Light & Shadow

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Purpose of the Study of Light & Shadow

Teachers delving into the Next Generation Science Standards (NGSS Lead States, 2013) to inform their STEM curriculum will find light and sound listed together because they are related in their forms of energy – waves. However, young children experience light and sound as very different phenomena. Understanding light as waves of energy, how light travels, is absorbed, reflected, and refracted will come later in a child's education.

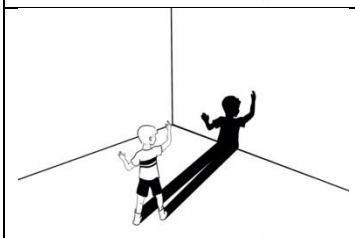
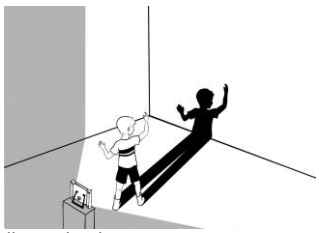
Young children are interested in light and shadow phenomena and are eager to explore it with their peers. When teachers provide materials, space, and opportunity to investigate over time, children can build on their prior experiences with light and shadow by planning and conducting investigations to answer their questions about light and shadow. This progresses to simple investigations based on fair tests, the collection of data based on children's firsthand observations, and the use of that data as evidence to support or counter a child's claim about light and shadow phenomena (NGSS PS4-1; PS4-2; PS4-3).

Through investigations, children deepen their conceptual understanding of how objects can only be seen if it is illuminated by light, light can be redirected by mirrors, and that some materials allow light to pass through and others block light resulting in a shadow on a surface beyond the object where light cannot reach (NGSS PS4.B). As children grapple with these concepts, they grow eager to use their understanding to engineer light and shadow to produce unique shadows, light and shadow scenes or displays, or a light and shadow performance to communicate a story (NGSS PS4-4). These engineering practices stretch spatial thinking as children make sense of causal relationships between light and shadow, and light-object-screen relationships (between the object and the shadow, object and screen, and between the shadow and screen).

Developmental Progression of Children's Understanding of Light and Shadow

Children need to understand darkness to make sense of light in their world. Without some notion of dark being the absence of light, children will have difficulty in deconstructing their light world and think about the notion of light. Young children need to experience dark places (complete and total darkness if possible) to understand they are able to control the light source and direction of light (Fleer, 1996).

There are levels in children's conception of shadows (DeVries, R. 1986).

	**Level 0: Little or no awareness of shadows.** Teachers can increase children's awareness by making comments about the child's own shadow, or by modeling observation of a shadow cast in the child's environment.
	**Level 1: Focus on object/shadow relationship.** Children begin to be aware that shadows resemble objects, and then show interest in causes of shadows. Children explore how they can change the shadow by moving the object closer to the screen, but do not consider the role of light. (Children coordinate relationships between the object and screen and the object and the shadow.)
	**Level 2: Awareness of the role of light.** Children in this stage become aware of the presence of light around the shadow and understand that light is needed to make a shadow. This grows to investigating the direction of the light. The child switches between a focus on an object, or the light as causes of the shadow (they cannot integrate the two). Finally, light is seen as an active force, and children are puzzled by a paradox of light making a dark shadow. (Children coordinate relationships between the object and the screen, the object and the shadow, the light and screen, the light and shadow.)
 Illustration by Hannah VanMeeteren	**Level 3: Coordinates spatial relations.** Children in this stage can coordinate spatial relationships to successfully manipulate shadows at a practical level. They understand shadows are made when they block light. However, at a conceptual level, them may still believe shadows exist when unseen. Children coordinate relationships between the object and the screen, the object and the shadow, the light and screen, the light and shadow, the light and the object, and the screen and the shadow.) **Level 4: Shadows are understood as the absence of light, and do not exist when unseen.**

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INTRODUCING LIGHT & SHADOW

There are many ways you can introduce Light & Shadow. Below are four examples:

1. **Investigate if we can see objects in a completely dark room, and how we can see using artificial light**
   - Secure enough small hand-held flashlights to provide a flashlight for each child and locate a room that can be darkened (preferably an inside room with no window).
   - Hand a flashlight to each child.
     - *Where have you seen these before?*
     - *What can you do with them?*
     - *Check with the person next to you to see how to turn it on and off.*
     - *Can you help me think of some times when these are helpful?*
     - *I wonder if we can still see when there is no light. What do you think? Let's find out.*
   - Lead children to the dark room with their flashlights.
     - *Let's see if we can see without light. Turn your flashlights on, and I'll turn the light out.*
     - *I'm going to keep my flashlight on, but I'd like you to turn yours off so mine is the only one left lit up. Is it getting lighter or darker? What do you think will happen when I turn mine off?*
   - Most children and adults believe their eyes will adjust to the darkness to eventually see what is in the room. Discussion and turning the light on and off will assist in understanding that the eye needs light to see.
   - Close the first discussion with a question.
     - *How many other things do you suppose we can find that make light*?
   - Before the children come the following day, place different light makers around the classroom (see list below for ideas.) Ask the children to find things in the classroom that make light. As each item is found, encourage the contributor to explain what the item is, how to turn the light on and off, and point out the part that makes light. Discuss how the artifacts are alike and how they are different. Create a classroom display or museum of these artifacts. Discuss how to label the items in the museum to inform visitors why they are in the exhibit.
2. **Create a provocation to entice children into noticing a changing shadow produced by an object in natural light.**
   Some teachers set up a provocation to start off an investigation by hanging an object (such as a cut-out of a butterfly) in the window to cast a shadow in the classroom and "discover" it with the children.
     - *I can see a shape of a butterfly here. It wasn't here earlier. What can you tell me about it?*
   - Observe the shadow with the children. Document their thinking on chart paper. Name the chart with the children and post it on the wall.
   - This can lead to children's investigations in shadows outside on the playground created by the sun.
3. **Introduce shadows outdoors.**
   - On a sunny day, ask children to take notice of their shadows. Help them to line up in a way so they can get the full measure of their shadow in relation to the sun, but do not draw attention to why you are doing this.
     - *How can you make your shadow move?*
     - *How do you make your shadow stop moving?*
     - *If we stand perfectly still, do you suppose you can still make your shadow move? Are you ready to try?*
     - *I wonder if we can make our shadow smaller. Taller. Wider.*
     - *Do you think it is possible to get away from your shadow? How could we try?*
   - End by introducing and playing shadow tag, or *Simon Says* making their shadows do specific things.
4. **Introduce shadows indoors**:
   - Introduce to whole group to gather their understanding of what they know about shadows.
   - Prepare ahead of time by closing drapes, doors, and cover windows to allow one light source overhead. Invite the children to create a shadow using their hand while remaining seated. Ask questions to generate curiosity about shadows and record the children's ideas. Accept and document all ideas on chart paper. Your purpose is to find out what they think before the investigation is underway. Some may parrot previous adult explanations or misuse vocabulary they have been taught without conceptual understanding.
     - *How did you make that shadow?*
     - *I wonder where it came from.*
     - *What do you suppose shadows are made of?*
     - *Where do we find shadows?*
     - *What will happen to shadows if we turn off the light?*

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Examples of light sources teachers may place in the classroom for children to explore:

LED flashlight	Maglite flashlights (various sizes)	rechargeable puck lights	LED goose-neck lamp
Light Bright toy	glow sticks	rechargeable headlamps	LED fairy lights
LED table lamp	rechargeable flashlights	light pads	LED closet motion lights
toys with lights	Christmas lights	rechargeable tea lights	sound sensitive lights

Exploring Stronger Light Sources (Larger light sources should be LED lights as they will not get hot)
Provide a variety of stronger light sources for the children to investigate.

Headlamps

These allow the child to always have the light source behind his/her shadow puppet

Rechargeable LED Work Light

This LED light is rechargeable allowing them to be used without cords. This LED light puts off a powerful light and does not get hot.

LED Work Light

This LED light puts off a powerful light and does not get hot.

INVESTIGATING SHADOWS USING ARTIFICIAL LIGHT (NGSS PS4-1; PS4-2; PS4-3)

Begin by closely examining larger light sources

- *What part is making the light?*
- *How many bulbs are there?*
- *Can you make it brighter? Dimmer?*
- *Is there a way you can change the color of the light?*

Inevitably, the larger lights will cast shadows on the wall. To more closely observe shadows, clear a portion of the wall to use as a screen, or use a large piece of cardboard or a shower curtain on a rod to create a screen. Observing shadows on a screen will prompt a new set of questions:

- *Can you find a way to change the size of the shadow?*
- *Can you find a way to change the shape of the shadow?*
- *Can you find two ways to make a shadow move?*
- *What happens to your shadow when you shine another flashlight on part of it?*

Often, children will make a claim that all shadows are black. You can challenge this claim by introducing a transparent object to cast a colored shadow such as a plastic green soda pop bottle. Again, a new set of questions will arise:

- *What color will the shadow be for this bottle?*
- *What is the difference between this bottle and this block?*
- *What other things could make a colored shadow?*
- **Note:** As children search for objects to try, they are making a prediction in their choice of what to try. Nonverbal children can demonstrate their deductive reasoning by their selection.

INVESTIGATING DIFFERENT KINDS OF SHADOWS (NGSS PS4.B)

When a child notices that not all shadows are black, provide them with materials that cast different types of shadows. Transparent, translucent, and opaque are words that describe how much light is able to pass through. Instead of expending effort to preteach this vocabulary, provide materials that are transparent, translucent, and opaque to use in making shadows. Encourage children to describe what they are noticing about the shadows. *Is there another object that makes the same kind of shadow? How are they alike?*

When children begin to sort the objects in relation to the types of shadows they cast, facilitate discussion on why each object is in each category. After children have a conceptual understanding of things that are clear make light shadows, things that are not completely clear make fuzzy or colored shadows, and things you cannot see through make dark shadows, you can say, "*Scientists have a special name for these different kinds of objects."* Then give them the words, transparent, translucent, and opaque.

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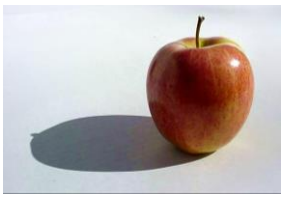
Transparent materials let most (but not all) light pass straight through so you can see clearly through them. The little light that is refracted results in a grayish shadow Glass is an example of a transparent material.

Translucent materials let some light through, but they scatter the light in all directions, so that you cannot see clearly through them. Tissue paper is an example of a translucent material.

Opaque materials do not let any light pass through them like an apple. They block the light resulting in a dark shadow. Wood is another example of an opaque material.



Engineering Challenge: What objects can you combine to make a unique kind of shadow? Is it possible to design a shadow picture? Could your shadow picture tell a story to an audience?

Materials: work light; screen; wooden unit blocks, blocks with windows; transparent, translocent, and opaque same-size plastic drinking cups; aluminum foil; plastic figures

Prompts:

- *Does it matter how close the light is to the objects?*
- *What happens to the shadow when you move the objects closer to the screen? Closer to the light?*
- *What could happen if you pointed the light at an angle to the screen?*
- *What does the shadow do when you move the light side to side?*

EXTENDING INVESTIGATIONS WITH LIGHT TABLES (NGSS PS4-1; PS4-3)

Teachers can promote children's development of concepts within properties of materials by providing them experiences with light pads. Children can engage in independent and purposeful investigations into how:

- light enables us to see details
- objects or materials are transparent, translucent, or opaque (NGSS PS4.B)
- the properties of materials interact with light to create effects that can be engineered to create designs, patterns, and structures that appear different when the light is turned off, dimmed or brightened
- overlapping translucent colors can make new colors

Using Light Tables to Investigate How Properties of Materials Interact With Light:

Collect a variety of materials that are opaque, translucent, transparent, and reflective and offer them to the children to explore at a light table. As children gain an understanding of how the properties of the objects affect how they interact with light, they are inspired to engineer the materials to produce artifacts to serve a need or want. They may arrange the objects into patterns, create temporary art (that can be captured with a photograph), or build 3-dimensional structures that are enhanced by uplighting.

Sheets of material

waxed paper; aluminum foil; construction paper; bubble wrap; plastic file folders; bubble wrap; paper doilies; newsprint; colored funnies; various thicknesses of cardboard; gift wrap; tissue paper; fabrics; cellophane

Building materials

K'nex; Legos; mini unit blocks; window blocks; translucent blocks; magnetic tiles; plastic petri dishes to contain other materials; clay; plastic drinking cups

Human made loose parts

marbles; flat gems; buttons; plastic cups; bingo chips; cut up units of plastic straws; a variety of sizes and thicknesses of rubber bands; easter eggs; popsicle sticks; nuts and bolts; washers; gears; ping pong balls; golf practice balls; clothespins, paper clips

Natural loose parts

pebbles; sliced rocks; pinecones; acorns; twigs; flower petals; plant leaves (variegated leaves are interesting), seeds and seed pods; sliced and whole fruits and vegetable, sand in a transparent container; cotton balls; yarn; wool

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USING CHILDREN'S BOOKS IN LIGHT AND SHADOW EXPERIENCES AND ENGAGING IN ENGINEERING

Strong reading and listening comprehension are dependent upon a reader's or listener's conceptual understanding of the topic and vocabulary used in the text to describe the phenomena within the topic. For this reason, we recommend to first engage young students in light and shadow experiences over time to develop their conceptual understanding of light and shadow phenomena, and the vocabulary associated with it.

Nonfiction books can be used later to engage children in critical thinking as they check their understanding with an author. Does the author agree with what they have been learning? Did the author leave out any important ideas? Did the author provide them with new questions or ideas to investigate in light and shadow experiences? Fiction books involving light and shadow will engage emergent readers and writers more quickly when they have personal experiences that connect with characters within the story.

Literacy (speaking, listening, viewing, writing, and reading) is naturally embedded in light & shadow STEM investigations as children collaborate, communicate, and document questions they have and what they are learning. Once children have had experience with different types of materials and the shadows they can make with them, they will be able to engage in engineering to design sets and puppets to put on a shadow puppet performance. Share some video examples of shadow stories and give them access to materials to design their own shadow puppets to engineer their own shadow puppet story (NGSS K-2 ETS1, 2, & 3). Don't put it away. It will be a popular choice in your literacy time block throughout the year.

Video examples of shadow puppets available on the internet:
The Three Little Piggies Shadow Puppet Workshop: https://tinyurl.com/yc3c4zx6
How to make a shadow puppet theatre out of a box: https://www.youtube.com/watch?v=BHw-4UOcj40
History of shadow puppets: https://www.youtube.com/watch?v=nbUlU02jc5c

Read More in
VanMeeteren, B. D. (2022). *Investigating light & shadow with young children*. Teachers College Press

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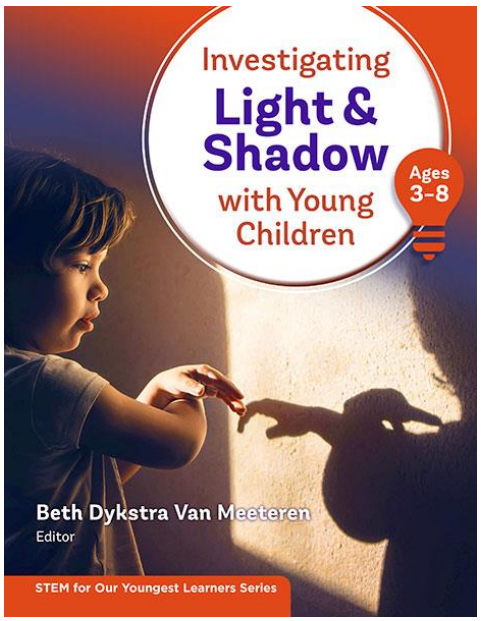

- Offers well-researched, teacher-and-child-tested STEM experiences.
- Addresses the nuts and bolts of implementing a high-quality, inclusive STEM curriculum.
- Focuses on four facets of the learning environment: cognitive, social–emotional, physical, and promotional.
- Addresses the power of an integrative curriculum, especially between STEM and literacy learning.
- Uses a framework of developmentally appropriate practice based on constructivist principles and inquiry.
- Includes modifications and accommodations for diverse learners using Universal Design for Learning.
- Offers guidance for establishing adult learning communities to support professional development.
- Shows how to build partnerships with administrators.
- Aligns with both the Head Start Early Learning Objectives Framework (ELOF) and the NGSS Science and Engineering Practices.
- Focuses on the development of students' engineering habits of mind (systems thinking, optimism, creativity, communication, collaboration, and attention to ethical considerations).

References

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Wulf, W. A. (2002). The importance of diversity in engineering. *Diversity in engineering: Managing the workforce of the future,* 8-15. Washington, DC: National Academy Press.

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