MACGILLIVRAY FREEMAN'S

DREAM BIG

ENGINEERING OUR WORLD

GRADE 1:

DAYLIGHT IN A BOTTLE

Grade level: 1

Lesson length: Lesson length: 2.5 hours (can be broken into smaller chunks)

Engineers are constantly looking for ways to bring natural daylight into buildings. It saves power and fuel for everyone. This concept is called “daylighting.” Students will experiment with radiant energy and the concept of refraction to develop a lighting system made out of recycled materials. Water bottle–based systems like the ones students create in this activity are in use in several impoverished areas.

In the Film

In *Dream Big*, we see ways that engineers are bringing light to the interior of buildings without the need for electricity. In the Transbay Transit Center, engineers have designed a way to bring natural sunlight into the station in order to make it more energy efficient. During this design challenge, students experiment with ways to make similar devices to light the homes of those in need.

NGSS Disciplinary Core Ideas

1-PS4.B Electromagnetic Radiation

Objects can be seen if light is available to illuminate them or if they give off their own light.

NGSS Engineering Practices

1-LS1-1 Crosscutting Concepts Influence of Engineering, Technology, and Science on Society and the Natural World

Every human-made product is designed by applying some knowledge of the natural world and is built by using materials derived from the natural world.

Key Words/Vocabulary

Daylighting: The idea of using skylights, mirrors, or other devices to bring natural daylight into a building.

Illumination: Lighting, or light. The light that comes into a room, or that shines on something.

Opacity: Not allowing light to pass through. If something has a high degree of opacity, no light can get through. If it has a low degree of opacity, a lot of light can get through.

Opaque: A material that light is not able to pass through. Roofs and walls made of wood or stone are opaque.

Refraction: The bending of light as it passes through one material into another. Light bends a little when it moves from the air into water, for example.

Translucent: A material that light is partially able to pass through. Ice is translucent; so is frosted glass.

Transparent: A material that light is fully able to pass through. A window is transparent.

Materials

Per class:

- ☐ Making the Testing Box instructions
- ☐ Testing box:
  - ☐ Large cardboard box
  - ☐ Box cutter
  - ☐ Piece of black cloth or felt large enough to drape over a child's head
  - ☐ Duct tape
  - ☐ 3 images
- ☐ Means of darkening the classroom
- ☐ Computer and projector for showing a YouTube video

Per student:

- ☐ Light in a Bottle Testing Sheet
- ☐ Pencil

Per pair:

- ☐ 1 empty .5L water bottle, with cap
- ☐ 1 empty .5L water bottle, with cap, painted on the outside
- ☐ 1 empty .5L water bottle, with cap, with a line marked around the middle
- ☐ Simple black-and-white picture that students can use during testing of the light
- ☐ Flashlight
- ☐ Water
- ☐ Vegetable or olive oil
- ☐ Food coloring
- ☐ Funnel

Teacher Prep Notes

Before beginning this lesson, collect empty water bottles. For the research component of the activity, each pair of students will need one empty .5L water bottle and one empty water bottle that has been painted on the outside.

For the construction component of the activity, each pair will need an empty .5L water bottle marked with a black permanent marker line around the middle. The line is to indicate how far you will place the bottle into the box.

Prior to introducing the challenge to students, build the testing box using the Making the Testing Box instructions.

Be prepared to explain the vocabulary terms in this lesson. Be able to relate these terms to the students' experiments with different substances in water bottles and the way those substances affect how they see a picture.

To Do

Determine the Problem or Question to Solve: 15 minutes

1. Before watching the IMAX movie *Dream Big*, give students an overview of what they are about to experience. This film is about engineering and the ways that engineering can inspire, challenge, and enrich our lives. Give students the following questions to think about as they are watching the film:
   - **a.** How do you think people used to light their houses before electricity was invented?
   - **b.** Why do you think natural sunlight might be better than electricity for lighting a house during the daytime?
   - **c.** If you didn't have electricity to light up your home, what would you do?
   - **d.** Why do you think some people don't have electricity to light their homes?
2. Debrief as a whole class after viewing the film. Encourage students to reflect on the guiding questions you gave them.
3. Introduce the design challenge. Explain that today, students will be engineers who figure out a way to bring sunlight into a room without using electricity, and by using recycled materials.

Research and Gather Information:

60 minutes

1. Make the classroom as dark as possible (turn off lights, and draw shades or close blinds if possible). Ask students how well they can see. Open the shades but keep the electric lights off. Is it any better? Are there any places in the room where it's too hard to read or work? Elicit responses to what they would do if they had to get dressed, eat, or work in a dim or dark room, and then explain that this is exactly what many children and families who can't afford electricity have to do every day in countries all around the world. Today, they will try to come up with a way to make life better for people in this situation by making a room light without electricity.

2. Show the following video: https://youtu.be/hPXjzsXJ1Y0. It shows how simple plastic "light bottles" are acting as valuable indoor lamps for people who don't have access to electricity in urban slums. Ask students to explain, as best they can, how these interior lights are made. Tell students that during this engineering challenge, they will explore how to make the best "Light in a Bottle" using materials available at school.

3. Divide students into pairs. Give each pair a .5L water bottle, a black-and-white picture of something very simple, and a flashlight. Tell students to prop the picture up against some books or a wall. Distribute the Light in a Bottle Testing Sheet to each student, along with a pencil. Make sure the students understand what they are supposed to write or draw on this testing sheet. You might write down words that they could use in their descriptions, such as *wavy*, *blurry*, *fuzzy*, and *clear*.

4. Instruct students to experiment with how light travels through their soda bottle (filled only with the air inside) by turning on the flashlight and shining it through the bottle toward the picture. Ask students to describe what the black-and-white image looks like as it is illuminated through the water bottle. Ensure that students understand the term *illuminated* as you use it in context.

5. Afterward, have the students fill the water bottles with water. Have them repeat the procedure, shining the light through the bottle and recording what they see of the black-and-white image.

6. Have students repeat the procedure three more times, once with a half-filled bottle of vegetable oil, once with a half-filled bottle of water with one drop of food coloring, and once with a bottle half filled with water and five drops of food coloring. Note: Depending on your students, you can choose to have them pour the new test material into the bottles, or you can have prefilled bottles available. Each time, have students use their testing sheet to record how the different substances affect the illumination of the black-and-white image. Finally, have students repeat the experiment using the bottles that have been painted on the outside. They should write down their findings for this step as well.

7. Talk about the terms *translucent*, *transparent*, and *opaque*. Ensure understanding by asking students to use these terms as they describe their findings. Talk about the concept of refraction and how that relates to the water bottles full of air, water, and oil. Explain that refraction is the principle behind why they were able to move light to the image in different ways.

Plan a Solution: 30 minutes

If students are unfamiliar with the concepts of criteria and constraints in engineering, take the time now to introduce these two key fundamental ideas. Engineers look at challenges through the lens of criteria (what does my device have to do?) and constraints (what are the limitations I face in making, testing, and using the device?). Spend some time as a whole class brainstorming the criteria and constraints of this particular engineering challenge.

Instruct each pair to draw a plan for what they think is the best combination and amount of materials (water, oil, paint, and food coloring) for their bottle, to make it light up a room by making use of sunlight. This plan should reflect the work conducted during the research stage and should demonstrate their understanding of light and refraction.

Make It: 15 minutes

Once students have drawn their plan, tell them to assemble the best version of their daylighting device. Visit each group and review how their experiences with the flashlight shaped their overall design and plan. If students are making obvious mistakes, allow them to continue and learn from those mistakes. Avoid offering solutions and instead encourage students to develop a secondary plan that demonstrates the evolution of their ideas and experiences.

Test: 20 minutes

Using the cardboard box you assembled beforehand, place student daylighting devices in the top hole, one at a time. Allow the students to look through the viewing hole into the box. You can either shine a flashlight onto the daylighting device while inside the classroom or take it outside to test with the sun!

Evaluate: 10 minutes

Allow students to think about and discuss the following questions:

1. Does your daylighting device illuminate the interior images of the box?
2. How does your daylighting device compare to the ones created by other teams?
3. How would you make it work better?

Taking It Further

Using littleBits electronics, develop a light meter that can be used by the students to gauge the success of their daylighting device, or use a Vernier Probe Light Sensor to measure their device's output.

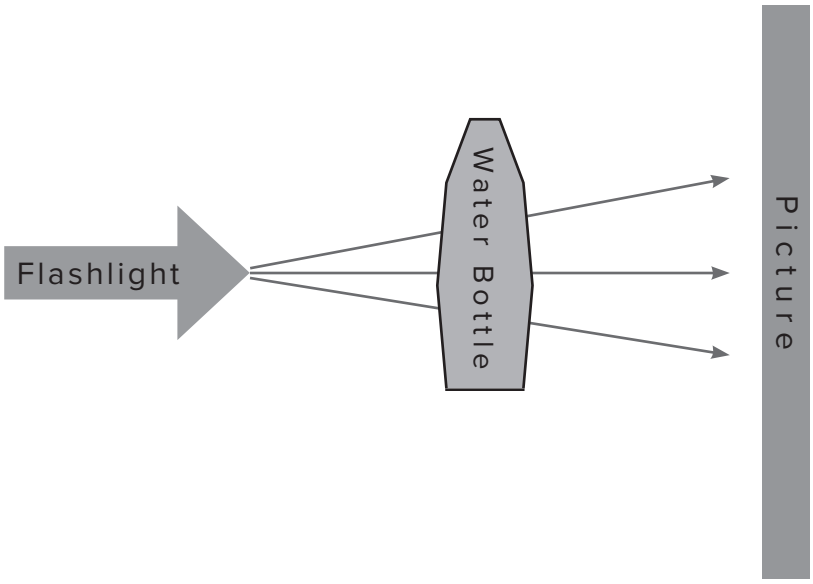
Engineers are exploring how to make current lightbulbs more efficient. Compare the new technologies that are in development to light our future: LEDs, MITs incandescent bulbs, and lasers.

Explore the Liter of Light Project deeper through the following link to the My Shelter Foundation—Global Lighting Project: sculptthefuturefoundation.org/portfolio/my-shelter-foundation-global-lighting-project/.

Document your students' work through our social media outlet: #dreambigfilm

LIGHT IN A BOTTLE TESTING SHEET

Prop a black-and-white picture up against some books or tape it to a wall. Place a water bottle 6 inches in front of it. Turn off the light to the classroom and turn on a flashlight. Shine the flashlight through the water bottle and onto the picture and record what it looks like!



1. Empty bottle:

2. Full water:

3. Half full with oil:

4. Half full with water and 1 drop food coloring:

5. Half full with water and 5 drops food coloring:

6. Painted outside of bottle:

MAKING THE TESTING BOX

Instruction Set

Materials

- ☐ Cardboard box (the larger the better)
- ☐ Box cutter
- ☐ Black cloth or felt
- ☐ Duct tape

1. Print three images of your choice to tape on the inside of the testing box. Students will use these images to determine and describe the amount of light illuminating the interior of the box when they test their device. The images can be of anything as long as they have enough detail for students to describe when light hits them. Suggestions are your school's mascot, a picture of someone's room, and so forth. Tape one picture on each interior side of the box, leaving one side blank. On the exterior of the box, mark the sides that have pictures so that you know their placement later.
2. Seal the box openings with duct tape to create a light-tight box.
3. On the top of the box, cut a 2.5-inch diameter hole. (This is the standard diameter of most .5L water bottles. If you are using bottles with a different shape or size, measure their diameter and cut a hole slightly smaller than that diameter for the bottle to fit snugly into.)
4. On the side of the box that you did not mark as containing an internal image, cut a viewing rectangle that is 6 inches wide and 2 inches high. This viewing rectangle should be about 1 inch above the bottom of the box.
5. Measure and cut a piece of black cloth that is slightly larger than the side of the box with the viewing hole.
6. Tape the cloth to the side of the box so that students must place their heads beneath it to look through the viewing hole when the box is resting on a table.

DREAM BIG VIDEO SERIES

WATCH *LEAN AND GREEN: ENGINEERING ALTERNATIVE ENERGY*

Alternative energy sources are one method engineers are using to grapple with the supreme challenge of slowing or halting climate change. Tour Ivanpah in California, the world's largest solar thermal plant: it reduces CO_2 emissions by over 1,000 tons every day. Learn how engineers are generating power through other sources too, like wind and ocean waves. Go to discovere.org/dreambig/media-assets and visit Educational Webisodes.

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