 1/10 of what it represents in the place to its left.

Diversity Integration

Cultural significance of light and matter
Light in symbolism and spirituality: Explore how light is viewed in different cultures and religions, including concepts of enlightenment, divinity, and purity.
Traditional uses of materials: Investigate how different cultures have utilized various materials for tools, art, and ceremonies, understanding their properties and significance within those cultural contexts.
Light in traditional practices: Explore how light plays a role in traditional practices like Scandinavian "Hygge" or Japanese "Shinrin-yoku" (forest bathing), according to Luminette.
Matter and identity: Consider how material culture reflects and shapes individual and group identities in diverse societies.

Exploring light and matter through diverse lenses
Legends and myths: Discuss myths and legends about natural phenomena like the aurora borealis from different cultures, comparing scientific explanations with traditional narratives.
Art and architecture: Examine how light has been used in art and architecture across different cultures and periods, analyzing the symbolism and cultural context.
Cultural uses of light and color: Explore how different cultures use and interpret colors in their art, clothing, rituals, and ceremonies.
Diverse scientific contributions: Highlight contributions to the study of light and matter from scientists of various backgrounds and cultures throughout history.

Labs and Resources

Scientific Inquiry

Exploring Light and Matter

Objective:
Students will investigate how light interacts with different materials to understand the concepts of reflection, refraction, and absorption.

Reflection Questions:
What happens to light when it hits a mirror?
Describe how light changes direction when it passes through water.
How does the brightness of light change after passing through water?
Assessment:
Students will submit a lab report with drawings and descriptions of their observations.
Include measured angles of reflection and refraction.
Answer reflection questions with detailed explanations.

Science and Engineering Practices

Asking Questions and Defining Problems: This unit intentionally develops this practice. Students ask “what happens if” questions to guide initial investigations with the box models in Lesson 2. They co-construct an experimental, testable question to guide a controlled investigation in Lesson 3. They ask “how” and “why” questions to motivate investigations and to explain the phenomenon (Lessons 4-7). Three Asking Questions Tools are provided to scaffold asking different kinds of questions.

Open and Closed Questions (Asking Questions Tool): Use this tool to support students in revising close-ended questions into open-ended ones. Avoid using it when students first offer questions for the DQB. Rather, use it later in a unit to transform close-ended questions into open-ended ones to investigate together.
Testable Questions (Asking Questions Tool): Use this tool to support students in asking testable questions that include enough specific information that one could gather evidence (e.g., measurements, observations) to answer the question. Note that this tool includes testable questions that are not specifically experimental ones, but ones that can be answered by gathering empirical evidence.
Experimental Questions (Asking Questions Tool) Use this tool to support students in asking experimental questions in which they will need to manipulate a variable in the system to observe its relationship to other variables.

Developing and Using Models: This unit intentionally develops this practice. In the first lesson, students discuss how to use physical models to test ideas about a phenomenon (i.e., the box model) and how to use diagrammatic models to represent and explain the phenomenon. They contrast the real-world system they are trying to understand (i.e., two rooms in the video) with their box models to consider limitations of physical models. In subsequent lessons, students discuss representation choices for diagrammatic models, such as using symbols and colors, and what these representations communicate about the phenomenon. New elements of modeling that emerge in 6-8th grades that are developed in this unit include modeling parts of the system at unobservable scales, including unobservable mechanisms that explain observable phenomena (e.g., light reflecting off microscopic, half-silvered, one-way mirror film) in Lesson 4, and modifying a model to match if a variable is changed (e.g., changing the light conditions or swapping the one-way mirror for glass) (Lesson 8).

Constructing Explanations and Designing Solutions. This unit intentionally develops constructing written explanations. In Lesson 7 students develop a written explanation for the phenomenon. First, they collaboratively write an explanation to one of their questions, with the teacher modeling how to write an explanation supported by a how and why account and evidence. Then students independently write an explanation for a second question about the phenomena, receive feedback from the teacher and peers, and revise their explanations.

Science and Society

Christiaan Huygens: In the 1670s, Huygens proposed that light is a wave and developed the Huygens' principle, suggesting that each point on a wavefront acts as a source of secondary spherical waves.
Thomas Young: Young's double-slit experiment in 1801 involved passing light through two slits, creating an interference pattern on a screen, which strongly supported the wave theory of light.
Augustin-Jean Fresnel: Fresnel built upon Huygens' work, developing a mathematical framework for the wave theory and successfully explaining phenomena like reflection, refraction, interference, and diffraction.
James Clerk Maxwell: Maxwell's equations, published in 1865, revealed that light is an electromagnetic wave, a form of energy that travels through space by the interaction of electric and magnetic fields.

Isaac Newton: Newton, while initially favoring a particle theory of light, explored light's interaction with prisms and developed ideas about how different colors of light are absorbed, transmitted, or reflected, according to the Science Learning Hub.
Albert Einstein: Einstein's work on the photoelectric effect in the early 20th century showed that light can also behave as particles (photons), leading to the concept of light's wave-particle duality.
Justus von Liebig: Liebig, a German chemist, developed a method for coating glass with a thin layer of silver, revolutionizing mirror production by making them more accessible and affordable, says Live Science.
Ibn al-Haytham: This 11th-century Arab scholar, also known as Alhazen, made significant contributions to optics, including studies on reflection and refraction, particularly with lenses and mirrors. He also authored treatises on visual perception and the nature of light from celestial bodies.
John Hadley: Hadley is credited with inventing mirrors for reflecting telescopes.

CSDT Technology Integration