Lesson 4: The Case of the Missing Wires – Conductors!

Overview

After reviewing the essential components of electrical circuits students will be guided through a mystery in which they investigate the conductivity of various materials. Explorations lead to a beginning understanding of the uses and safety concerns associated with conductors and insulators.

Teacher Background

Current electricity requires an unbroken pathway, also known as a complete circuit, to power electrical devices. Materials differ in their ability to provide a pathway of electrical energy. Some materials allow electricity to flow better than others. Materials that allow electricity to flow readily through them are called conductors, and materials that do not allow electrical energy to flow through them readily or at all are called insulators. Common examples of conductors include metals, aqueous salt solutions (salts dissolved in water), graphite, water, and the human body. Common examples of insulators include plastics, porcelain, Styrofoam, paper, rubber, glass, and dry air. While this listing may imply that materials can be cleanly categorized as a conductor or an insulator, materials have varying levels of conductivity. It is more accurate to think of materials as being placed somewhere along a continuum of electrical conductivity.

Conductors and insulators play very important roles in the movement of electrical energy. The majority of metals conduct electrical energy but copper is the most commonly used metal because it is such a good conductor of electrical energy and it is relatively inexpensive. Humans have used this knowledge of conductors and insulators to control and direct the flow of electrical charges, delivering electrical energy safely to millions of people worldwide. If an electric current is desired then conductors are used. If a barrier is needed to prevent electrical energy from flowing, an insulator is used. An example is the plastic or rubber coated wires of a typical lamp cord. The wires that carry the electrical current are inside the coating and are made of a material that allows the electric current to flow freely and easily. On the other hand, the material for the coating does not allow an electric current to pass through and is chosen to prevent the electric current that is running through the wires from passing through into the surrounding environment, thus preventing electrical shock and/or fire.

Key Ideas

- While electrical circuits can be connected in different ways, all circuits have three essential parts: a source, a pathway, and a receiver.
- A complete path to and from the source (loop) is needed for the electric current to flow.
- Current electricity can exist in and move through a conductor. A conductor is a material that allows an electric current to pass through it.
- An insulator does not allow an electric current to pass through it.

Lesson Goals

Students will:

- recognize that all materials are not able to provide a pathway for the flow of electricity.
- examine the differences in electrical conductivity of a variety of common materials.
- use knowledge of conductors and insulators to explain why and how certain materials are used in simple electrical devices, i.e. light bulbs, extension cords, desk lamps, etc.

Vocabulary

conductor: a material through which electric current readily flows.

insulator: a material through which electric current does not readily flow.

Preparation

Gather a variety of common household items for students to use in conductivity tests.

Materials

Item	Quantity
Aluminum foil strips (use heavy duty foil)	1 roll, (sheets or strips)
Basic Circuit Kit: • Wire, 22-gauge, insulated (one 12" piece, stripped) • D battery • Replacement incandescent flashlight bulb	1 per student (Have spare materials on hand)
Supplementary Circuit Components: • Bulb holder (some bulb holders may require a Philips head screwdriver) • Battery holder • Two additional 12" pieces of wire, stripped	1 per student pair
Scientist's Notebook	1 per student
Chart paper and markers (optional)	1
A variety of miscellaneous familiar items for students to test the conductivity of, such as: • Glass (marble) • Styrofoam • Plastic (bag, spoon, lid, straw) • Paper • Wax (birthday candles) • Ceramic mug • Rubber (erasers, stoppers) • Chalk • Sharpened pencil • Chenille stick • Various metal objects (old keys, paperclip, penny, quarter, brass fastener, bolt, screw, nail, washer, spoon, soup or soft drink can.) • Lemon juice • Salt water	1 set per group of 4-6 students to share at tables
Student Handout 4.1 (optional): Conductors and Insulators	1 per student
Micro ammeter (optional)	1 per class

Note: *Students should keep their circuit testers intact in case they need to complete more testing the next day. Students may put their names on sticky notes and attach them to a tray with their testing materials. The next day, their materials are ready for more testing.*

Safety Notes

- Aluminum foil may get hot to the touch as students use as a substitute wire.
- If students examine the internal components of old electronic equipment advise them of how to do so safely. Appliances should be unplugged (consider cutting cords) and research devices ahead of time to make certain they do not contain mercury (switches) and/or radioactive elements (smoke detectors)."

Time Required: 2-4 sessions

Connection to *Benchmarks for Science Literacy (BSL)*, and *National Science Education Standards (NSES)*

- Electricity in circuits can produce light, heat, sound and magnetic effects. Electrical circuits require a complete loop through which an electrical current can pass. NSES B(K-4)
- Materials vary in how they respond to electrical currents, magnetic forces, and visible light or other electromagnetic waves. new BSL 4D/M9(6-8)
- Offer reasons for their findings and consider reasons suggested by others. BSL 12A (3-5)
- Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge). Good explanations are based on evidence from investigations. NSES A (K-4)
- Keeping records of their investigations and observations and not change the records later. BSL 12A (3-5)

Teaching The Lesson

Engage

1 Review a complete circuit.

Begin by sharing with the class some of the typical solutions students suggested for the prompt on Student Handout 3.1. This reviews the essential parts of a circuit and the parts-wholes relationships discussed previously in Lesson 3. As solutions are shared, it may be beneficial to illustrate them on chart paper or on a white board/chalkboard. Reaffirm how the suggestions describe the movement of electrical current through the circuit. Continue to revisit and discuss the parts-wholes ideas by interspersing questions when appropriate such as:

- *If one of the components were missing or broken, how would this affect the circuit? Why?*
- *If this configuration did not have a power source, how would this affect the circuit? Why?* (Refer to sample student responses noted in Lesson 3.)

2 Unfold the mystery.

Present the following scenario to students: Hold up a battery and a bulb and explain to students that there is a problem. While preparing for electricity explorations this morning, you (the teacher) noticed that the wires that had been used before were missing. Explain that there is no way to go to the store and get more wire so you asked other teachers for suggestions about available materials in school that could be used in place of wires to light the bulbs. One teacher suggested using aluminum foil. Explain that you have not had a chance to try this idea, but were hoping the students might be willing to give this a try. With a note of skepticism in your voice ask: *How do you think aluminum foil can be used to light a bulb?* Ask students to write this focus question "*How do you think aluminum foil can be used to light a bulb?* Use words and sketches and/or diagrams to describe your thinking in your scientist's notebook. Instruct students to do a "quick write," supported by reasoning, in their notebooks regarding their thoughts about the scenario presented. As students work, circulate among students and question their ideas. Guide students toward the idea of pathways, complete circuits, and making a drawing with descriptive text explaining why or why not they think foil could be used to light the bulb.

3 Share "quick writes."

Ask students to share their ideas with a partner. Instruct students to refer to their quick writes as they discuss their ideas. Have two or three students share what their partner thought about using aluminum foil to light a bulb. Explain that momentarily students will be given the opportunity to test out this idea of whether or not foil could be used to complete a circuit

Explore

4 Test foil wires.

Provide each student with a bulb, battery, and a strip of foil. Allow a few minutes for students to explore arrangements with the foil and ask that students to use words and diagrams or sketches to record their findings, such as configurations that work and other observations in their notebooks. As students work, circulate around the room and encourage them to try a variety of arrangements using the foil.

5 Share findings.

Gather students in a circle and direct them to use their notebooks to share some of the configurations that worked to light the bulb using the foil. Have a bulb, battery, and foil on hand to allow students to demonstrate or clarify their configurations. Through this discussion, students should recognize that the foil can be used to light the bulb in (much) the same way as wire. One difference that will most likely be mentioned is that the foil becomes noticeably hot as electricity passes through the foil.

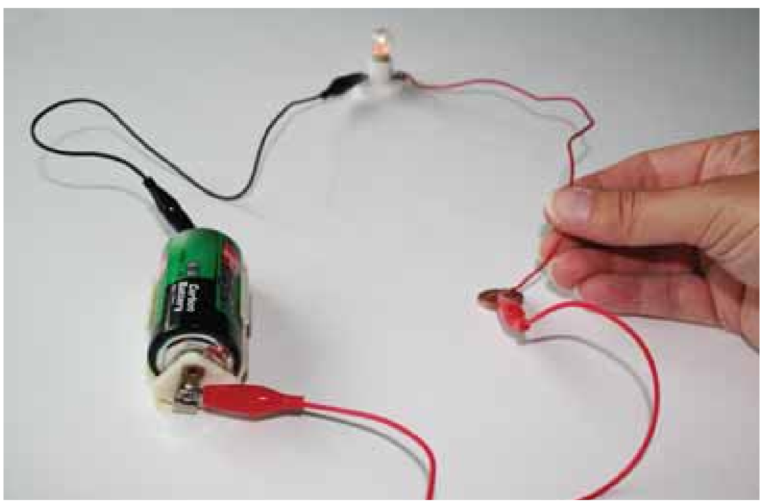
Throughout the discussion encourage students to use their drawings to show the pathway of electricity through the various configurations. Students may or may not offer the term *conductor* during this discussion. If students do not suggest the word conductor, introduce the term. Write the word *conductor* on chart paper or white/blackboard and ask students to elaborate on what they think is meant by this term as it relates to the configurations. Encourage students to use the term in context as they explain what they think it means.

6 Develop focus question for investigation.

Pose the following question to students: *What would you like to find out about conductors?* Instruct students to work with a partner to develop a list of questions about conductors. After students have had a chance to develop questions with a partner, compile a class set of focus questions. As this list is being compiled, help students to rephrase their questions from “yes” or “no” type questions to those that can be investigated. At this point in the lesson, guide students toward the class focus question: *Which materials conduct electricity?* Ask students to record the class focus question in their notebooks. Alternatively, depending on available time, student ability, class chemistry, and/or teacher familiarity with supporting students in developing focus questions, teachers may allow students to investigate one of the class questions.

7 Prepare to investigate conductors and insulators.

Remind students about the focus of the investigation by posing the following to students: *What are we trying to find out?* Refer students back to the class focus question: Which materials conduct electricity? Ask: *How can we find this out safely, given the available time and materials?* Ask students to suggest what they could do to find out if different materials can provide a pathway for electrical energy. Discuss with students a safe and simple way to test the conductivity of various materials. Demonstrate how to create a simple testing device by using their bulb, battery, and 3 wires. Two disconnected ends of wire are connected to the test materials. To make sure students understand how to test materials, demonstrate using a piece of aluminum foil. The picture below shows a penny being tested:



Work with students to develop a recording strategy or provide students with a copy of Student Handout 4.1 to paste in their notebooks. Be certain that the recording strategy incorporates student predictions. Model how to record data using the aluminum foil example, including the prediction using the recording strategy. Remind students that before they begin testing materials, they need to make a prediction about whether they think the material will conduct electricity and support their prediction with knowledge from past observations, first hand experiences, and prior knowledge.

8 Investigate conductors.

Introduce students to the materials available for testing. Have students work in pairs to test the conductivity of these materials. Remind students to use their notebooks throughout the investigation to record their predictions, observations, data, and questions. Circulate around the room listening to students' conversations and posing additional questions. If any students notice that some materials allow the bulb to light up, but not as brightly, encourage them to capture this detail in their data table.

> **Note:** *Students may wish to test the conductivity of items that are not provided, but this is not advisable unless given prior approval from the teacher. Teachers should be made aware that because students are testing materials using a simple device, conductive materials such as water or the human body may appear not to conduct electricity. A "false" reading may give students the wrong idea with respect to electrical safety. Teachers may wish to address this idea stating that their testing devices are simple and somewhat limited and may not be able to detect small amounts of electrical energy flowing through them. Suggest to students that there are more sophisticated devices, such as a microammeter, that can more accurately determine the amount of electricity that passes through materials.*

Reflect And Discuss

9 Write claims and discuss findings.

Ask students to individually reflect on the data they collected during the investigation. Prompt students to record one or two claims based on evidence about which materials conduct electricity. Provide students with the following sentence starter to support their writing: I claim ______ because ______. Alternately, students may write a group claim or the teacher may guide students in developing a class claim(s).

For example, students may write: "I claim that metals conduct electricity because when the key, washer, penny, and metal spoon were included in the circuit, the bulb lit up." Or conversely "I claim that glass and rubber are not conductors because when the marble and rubber stopper were included in the circuit, the bulb did not light up." Some students may write claims that focus on the variability of conductors: "I claim that some materials conduct electricity better than others because when ______ was included in the circuit the bulb lit dimly but when ______ was included in the circuit the bulb lit brightly."

> **Note:** *Emphasize the importance of writing claims that can be supported by evidence found in their data.*

10 Discuss claims and evidence.

Ask students to share and discuss their claims in small groups at their tables. Alternately, this could be done as a class discussion. Discussions provide students with the opportunity to hear the claims supported by evidence of other students before they are asked to write their own conclusions in Step 11. It is important that students understand that their individual or group results may be different from others. Discrepancies can encourage students to replicate investigations or review methodologies. Discussions regarding differing results may also help reduce confusion regarding any seemingly irregular data that may have been collected.

During the discussion, make certain that the following points regarding conductors are addressed:

- *What are conductors? How would we describe a conductor?* Conductors are materials through which electric current will flow.
- *Which materials conduct electricity?* Metals are good conductors of electric current.
- *Did all of the materials conduct electricity in the same way? What evidence do you have that supports this?* Some conductors allow electric current to flow more readily than others. Students may cite bulbs not lighting as brightly as evidence.
- *Which materials did not conduct electricity?* Examples of materials that do not allow electric current to flow are glass, plastic, ceramic, and rubber. These materials are called insulators.

11 Write conclusions.

After students have had the opportunity to discuss their claims and evidence, prompt students to write a conclusion, summarizing their findings. Provide the following sentence starters:

- *Conductors are….*
- *Examples of conductors are...*
- *Examples of insulators (non-conductors) are…*

12 Bring lesson to a close.

Bring closure to the lesson by asking students to "Give Me 5." Ask students to quietly and individually reflect on what they learned about conductors and insulators in this lesson. Ask five volunteers, one at a time, to share their reflection. Use ample wait time to encourage more hesitant students to respond. Hold up your fist, showing a finger each time a student shares a reflection until you have completed five responses. Explain to students that in the next lesson, students will use their knowledge of conductors and insulators to make suggestions for using electricity safely.

Extensions

Student may:

- Watch *Mythbusters* episode that debunked Ben Franklin's kite/key experiment. History tells us that if this had happened, Franklin would have died. Videos are online through a subscription based service: http://www.cosmeo.com/videoTitle.cfm?guidAssetId=0cc27279-5ed3-4eb3-aad3-35c0dfe16f79&&nodeid=
- Examine other materials historically used as filaments.
- Investigate the effect of adding another battery to a circuit on materials that did not initially conduct electricity. Caution students to not use more than 3 batteries per light bulb, as the bulbs can be blown if connected to too many batteries.
- Discuss conductivity as a being on continuum as opposed to being an absolute. Students could devise a way to order materials along a scale from "good" conductors to "good" insulators. For example, students could use the brightness of the bulb or micro-ammeter (if available).
- interview an electrical engineer to learn more about how they use their knowledge of conductors and insulators in their work.

Connection to Maine Agencies

MEEP (Maine Energy Education Program) has an *Apple Battery* exploration and will come to interested schools, free of charge. Students experiment with making a battery by inserting different types of metals into an apple and measuring the electrical current they generate. The MEEP website is:
http://www.meepnews.org/classroomactivities

For schools in Aroostook County, a Maine Public Service (MPS) representative will come to interested schools, free of charge, to guide and support concepts developed in this lesson. A description of programs is available at www.mainepublicservice.com. Click on the education section of the site. To schedule a visit contact Nancy Chandler at 207.760.2556 or nchandler@mainepublicservice.com.

Online References and Resources

http://www.allaboutcircuits.com/vol_1/chpt_1/2.html

Conductors and Insulators

Name of Material	**Describe and Sketch Material**	**Make a Prediction** *Is this material a conductor of electricity?* Support prediction with reasoning:	**Record Results** *What happened?* Describe what you observed: (brightness of bulb, etc.)

Lesson 5: Signs of Safety

Overview

After taking a closer look at the materials making up the components of familiar light emitting devices, students extend their understanding of conductors and insulators by identifying potential electrical hazards, discussing what makes them hazardous, and suggesting what can be done to prevent such hazards.

Teacher Background

Power lines, wires, and metals are likely to come to mind when thinking about strong conductors of electric currents. The human body, made up of large quantities of water and salt, is also capable of conducting an electric current. In general terms, humans are poor conductors of electricity but strong electric currents can pass through the body, causing serious injury or death. Electricity passing through the body can cause the heart to go into cardiac arrest; muscle, nerve and other body tissue can be damaged due to electrical current; and burns can occur where the body contacts an electrical energy source. The severity of injury depends on several factors including the voltage of electricity, how the current travels through the body, the state of the person’s overall health, and how quickly medical help is received following electrocution.

Children, construction and utility workers, pets, and livestock are particularly vulnerable to electrocution. This lesson allows students to apply their knowledge of conductors and insulators to everyday items and situations and recommend precautions that should be taken when using electrical energy. As noted in the previous lesson, humans have used their knowledge of conductors and insulators to deliver electrical energy safely to millions of people worldwide. Electrical energy is an essential in today’s modern world. As consumers of electricity, students should be made aware of electrical hazards in and around their homes, businesses, and schools and take simple measures to use electrical energy safely.

While not a focus of this lesson, students may be aware of such things are fuses, circuit breakers, power strips, and other devices that automatically shut off current to various devices when the electrical current is too high. Large power overloads are dangerous, potentially destroying electrical equipment or causing a fire. The simplest circuit protection device is a fuse. Fuses are an early technology and date back to the 19th century. A fuse is a small piece of metal across which electricity must pass. During normal levels of electrical flow, electricity passes across the fuse unobstructed. However, when overloaded, the small piece of metal melts, interrupting the flow of electricity. Fuses must be replaced after the electrical problem is fixed.

Circuit breakers are a more modern invention that improved upon fuse technology. Similar to fuses, circuit breakers are electromagnetic switches that turn off or "trip" when the electrical flow becomes too high. Unlike fuses, circuit breakers can be reset after the electrical problem is corrected.

There are a number of different types of power strips available to consumers today. Some are designed to keep electronic devices from receiving power surges while others aim to protect against overloading electrical circuits. Students may be interested in learning more about these sorts of devices aimed at protecting wiring in homes from overheating and causing a fire and keeping appliances operating safely.

Key Ideas

- A complete path to and from the source (loop) is needed for the electric current to flow.
- Current electricity can exist in and move through a conductor. A conductor is a material that allows an electric current to pass through it.
- An insulator does not allow electric current to pass through it easily.
- Electrical energy can be used safely in our homes, businesses, and schools, but it is not without risks. By understanding how electric current travels, people can minimize their chances of being seriously injured or killed from electrical hazards.

Lesson Goals

Students will:

- recognize the applications of conductors and insulators in everyday devices and situations.
- identify electrical hazards in homes, businesses, and schools.
- suggest ways to prevent serious injury and death from electrical hazards.

Vocabulary

electrocute: to kill by electric shock

hazard: something that is dangerous and can cause harm or serious

short circuit: the action of an electric current flowing along a path other than the one intended

Preparation

• Become familiar with the electrical safety handout.

Materials

Item	Quantity
Flashlight with batteries	1 per group
Incandescent flashlight bulb	1 per group
Extension cord	1 per group
Desk lamp	1 per group
Scientist's Notebook	1 per student
Safety Sign examples (optional)	1 set per class
Poster or large sheets of paper	1 per student
Markers, colored pencils, crayons	1-2 sets per group
Electrical Hazards Handout: http://www.dolceta.eu/malta/Mod4/IMG/pdf/TB_FINAL_Secondary_Resource_10-12_Worksheets_1-3_REV.pdf	1 per student or pair

Time Required: 1 or 2 sessions

Connection to *Benchmarks for Science Literacy (BSL)* and *National Science Education Standards (NSES)*

• Electricity in circuits can produce light, heat, sound and magnetic effects. Electrical circuits require a complete loop through which an electrical current can pass. NSES B(K-4)

• The potential for accidents and the existence of hazards imposes the need for personal injury prevention. Safe living involves the recognition of risk in personal decision. NSES F (5-8)

• Materials vary in how they respond to electrical currents, magnetic forces, and visible light or other electromagnetic waves. new BSL 4D/M9(6-8)

Teaching The Lesson

Engage

1 Review of conductors and insulators.

Briefly review which materials are good conductors of electric current and which materials are good insulators of electric current. Ask students if they think humans are conductors or insulators of electric current. (Humans are conductors of strong electric currents. The electric current in the battery and bulb circuit was not very strong. Electric current in household wires and power lines is strong.)

Introduce the focus of today's lesson by explaining to students that people use their knowledge of how electric current travels and of conductors and insulators to develop safe ways to use electricity.

78

Ask students to write the following focus question in their notebooks and provide two examples in response to the question:
How do you think people use their knowledge of electric currents, conductors and insulators to use electricity safely?

Explore

2 Identify conductors and insulators in components of light emitting devices.

Explain that students will take another look at some items that emit light and think about how people have used their knowledge of circuits, conductors, and insulators to design light devices that humans can use without getting hurt. Provide small groups of students with a bulb, battery-operated flashlight, extension cord, and (desk) lamp. Have each student in the group select one item to examine more closely to find out what materials direct the electric current (conduct) to the desired parts and what ones prevent unwanted or dangerous electric current from traveling. Ask students to make a labeled diagram in their notebooks of the item they select and to describe what conductors and insulators they observe in the item. Students share their findings with others in their group, focusing on what materials the items had in common as conductors and insulators. (Metal wires are coated with plastic and bulbs have metal sides and bases separated by ceramic or rubber.)

Reflect And Discuss

3 Discuss the importance of conductors and insulators in electrical safety.

Using one of the items students examined, ask them if the item would be functional without a particular insulating or conductive part. For example, if the plastic coating were removed from the extension cord, would an electric current still flow through it? (Yes, the cord would still allow electric current to flow but without the plastic covering the electric current could come in contact with other materials that are conductors, allowing electricity to pass through other materials that we may not want it to pass through. Students may also recall from their earlier experience with the "uncovered" foil wires that uncoated wires become quite hot. Exposed wiring can cause fires if they are near materials that can ignite.)

4 Discuss the role of the electrical pathway to electrical safety.

Make note that there are two types of dangers associated with electricity:

1) Electric current flowing through a person – People are conductors and if they become part of the electric current pathway, they "complete" the circuit, and current will flow through them. If the current is strong enough, it can cause serious injury or death.

2) The presence of dangerous amounts of strong electric current – Having too much current can cause things to overheat and start fires. This is why exposed wiring and short circuits are electrical hazards.

> **Note:** *Students may have heard the term "short circuit" and may have experienced a "short circuit" when working with the batteries and bulbs in earlier investigations. The term short circuit refers to the flow of electric current along a pathway that is different than the one that was intended. This pathway bypasses the rest of the current and can allow too much current to flow and produce too much heat, causing a fire.*

5 Identifying electrical hazards.

Students will use their knowledge of conductors, insulators, and electrical pathways to identify indoor and outdoor electrical hazards. Clarify what is meant by a hazard- a source of danger and, in this case, one that involves electricity.

Provide each student with a drawing(s) that depict indoor and outdoor electrical hazards. This can be found at: http://www.dolceta.eu/malta/Mod4/IMG/pdf/TB_FINAL_Secondary_Resource_10-12_Worksheets_1-3_REV.pdf (Answers are included for reference, if needed).

Students work in pairs to identify and describe why a particular activity or situation is hazardous and suggest what can be done to prevent the hazard. Students record this information in their scientists' notebooks. It may be helpful to provide suggestions as to how students might organize their notebook entries. For example, suggest a chart with one column for identifying the problem, one for explaining why the activity/situation is hazardous, and one for suggestions for fixing/avoiding the situation.

Have students share what they identified, why they think it is hazardous, and their suggestions for preventing those types of problems.

> **Note:** *Alternatively, this activity could be done by visiting Alliant Energy for Kids' virtual indoor and outdoor electric safety house. As the user moves the mouse over the various parts of a typical home, various electrical hazards are highlighted. If students have access to computers, suggest that students review the site in pairs. If only one classroom computer and an LCD are available, consider reviewing the site as a class.*

6 Bring lesson to a close.

Publicize electrical safety suggestions. Summarize students' safety suggestions by either:

1) Creating a class list of precautions people should follow to prevent electrical hazards that can be shared with others **or**

2) Having students each adopt one safety issue and create an electrical safety message poster or public safety slogan. Ask students to explain why they chose a particular hazard and how it relates to what they know about electrical circuits, conductors, and insulators **or**

3) Having pairs of students create 3 sided "table tents" depicting an electrical safety message that could be displayed on cafeteria tables for a period of time.

Extensions

Student may:

- go on a scavenger hunt to find different types of electrical safety devices, including circuit breakers, automatic shut off appliances, outlet covers, ground fault circuit interrupters (GFCI) near sinks and tubs, surge protectors, etc., and research out how they work. Investigate what it means to be a "UL listed" product.
- invite a guest speaker, such as an electrician or utility worker to describe the precautions they take when they work. Encourage the speakers to share special equipment and protocols they follow to ensure safety.
- examine common "signs" provided by the teacher that warn of electrical hazards and determine what the message is trying to convey and why the item or situation referred to is an electrical hazard.

Connection to Maine Agencies

For areas served by Central Maine Power contact: Brad Kaherl at 207-377-4599 for the Safety City Presentation. The target audience for an electrical safety presentation is Grades 4-6. It is suggested that, before contacting CMP, teachers check to see if their school has already scheduled a presentation. Schools receive a brochure in September describing the program. Areas covered: Bangor and north; Augusta – Portland; Portland south

For areas served by Maine Public Service contact Nancy Chandler at 207-760-2556 for the interactive Hazard Hamlet presentation. The target audience is preschool to fifth-grade students. The presentation provides information on the do's and don'ts of electrical safety. Students have the opportunity to see the power of electricity and learn about potential hazards associated with unsafe behavior around power lines and household circuitry. Areas covered: all of Aroostook County.

Online References and Resources

Dig Safe

http://www.digsafe.com/

(State laws require anyone who digs to notify utility companies before starting. Digging can be dangerous and costly without knowing where underground facilities are located.)

Electrical safety checklists

http://www.pueblo.gsa.gov/cic_text/housing/indoor-safety/checklist.htm

Electrical Safety in the Home Fact Sheet: UMaine Cooperative Extension

http://www.umext.maine.edu/onlinepubs/htmpubs/2350.htm

Electrical Safety Myths

http://www.cmpco.com/UsageAndSafety/electricalsafety/safetymyths.html

How Electricity Can Hurt You

http://www2.cmpco.com/safety_world/hurt/index.html

Maine Public Service Safety Tips

http://www.mainepublicservice.com/safety/safety-information.aspx

May is Electrical Safety Month

http://www.eei.org/newsroom/energynews/Pages/20090501.aspx

Online article from How Stuff Works: "How Circuit Breakers Work."

http://electronics.howstuffworks.com/circuit-breaker2.htm

Online article:
What is the Difference between a fuse and a circuit breaker?

http://www.wisegeek.com/what-is-the-difference-between-a-fuse-and-a-circuit-breaker.htm

Review one or more of the electrical safety websites listed below:

Alliant Energy Kids: Electrical Safety

http://www.alliantenergykids.com/PlayingItSafe/ElectricSafety/index.htm

Bangor Hydro

http://www.bhe.com/kidscorner/kidscorner.html

Electrical Safety World (Multiple links to CMP resources, including a Teacher's Guide.and Is Your Home Safe: Electrical Safety Checklist

- Home Page: www.cmpco.com/safety
- Safety Checklist: http://www2.cmpco.com/safety_world/home_safe/index.html

Frankenstein's Lighting Laboratory: with links to Electrical Safety, Static Electricity, and Fruity Electricity

http://www.miamisci.org/af/sln/frankenstein/index.html

Maine Farm Safety Program: Bulletin #2350

University of Maine Cooperative Extension

http://www.umext.maine.edu/onlinepubs/htmpubs/2350.htm

Switched on Kids: Electricity and How to Use it Safely

www.switchedonkids.org.uk

(Select #2: Electrical Safety in Your House)

Lesson 6: People Have the Power!

Electricity Generation

Overview

Where does electricity that is used to light our homes, schools, and businesses come from? In this lesson, students investigate how electricity is generated on a wide scale basis. The major components of electric production: the turbine, the generator, and energy source are introduced in this lesson.

Teacher Background

Widespread distribution of electric light became a reality in the late 1800's in conjunction with the development of two key technologies—the invention of the incandescent light bulb by Thomas Edison and Nikola Tesla's invention of alternating current equipment (http://www.pbs.org/tesla/index.html). Initially, centralized power houses allowed homes and businesses a few blocks away in America's larger cities access to low voltage electricity. The desire for street lighting, power for trolleys, and lighting for businesses stimulated rapid development of power plants across the country. In 1882 Edison's Pearl Street Station was the first power station to be built. During this same year, the first hydroelectric power plant was constructed in Wisconsin along with eight others across the country. In the United States, the number of power plants generating electricity rose from 468 in 1889 to 1,807 in 1899. The evolution of wide scale electricity production has a fascinating history and is a prime example of science inquiry. The inventors who first experimented with the world of electricity experienced numerous trials and errors in developing wide scale systems, but their hard work, perseverance and dedication laid the foundation for wide scale electrical production used today.

During the late 1800's Maine began utilizing its beautiful and pristine rivers to produce hydroelectric power. Hydropower plants were built on the shores of the Androscoggin, Kennebec, Penobscot and Saco Rivers. In Portland, a steam-driven generator was built by the Consolidated Electric Light Company. In 1910, Maine's oldest electric company, Central Maine Power, was founded. Despite the growing expertise in producing power on a more wide scale basis, the infrastructure to support transmission of electricity over long distances limited the availability of power to many areas. It wasn't until the 1920s that the Rural Electrification Project, initiated by President Roosevelt's New Deal, began to extend electricity lines to rural parts of Maine. By 1950, 90% of American farmers were able to access electricity, which transformed life on the farm, lit those homes, and was used for innumerable daily tasks of farm life.

Because electricity isn't a substance and it can't be bottled up or put into a pile, electricity must be generated from energy sources. Much large scale generation of electricity is accomplished using an old, but very successful, method that combines the use of a turbine, a generator, and an energy source. When coal or natural gas is the energy source used to generate electricity, the coal or natural gas is burned to heat water to produce steam which spins a turbine. The spinning of a turbine is an integral component in nearly all methods of wide scale electricity production. The turbine either spins coils of wire around stationary magnets or magnets are spun around coils of wire. The "spinning" sets in motion the flow of electricity. Electricity is delivered to homes, schools, and businesses through a series of power lines. When wind or water is the energy source used to generate electricity, the water is not heated to produce steam to turn a turbine. The force of wind turns the wind turbine and the force of water turns the water turbine.

In many parts of the United States, coal continues to be a dominant energy resource used for electricity production. Coal has been a top energy choice since the late 1800's. Alternative energy sources being explored in Maine include wind, biomass (plant and other once living material), solar, geothermal, and ocean tidal and wave. The resource *What You Need to Know about Energy* from the National Academies Press http://www.nap.edu/ provides a more detail description of energy sources used in the generation of electricity. This material can be accessed online.

Key Ideas

- Electricity can be generated using a variety of energy sources.
- Presently, the majority of electricity generated uses some of the same methods used for over 100 years.
- Electricity generation most commonly involves a turbine and generator.
- Some energy sources are renewable and some energy sources are nonrenewable.

Lesson Goals

Students will:
- explore how electricity is generated.
- investigate several energy sources used in the generation of electricity.
- consider why different energy sources are used in the generation of electricity.
- be introduced to the idea that some energy sources are renewable and some energy sources are nonrenewable.

Vocabulary

circuit: a complete pathway or loop for electricity to travel (flow).

energy source: a material such as coal, gas, oil, or wood used in the generation of electricity.

generator: a device that converts mechanical energy into electrical energy usually by passing magnets through an electric field (electromagnetic induction).

nonrenewable resource: resource that do not replenish as part of natural ecological cycles.

pathway (electrical): the course that electric current follows; most typically a wire.

renewable resource: a resource that replenish as part of natural ecological cycles.

turbine: a device made up of a series of blades that is turned by a fluid (gas or liquid) and as it turns, converts mechanical energy into electrical energy

Preparation

- Prepare *PowerSleuth* student puzzle sets and a large class puzzle set. Prepare a picture set of power generation methods (power plants).
- Consider that a variety of student groupings are used for the puzzle activity. Because of this it is suggested that groupings be chosen prior to the start of this lesson. Initially, students work in pairs to complete one of four puzzles: coal, wind, natural gas, or water (hydro). After each pair completes their puzzle, it is suggested that they be paired with another group in the following way: students with a coal puzzle are paired with students with a wind puzzle; students with a natural gas puzzle are paired with students with a water (hydro) puzzle. In last part of the activity, all pairs that started with the coal puzzle will work together, and likewise for the wind, water, and natural gas pairs. The terms renewable and nonrenewable energy sources are introduced in Step 6 in this lesson.
- Set up LCD projector, speakers, and computer with internet access or arrange for use of computer lab. Preview website: http://www.energyclassroom.com/powerplanttour.php and those listed in the extension section of this lesson.
- Preview the book *My Light* by Molly Bang. Review the caveats in using this book.

Materials

Item	Quantity
Picture Set of Power Generation Methods (Plants, etc.)	1 set per class
Teacher Resource 6.1: *PowerSleuth* Student Puzzles http://www.powersleuth.org/teacher/energy-lights/lesson6-overview	1 set per pair
Teacher Resource 6.2: *PowerSleuth* Puzzle Descriptions	1 set per class
Teacher Resource 6.3: *PowerSleuth* Class Puzzle	1 set per class
Scientist's Notebook	1 per student
Computer, LCD projector, speakers, internet connection	1 per class
My Light by Molly Bang	1 per class

Time Required: 1-2 sessions

Connection to *Benchmarks for Science Literacy*

- The sun is the main source of energy for people and they use it in various ways. The energy in fossil fuels such as natural gas and coal comes from the sun indirectly, because the fuels come from plants that grew long ago. BSL 8C(3-5) b
- Electrical energy can be produced from a variety of energy sources... Moreover, electricity is used to distribute energy quickly and conveniently to distant locations. BSL 8C (6-8) d

Teaching The Lesson

Engage

1 Review electrical hazards.

Open the lesson by briefly reviewing some of the electrical safety ideas from Lesson 5, perhaps using students' safety messages to seed the discussion. Remind students that there are two types of dangers associated with electricity:

1) People are conductors and if they become part of the electric current pathway, they complete the circuit and current will flow through them. If the current is strong enough it can cause serious injury or death.
2) Having too much current can cause things to overheat and start fires. This is why exposed wiring and short circuits are electrical hazards.

2 Introduce the idea of large scale production of electricity.

Briefly remind students that they have primarily explored light emitting devices powered by batteries. Ask students to describe the energy source and the electrical pathway found in a simple circuit and flashlight. The idea is to remind students that the simple circuits they made and the flashlights they examined were powered by batteries. These devices emitted light because they had an energy source (a battery) and a complete pathway (wires) for electric current to travel.

Pose the following to students and allow discussion after each:

When you turn on a light at home or at school, where do you think the electricity comes from? What's the source? What is the pathway? Students may or may not have answers for these questions. Accept students' answers.

Hold up a battery and/or flick on/off a light switch and inquire:

Is there an enormous battery somewhere that people plug into to get electricity to light their homes and businesses?

Students may suggest that electricity comes from a power plant. If they don't, guide them to the idea of a power plant as producing our electricity. If students do mention a power plant, ask them what they think happens in a power plant or how the power in the plant gets to homes, businesses, and schools.

Explore

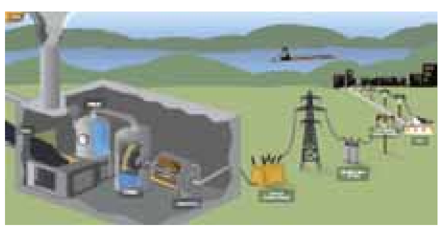
3 Introduce the use of energy sources in the generation of electricity.

Show students the pictures of power generation methods. These pictures can be found at: http://www.powersleuth.org/teacher/energy-lights/lesson6-overview

Explain to students that power plants are in some ways similar to the batteries used in the simple circuits and flashlights they examined earlier. Just like batteries, power plants use an energy source to get electric current moving through wires. Major differences between power plants and batteries are: the kind of energy source they use to generate electricity, the way electricity is transmitted (over much greater distances and in complex networks), and the amount of electricity that can be carried.

4 Distribute PowerSleuth Puzzles.

Give pairs of students a PowerSleuth puzzle set. Puzzle pieces can be downloaded with or without puzzle lines from http://www.powersleuth.org/teacher/energy-lights/lesson6-overview Puzzles include: coal, natural gas, wind, water (hydro) and are the focus of this exploration. To have an even distribution of puzzles, divide up the class so each puzzle is equally represented. For example, 2 sets of coal, 2 sets of water (hydro), etc.



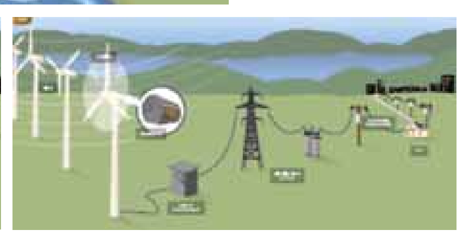
Coal

Solar

Hydro

Natural Gas

Wind



Direct student pairs to work cooperatively to put the pieces of the puzzle in order using the descriptions provided. As pairs finish their puzzles, partner coal students with wind students, and natural gas students with water students. This encourages a discussion about the different types of energy sources used in the generation of electricity.

> **Note:** *Assembling the puzzles will not be, nor is it intended to be a difficult task for students at this grade level. The puzzle format is a tactile alternative to reviewing diagrams of various power generation methods and serves as a springboard for discussion.*

Reflect And Discuss

5 Compare and discuss findings.

Bring students back together as a large group. Ask students to think about the different *PowerSleuth* puzzles they examined and discussed. Ask for a volunteer to share their group's puzzle solution by posting up the class size *PowerSleuth* puzzle pieces on the wall. After the pieces are displayed, poll the class using thumbs up (agreement with the puzzle order) or thumbs down (disagreement with the puzzle order). If there is disagreement, provide an opportunity for students to comment about their disagreement. Explain to students that after all four puzzles have been posted and polled, an opportunity will be provided to change the order of their pieces if new ideas arise.

Once all puzzles have been posted and polled, provide one more opportunity for students to discuss and agree on the puzzle pieces. For this final discussion, group all coal puzzle students together. Do the same for natural gas, water (hydro), and wind. If a group would like to change the order of their group's posted puzzle, they may do so. This is an opportunity to listen to students' thinking and ask guiding questions that direct the group's thinking. The intent of this activity is to familiarize students with the common steps involved in the generation of electricity as opposed to memorizing the sequence.

In a large group, explore the following points by asking questions such as:

- *What parts or "pieces" did your puzzles have in common?* (energy source, pathway, turbine, generator)
- *What if one of the parts was removed?*
- *What parts were different?* (energy source)
- *Why do you think these parts (energy sources) are different?*

6 Introduce terms renewable nonrenewable resource.

Ask students if they have ever heard of energy sources referred to as "renewable" and "nonrenewable." Explain to students that one way the power puzzles differ is in their use of different kinds of energy sources. Nonrenewable energy sources are those that cannot be replaced in a practical amount of time, making their amount limited to what is what is on the Earth right now. Fossil fuels (such as coal, petroleum, and natural gas) take millions of years to form. Renewable energy sources are those that can renew themselves or be replenished by natural processes. Energy from the sun, wind, and water are examples of renewable energy sources.

Optional: Follow this discussion by taking the virtual power plant tour found at:
http://www.energyclassroom.com/powerplanttour.php
This could be done as a whole class activity or individually if sufficient computers and headphones are available. Students could also tour a power plant in their area, but be aware that visits to such facilities may be challenging to arrange due to new security measures set in place after 9/11.

7 Introduce the sun connection.

Post the large sun puzzle piece in front of the coal, wind, water (hydro), and natural gas sequences. Ask students what they think about the addition and position of this extra piece. Allow student to share a few of their ideas. Prepare to read the book *My Light* by Molly Bang. Tell students that while the book is being read aloud, they are to think about the extra puzzle piece and its connection to the generation of electricity. Read the book aloud. At the conclusion of reading *My Light*, ask students to share their thoughts on the sun's connection.

8 Bring lesson to a close.

Ask students to reflect on their understanding of how electricity is generated as well as renewable and nonrenewable resources from this lesson by responding in writing to the following sentence frames in their notebooks:

- *Today I learned…*
- *I wonder…*
- *Questions I have now are…*

Review student's entries to determine if students have grasped the key ideas of the lesson. Make note of students' wonderings and questions for the purpose of addressing these in future lessons.

Extensions

Student may:

- explore the hand-crank generator flashlights. *How are these similar to and different from how electricity is generated in a power plant?*
- read Joanna Cole's *The Magic School Bus* and the *Electric Field Trip*. Caution: This book discusses electricity in terms of electrons, which is above the sophistication level for students in this grade span.
- explore emergency home generators and/or security lights in public buildings.
- research the historical basis for power plant locations. (History and Social Studies in locating where power plants are located).
- take a virtual walk through a hydroelectric power plant at: http://www.fwee.org/walktour
- read Science News for Kids article: entitled "Weaving with Light" Oct. 17, 2007; found online at: http://www.sciencenewsforkids.org/articles/20071017/Feature1.asp
- write a persuasive essay or editorial about renewable and non-renewable resources.
- graph a bar graph showing the distribution of energy sources that generate Maine's electricity. Note: Residential electric bills provide this information.
- create a Maine map showing the power plants responsible for Maine's electricity.
- find the closest energy source to home. Investigate whether the community that they live in has a dam (or mill) or other energy source that has been used or is currently being used to generate electricity.
- debate the pros and cons of "The Flooding of Flagstaff." Ask students to view the 2½ minute clip describing the flooding of Flagstaff, Maine in 1949. Have students discuss what they would do if faced with a similar dilemma today. http://windowsonmaine.library.umaine.edu/fullrecord.aspx?objectId=9-35
  Note: The clip above is part of a longer video (approximately 27 minutes) called "Power Lines" that describes the development of early wide scale distribution of electricity to Maine homes. http://windowsonmaine.library.umaine.edu/fullrecord.aspx?objectId=9-204
- research the connection between the *Furbish lousewort* and the Dickey-Lincoln dam and discuss Congress' 1986 decision.
- interview parents and/or grandparents or talk with others in the community about "log drives." *What are they? What connection do they have with Maine and energy? Do they still occur today?*

Connection to Maine Agencies

MEEP (Maine Energy Education Program) has a *Great Energy Debate Game (4th to 12th grade).* What are the pros and cons of renewable versus nonrenewable resources? Do you have any pre-conceptions as to which energy sources is the best? In this debate, students take on the real world challenge of convincing others that one energy source is the best. A MEEP representative and will come to interested schools, free of charge, to guide this activity.

MEEP also has a Coal-fired Power Plant Activity. Students learn how electricity is made in a power plant and discuss the pros and cons of using coal. They then discover alternative ways to spin a turbine to run a generator. A MEEP representative and will come to interested schools, free of charge, to guide this activity. The MEEP website is http://www.meepnews.org/classroomactivities

For schools in Aroostook County, a Maine Public Service (MPS) representative will come to interested schools, free of charge, to guide and support concepts developed in this lesson. A description of programs is available at www.mainepublicservice.com. Click on the education section of the site. To schedule a visit contact Nancy Chandler at 207.760.2556 or nchandler@mainepublic service.com.

A note about *My Light* by Molly Bang

Children's literature can be used in science to engage students, guide scientific inquiry, and aid in scientific comprehension of concepts. *My Light* by Molly Bang uses simple poetic phrases and engaging artwork to describe how flipping a switch is related to the Sun. The book describes various ways electricity is generated, presenting Earth's energy story in an interconnected and subtly comprehensive way. However, there are some issues that need to be mentioned, as this book is used to some degree to supplement content.

- The book is written in the first person which anthropomorphizes the Sun. (The Sun is the "narrator.") Most students should be able to recognize that the Sun is not a living thing even though it is given human qualities in the story.
- Text that reads "Tiny drops of warm water rise and form clouds" and on the following page "The clouds cool down" is misleading. Water vapor rises. Clouds are formed when water vapor in the air cools and condenses.
- The text that accompanies the hydroelectric dam is incomplete. The water moves the turbine. The turbine turns a magnet that is surrounded by coils of wire. This causes electricity to flow.

• “Green plants catch my light and use my energy to help build leaves and stems” is misleading text and may perpetuate the common misconception that plants make their food out of light. Light is not a substance. Plants use light energy during photosynthesis to convert water and carbon dioxide into sugars.
• Oil is not mentioned in the book.

These points are made as cautions, not to discourage the use of the book.

Consider visiting the book’s companion website:
http://www.mollybang.com/mylight.html

Online References and Resources

Life and Legacy Inside the Lab: Tesla – Master of Lighting
http://www.pbs.org/tesla/index.html

PowerSleuth Puzzle Descriptions:

Coal *PowerSleuth* Puzzle

1. Coal is delivered to the power plant to be burned.

2. The burning coal releases heat which boils the water in the boiler and turns the water into "steam." This steam turns the blades of huge turbines.

3. The turbines spin a generator, creating electricity.

4. The electricity moves through power lines to a "step up" transformer. The step up transformer increases the voltage or "push" needed to send the electricity further down a network of power lines.

5. The electricity moves through local "step down" transformers that reduce the voltage to a correct level for homes, schools, and businesses.

Natural Gas *PowerSleuth* Puzzle

1. Natural gas is piped in to the power plant to be burned.

2. The burning gas releases heat which boils the water in the boiler and turns the water into "steam." This steam turns the blades of huge turbines.

3. The turbines spin a generator, creating electricity.

4. The electricity moves through power lines to a "step up" transformer. The step up transformer increases the voltage or "push" needed to send the electricity further down a network of power lines.

5. The electricity moves through local "step down" transformers that reduce the voltage to a correct level for homes, schools, and businesses.

Hydro Power *PowerSleuth* Puzzle

1. Water is backed up behind a dam. The water falls through an opening in the dam.

2. The falling water spins the blades of huge turbines. The turbines spin a generator, creating electricity.

3. The electricity moves through power lines to a "step up" transformer, which increases the voltage or "push" needed to move the electricity through more power lines.

4. The electricity moves further down a network of power lines.

5. The electricity moves through local "step down" transformers that reduce the voltage to a correct level for homes, schools, and businesses.

Wind Power *PowerSleuth* Puzzle

1. The air moves creating wind. As the wind blows, it turns the blades of the wind turbines.

2. The turbines spin a generator, creating electricity.

3. The electricity moves through power lines to a "step up" transformer, which increases the voltage or "push" needed to move the electricity through more power lines.

4. The electricity moves further down a network of power lines.

5. The electricity moves through local "step down" transformers that reduce the voltage to a correct level for homes, schools, and businesses.

Solar Power *PowerSleuth* Puzzle

1. When the sun shines, the sunlight hits the solar cells of solar arrays, creating electricity.

2. Electricity is delivered through wires to the house and may be used immediately.

3. Unused electricity is stored in wall-sized batteries, which are located inside the house.

4. Sometimes solar arrays produce extra electricity that may be delivered through power lines to the electricity company for other homes, schools, and businesses to use.

Lesson 7: Around and Around They Go

Turbines

Overview

Turbines are a common component in most forms of electricity production. During this lesson, students explore turbines by designing and building blades for a simple wind turbine.

Teacher Background

This lesson has two major goals: the first is to take a closer look at how turbines work in terms of their role in electricity generation. The second is to provide students with the opportunity to experience working through a technological design process as they observe, design, and build blades for a simple paper wind turbine.

When a force from something such as wind, water, or steam hits the blades of a turbine, the blades turn freely. It is this energy of motion that is used to do work such as spinning a generator to produce electricity or rotating great stones for grinding grain or lifting water from a moving stream to irrigate crops. Wind, water, and steam turbines have all been used throughout Maine to generate electricity.

The harnessing of wind has a long history. Early records indicate that wind was being used to push on the sails of a boat as a way to move the boat across water. This was followed by the advent of people attaching sails to wheels perched atop tall structures. As the wind moved the sails, shafts connected to the sails would turn and grind or mill grain into flour, thus the name “windmill.” The modern-day interest in wind is focused on figuring out ways to conveniently harness it for the purpose of generating electricity to meet the increasing energy demands of society. People often use the words windmill and wind turbine interchangeably when talking about wind energy. Traditionally windmills refer to structures that grind or mill grain and wind turbines are devices that harness wind to generate electricity. Windmills and wind turbines may vary in their appearance, but they operate using essentially the same basic design.

Wind energy can be thought of as a form of solar energy since the Sun is the ultimate source of wind. Wind is, very simply, moving air. Air moves due to the uneven heating and cooling of the Earth’s surface. The Sun will shine for billions of years so wind energy will be here for a very long time. This is why wind energy is considered renewable. The wind keeps blowing! There are places on Earth that have more wind than others, such as near the oceans, along the open plains, and on the tops of hills and mountains. The availability of wind is one factor that needs to be considered when people think about erecting wind turbines. Other considerations include the migratory patterns of birds and bats, aesthetics, noise pollution, and shadow flicker.

The opening paragraph of the *Maine Learning Results: Parameters for Essential Instruction* states "…it is important for students to learn how science and technology connect with the demands of society... It is equally important that students are provided with learning experiences that integrate tools, knowledge, and processes of science and technology. Instruction should support students in asking questions and making inquiries, to help them understand and solve problems that require the integration of knowledge and processes in authentic contexts." The study of our society's energy needs and the wind power available in Maine sets the stage for an engaging opportunity to combine inquiry and technological design into the study of energy. By designing, building, and testing the blades of a model wind turbine, students are able to put into practice the skills of scientific inquiry and experience technological design in a hands-on and meaningful way. Building a model turbine using blades that they design will aid in the students' understanding of how turbines work and some of the complexities they entail. Whether you refer to this as technological design or engineering, this is a real life use of a design process to study the generation of electricity using a renewable energy resource that is becoming more popular in Maine, the United Sates, and throughout the world.

100

Key Ideas

- Wind can be used to make things happen. In the context of generating electricity, wind energy can be used to spin a turbine.
- Technological design involves using scientific principles to solve problems.
- Predicting, observing, designing, building, testing, analyzing, and retesting are all part of technological design.

Lesson Goals

Students will:

- describe how wind, water, or steam can be used to make things happen.
- identify different uses of windmills and wind turbines.
- observe and describe how different blade materials and shapes harness wind.
- analyze turbine designs for strengths and weaknesses and implement some of their improvement ideas.

Vocabulary

turbine: a device made up of a series of blades that is turned by a fluid (gas or liquid) and as it turns, converts mechanical energy into electrical energy.

Preparation

- Construct the model steam turbine following the directions found at the end of this lesson. **Practice before doing this demonstration with students!** An alternative method for showing steam power can be found at Combustion Demonstration: http://teachengineering.org/view_activity.php?url=http://teachengineering.org/collection/cla_/activities/cla_activity2_energy_conversion/cla_activity2_energy_conversion.xml
- Collect materials and prepare a materials area for students to construct their model wind turbines.
- Make your own model wind turbine that lifts pennies using the blow dryer following the procedure students will follow.
- Elicit the help of parent volunteers for testing days.
- Post/have on hand PowerSleuth puzzles if previously taken down.
- Preview and bookmark websites used in this lesson:

  http://www.teachersdomain.org/resource/phy03.sci.phys.matter.wind/

  http://cr.middlebury.edu/es/altenergylife/turbinecutaway.gif

  http://www.jpmorganclimatecare.com/media/images/low_cardbon_technologies/WindTurbine_diagram_WEB.jpg

  http://www.teachersdomain.org/asset/phy03_vid_zmill/
- Consider taking digital photos. Taking photos throughout this lesson to capture each stage of students at work provides an opportunity to capture a snapshot of students at a particular phase of their work and document their progress. Students can write about and discuss what they were thinking, learning, and doing at that time. This provides another opportunity for individual and group reflection. Photos may be added to students' notebooks or to a wall dedicated to the photos.

Materials

Item	Quantity
Model steam turbine demonstration: • 4 disposable metal pie pans • lightweight metal washer (approximately ½ inch) • heat resistant (metal) funnel • electric hot plate, extension cord, 3 prong adapter • oven mitt • unsharpened pencil • push pin • safety goggles	1 for teacher, assembled in advance. Includes additional pans for making replacement turbines
Blow Dryer	At least 1 for the class
A variety of pinwheel making materials, such as • Heavy duty aluminum foil • Index cards (4 X 6) • File folders • Wax paper • Plastic bags	1 per student (Have spare materials on hand)
Plastic straw	1 per student pair
Unsharpened pencils	1 per student pair
Push pins	1 per student pair
Washers	1 per student pairs
Scotch and masking tape, scissors	Enough for the class
String	Enough for the class
Small paper cups (3 ounce)	1 per student pair
Pennies	Enough for all the cups (approx. 100)
Computer with internet & LCD projector	1 for class
Store bought pinwheel (optional)	1
Pinwheel template (optional)	1
Miscellaneous materials such as: wax coated hanger wire, dental floss, paper, different weight papers, plastic 2 L soda bottles, etc. (optional)	For an extension for students who finish early or want to be challenged further
Scientist's Notebook	1 per student
From Lesson 6: *PowerSleuth* Puzzles	1 set posted
Digital camera (optional)	1 per class

Time Required: 2-4 sessions

Session 1: Steam demonstration and drawing initial design.

Session 2: Constructing and testing turbines.

Session 3: Redesign and test turbines.

Session 3: Debrief design process and discuss real world issues about wind power.

Connection to *Maine Learning Results: Parameters for Essential Instruction*

- Propose a solution to a design problem that recognizes constraints including cost, materials, time, space, or safety. MLR B2 (3-5) b
- Evaluate their own design results, as well as those of others, using established criteria. MLR B2 (3-5) e
- Modify designs based on results of evaluations. MLR B2 (3-5) f
- Present the design problem, process, and design or solution using oral, written, and/or pictorial means of communication. MRL B2 (3-5) g
- Explain that natural resources are limited, and that reusing, recycling, and reducing materials and using renewable resources is important. MLR C3 (3-5) c
- Predict the effect of a given force on the motion of an object. MLR D4 (3-5) a

Teaching The Lesson

Engage

1 Observe and discuss the nature of steam.

Set up the materials for the model steam turbine demonstration in a safe area away from students. Bring a partially filled pot of water to a rolling boil until steam escapes through the funnel.

Call students' attention to the demonstration by asking them what they think it might feel like if they were to put their hand over the pot of boiling water.

> **Safety Note and Caution:** *Prepare and practice this demonstration prior to class. Do not leave the pot of boiling water unattended at any time. Use extreme care in working with students during this demonstration! Electric hot plates and steam are very hot and this is designed as a teacher demonstration for that reason. Students should not be allowed near the hot plate or steam device.* ***Students should not put their hand over the steam!*** *Be sure the demonstration is set up so that the handle of the pot is faced away from the class and that the cord placement eliminates the risk of students tripping.*
>
> **Note:** *Scientifically, steam is vaporized water which can't be seen. As used in common every day language, steam typically refers to the white mist that is often visible above boiling water. This mist is visible because the cooler air above the boiling water causes the water vapor escaping from the boiling water to condense, forming tiny droplets of water, which are suspended in the air. In this exercise, the every day use of the word steam will be used since it is familiar to students at this age.*

Students may say that their hand would get hot or become wet. Use this observation to segue into the notion that steam is "stuff." (If steam wasn't "something," it wouldn't collect on hands.) In more scientific terms, steam is matter and is made up of molecules of water.

> **Note:** *Very often children do not see steam as being "something" or made up of molecules so they struggle with the idea that steam is capable of exerting a force on something.*

Explain that steam is very hot water escaping from the pot. Caution students about this point, noting that steam is very hot and capable of causing severe burns.

Note: *The steam is formed by water molecules being heated so much that they begin to move faster and faster as they get hotter. This causes some of the molecules to break away, change state, and become water vapor (gas). As the water vapor comes into contact with the cooler air above the boiling water, the water vapor cools down, causing the water molecules to slow down and condense, changing back into tiny droplets of liquid water.*

2 Demonstrate model steam turbine.

Show students the model metal turbine. Ask students to predict what they think will happen if the turbine was held over the rising steam and why. Most students may not have thought about steam as a force and may not offer the idea that steam can exert enough force to turn the turbine. Accept students' ideas at this point.

With your hand inside an oven mitt, hold the model (metal pie pan) turbine face down several inches above the steam device and carefully allow the steam to turn the turbine. Ask students to share what they observe and any questions they may have. It may be beneficial to record their questions for further investigation or discussion.

After discussing students' observations, refer to the *PowerSleuth* puzzles used in Lesson 6. Ask the students how the spinning turbine they observed relates to the power generation methods depicted in the puzzles. Remind students of the idea that turbines are key components in electricity generation as evidenced by their presence in all the different electricity generation scenarios pictured. Explain that steam is often used to turn those turbines just like the steam used here turns this model.

Safety Note and Caution: *Immediately following this demonstration, unplug the hot plate and move the pan of hot water and the hot plate to a safe place out of the way where students can't accidentally bump into it while it is cooling.*

Note: *An alternative method for showing steam power can be found at Combustion Demonstration: http://teachengineering.org/view_activity.php?url=http://teachengineering.org/collection/cla_/activities/cla_activity2_energy_conversion/cla_activity2_energy_conversion.xml*

3 Discuss energy technologies in the news.

Say something like: *Energy is a topic that is frequently in the news these days. There is a lot of troublesome news related to energy lately, but what have you read or heard that highlights innovative energy technologies?* Students may be quick to offer energy news that is related to the high cost of energy or that focuses on some of the challenges in meeting society's energy demands. Acknowledge these issues, but maintain focus on the innovative technologies people are introducing as possible solutions to the energy crisis. (Alternately, the teacher can pre-select an "exciting energy news" article to brief students on.) Use this opportunity to explain that humans are amazing at designing solutions to problems. It is very important that students at this age see that problems have solutions and that each problem encountered also offers an opportunity to create an innovative solution.

4 Introduce wind as a resource.

Hold up the model steam turbine and ask students what else besides steam could be used to spin a turbine like our model turbine. Most will have had experiences with pinwheels and will be able to cite wind for an answer. Blow gently on the model turbine. Guide students' discussion by asking how the use of wind to spin the turbine relates to the electricity generation process. Explain to students that in Maine and around the world people have been and are continuing to design and build creative solutions such as wind turbines to address our energy needs. For example, in some places wind farms (a collection of wind turbines in one area) or wind "power plants" are being used to generate electricity. Remind students that wind is an example of a renewable resource.

5 Discuss technological design.

Engage students in a conversation about technological design. Ask about what they have designed and/or built? Extend the conversation by asking if anyone has designed and built something to solve a problem. Accept all answers and encourage creativity in ideas. Explain that humans are still exploring different designs of wind turbines. They are trying to design and build the "most effective" turbine; the ones that will harness the most wind energy, have the safest design, and generate the most electricity. Tell students that they will join this challenge by designing and building blades for a model wind turbine.

6 View "Windmill Gallery."

Say: *Describe what you think a windmill looks like.* Explain that they are about to view a collection photographs showing a variety of styles of windmills and wind turbines. Ask students to pay particular attention to the blades of the turbines in this collection.

View the gallery of photos with students at: http://www.teachersdomain.org/resource/phy03.sci.phys.matter.wind/

Ask students to share what they noticed about the windmills and wind turbines and what they noticed about the blades of the turbines. Consider showing the slide show twice, directing students to pay particular attention to the blades.

Explore

7 **Design a wind turbine.**

Introduce students to the challenge of designing blades for a model wind turbine that will perform a task. Explain to students that instead of generating electricity, the wind energy captured by their model turbine will be used to lift a paper cup filled with pennies. The challenge is to design a turbine using the materials available to lift as many pennies as possible. Explain that a hair dryer will be used as the "wind."

Diagrams of wind turbines are available online:

http://cr.middlebury.edu/es/altenergylife/turbinecutaway.gif

http://www.jpmorganclimatecare.com/media/images/low_cardbon_technologies/WindTurbine_diagram_WEB.jpg

The following clip from the popular public television show ZOOM, can be used to introduce the activity:

http://www.teachersdomain.org/asset/phy03_vid_zmill/

To initiate the process of students designing and building a model wind turbine have students work in pairs to brainstorm suggestions for the following:

- *What do the blades of the wind turbine have to do?*
- *What will they look like?*
- *How can we use the available materials the best way possible?*

Give students time to discuss and record their thinking in their notebooks. Encourage students to try out a few designs by sketching their ideas in their notebooks. Additional instruction on how to capture the details of their design in drawings or diagrams may be needed. Model for students how to draw something using different perspectives and/or close up or cut away views of various parts. Ask students to decide on one design and make a detailed drawing of the turbine that they would like to build. Students' design plans should include labeled drawings and a materials list.

Note: *Each student should record in his or her own notebook.*

8 Peer review.

When students are done designing their wind turbines they will share their designs with another pair of students. During this time, students work together explaining their designs. Peers write constructive comments and questions they have on sticky notes and then post the notes in the reviewed notebook. It may be necessary to define a "constructive comment" or question as those that would help the designer think about their model in a new way and make improvements upon or enhance some aspect of their model. Consider requiring each student to offer one constructive comment and/or one question for the design that they review.

> **Note:** *Review each notebook to get a sense of students' ideas before students begin to build.*

9 Build and test the blades of the turbines.

Provide time to review their designs before they gather materials and build the blades for their turbines. Encourage students to follow their design. As students are working, circulate among students. Ask guiding questions and support students in constructing their models as needed.

> **Note:** *Guiding questions about students' designs are appropriate and helpful. However, it is often tempting to correct a flawed design. Part of the design and building process is the experience of making something that may not work and redesigning and rebuilding it until it does. Be careful not to take that learning experience away from the students.*
>
> *It is easy to place too much emphasis on having students follow their designs rigidly. While following a plan is important, it is also important to balance students' need to experiment with the building process. Often children at this age get so excited with the building process that they don't exactly follow their design or remember to record the changes they make to their designs. Encourage students to keep good records without squelching their excitement, enthusiasm, and creativity that this type of activity brings out. Excitement, enthusiasm, and creativity are all scientific traits that should be encouraged. If students are struggling with following the design/build process then consider allowing a certain amount of time for less structured "free" exploration with the materials prior to the building. Keep in mind that "free" exploration may not be practical if materials are limited and/or if involves cutting or activities that are challenging for teachers to safely monitor.)*

10 Test the blades of the wind turbines.

Coordinate supervised opportunities for students to use the blow dryer(s) to test the blades of their wind turbines as they are being constructed. Consider having each team carefully try their model wind turbine without the lifting of pennies initially. If their model is successful, add pennies to the cup, starting with a penny or two and gradually increase to the maximum number of pennies the turbine will lift.

> **Safety Note:** *Most hair dryers have a cool setting; if so use this setting. If not, be mindful that blow dryers may get hot! Use the utmost caution when using a blow dryer in the classroom especially when students are encouraged to interact with it as they are in this lesson. Go over safety rules with students, including not pointing hair dryers in anyone's face.*
>
> **Note:** *It is rare for a first design to be entirely successful. Repeated attempts are part of the engineering process. When students' trials aren't as successful as they would like them to be, use the opportunity to ask guiding questions to aid in the redesigning of their turbine's blades. Questions can focus on any areas of their turbines that appear to be problematic, such as the quality of the turbine base and blade construction, attachment points of blades, number of blades, size and weight of blades, angle of blades, base height and stability, etc. This is also a good opportunity to remind students that many inventions begin with partially successful or unsuccessful attempts. This is part of the designing and building process and is to be expected. Encourage students to think of these attempts as learning opportunities!*

11 Redesign, rebuild, and retest.

Guide students to use both words and sketches to record their thoughts on what aspects of their first model worked and didn't work. Students can then begin to "tweak" their design on paper using labeled drawings. Once their new designs are entered into their notebooks, they may partner up with their peer reviewers to discuss any new design elements. As before, peers use sticky notes to add constructive comments and/or questions to their peer's notebooks. Once students have reviewed their new designs with peer reviewers, they may move on to rebuilding and retesting.

> **Note:** *As tempting as it may be to eliminate this step due to time, the redesigning, rebuilding, and retesting process is an integral component of the design process.*

Reflect And Discuss

12 Reflect in notebooks.

Once building materials have been cleaned up and put away have students take a few minutes to reflect and write about their experiences in their notebooks. Include the following:

- *What parts of my model turbine worked well _________*
- *If I could redesign the blades of our wind turbine again I would _________ because _________*
- *How do you think that wind energy could be used to generate electricity for a community?*
- *What else besides blade design would need to be considered before building wind turbines in a community?*
- *If you were asked to build a turbine that utilized the energy from falling water, how would the turbine blades be similar to and different from the turbine blades you constructed for wind?*

13 Debrief the experience as a large group.

After students have finished writing in their notebooks, have them bring their notebooks to the group area for a class discussion. In addition to discussing the questions above, ask questions that focus students on their designing and building experiences. For example:

- *What were some challenges you and your partner experienced during this process?*
- *What parts of the designing and building process were most challenging or difficult?*
- *What was the purpose of having the chance to redesign your model?*
- *What are some design characteristics that made turbines successful?*

14 Bring lesson to a close.

Compare students' designing process and their models to "real world" applications of energy issues and solutions. Explain that there are and always will be problems with all types of electricity generation; there are always positive aspects and negative aspects for every resource and design used. Problems include finding enough resources to generate electricity in nonpolluting and safe ways as well as designing new machines that use new types of resources. The exciting part is that there are people who have jobs studying energy and designing machines like wind turbines. They work together creatively to solve our world's energy crisis.

> **Note:** *This is a nice time to make the connection to careers. Use the careers section of the Energy Lights Maine website to look for ideas to include in this discussion/exploration.*

Extensions

Student may:

- improve their models using additional materials. Aluminum foil, wax paper, different weight papers, tissue paper, manila folders, various plastics (recycled milk jugs and/or butter tubs) allow for added creativity.
- engage in additional activities related to using wind as an energy source. The 4-H Youth Development Program has developed an in-depth curriculum called *The Power of the Wind*. Materials can be accessed at and are available for use at no charge at: http://projects.4-hcurriculum.org/curriculum/wind/
- make a waterwheel. Simple waterwheel instructions can be found on the ZOOM website: http://pbskids.org/zoom/activities/sci/waterwheel.html or at http://www.youtube.com/watch?v=x8xow_R0YRI
- visit a wind turbine site in Maine.
- measure the wind speed around the school's campus to determine best place for a wind turbine at school. Directions for making a simple wind anemometer can be found at: http://www.ciese.org/curriculum/weatherproj2/en/docs/anemometer.shtml
- investigate where and why does the wind blow. Study the two wind resource maps found on the US Department of Energy's website: http://www.windpoweringamerica.gov/wind_maps.asp *What do these maps tell us about wind as a resource in different parts of the country?*
- find the locations of wind turbines in Maine.
- measure the weights of the coins lifted by their models.
- explore the uses of wind energy in schools:

  MSAD 3 considers using wind turbine to cut energy costs: http://www.unity.edu/News/wwind107.asp

  US map showing states with Wind Energy for Schools Project Locations: http://www.windpoweringamerica.gov/schools_projects.asp#ME

Connection to Maine Agencies

MEEP (Maine Energy Education Program) has PV Fan and Mini-Wind Turbine activities where students make electricity from renewable resources. A representative from MEEP will come to interested schools, free of charge. The MEEP website is: http://www.meepnews.org/classroomactivities

For schools in Aroostook County, a Maine Public Service (MPS) representative will come to interested schools, free of charge, to guide and support concepts developed in this lesson. A description of programs is available at www.mainepublicservice.com. Click on the education section of the site. To schedule a visit contact Nancy Chandler at 207.760.2556 or nchandler@mainepublic service.com.

The Power of the Wind is part of a 4-H national curriculum designed for middle school aged youth. This comprehensive guide examines wind power in-depth through hands-on investigations and is applicable to the classroom setting. Guides and additional support materials can be accessed through: http://projects.4hcurriculum.org/curriculum/wind/.

Website includes information about 4-H wind power afterschool clubs in Maine.

Constructing a Model Steam Turbine

This model steam turbine uses a small, partially filled pan of water, a hot plate, two aluminum pie pans, a pushpin, a small metal washer, and a heat resistant funnel. When the pie pan and funnel are put over a small pan of boiling water, steam from the boiling water is forced up through the top opening of the pie pan and through the funnel. The force of the steam exiting through the top of the funnel turns the blades of the model turbine constructed out of a metal pie pan. The step by step directions that follow include two parts: 1) how to set up and construct steam emitting device, and 2) how to construct the model steam turbine.

Safety note: *Use caution when cutting metal pie pans–edges are sharp!*

Construct steam directing device

1) Use the funnel to trace a circle onto the center of one aluminum pie pan. The hole should be approximately ½" smaller than the traced circle. This makes the hole smaller than the funnel itself. This is important so the funnel can sit on top of the pie pan without falling through the hole. The top of the pie pan also needs to be flush with the funnel, to prevent steam from escaping between the pie pan and funnel.

2) Refer to diagram – Cut a small opening to allow a spot for the pot handle to go. This will allow the pie pan to stay level with the pot of boiling water while being used.

Construct model steam turbine

1) Cut the circular bottom off of the second metal pie pan. Discard sides.

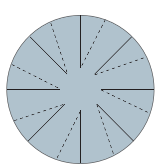
2) Refer to the diagram of the model steam turbine blade arrangement – Using a ruler and pencil; divide the cut circular pie pan bottom into halves, then fourths, then eighths. Create eight blades by cutting partway up the lines, stopping at the inner circle markings found on most pie pans.

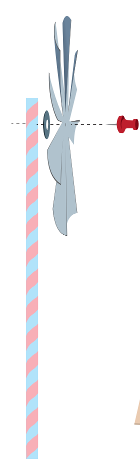
3) Take one side of each blade and carefully it bend up (as indicated by the dashed lines in the diagram) so that all of the blades are curved up on the same side of the blade. The blades may need adjusting as the turbine is being used.

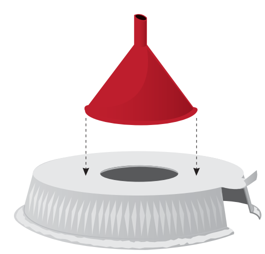
> **Note:** *Consider making a spare turbine out of the extra pie pans in advance. After use, the models can become bent and somewhat difficult to use.*

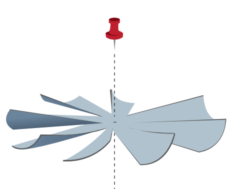
4) Place a washer between the pencil and turbine before securing the turbine to the pencil. This maintains a small gap between the turbine and pencil allowing the turbine to move freely. Use a pushpin to attach the turbine to the eraser of an unsharpened pencil as shown in the diagram.

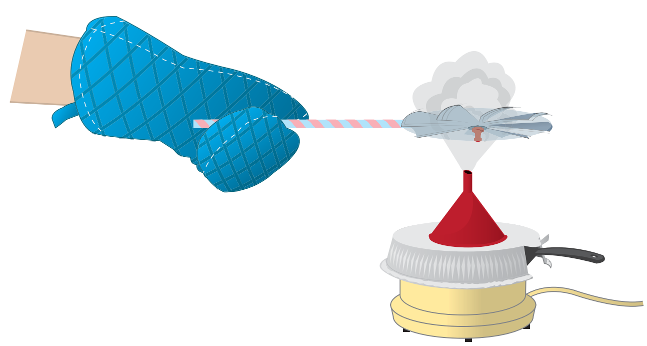
5) To demonstrate steam turning the turbine, hold (cover hand with oven mitt) the turbine blades down over the steam escaping from the funnel.











Online References and Resources

Energy Education Group. (2005). *Energy for Keeps: Electricity from Renewable Energy*. Tilburon, CA: Energy Education Group. www.energyforkeeps.org

Energy Quest:
http://www.energyquest.ca.gov/story/chapter16.html

KidWind Project:
http://www.kidwind.org/

Wind with Miller:
http://www.windpower.org/en/kids/index.htm

Wind with Miller's Crash Course:
http://www.windpower.org/en/kids/intro/

Additional Print Reference:
A first energy grant: ***Pinwheel electrical generation*** article in NSTA's *Science Scope* magazine, October 2007, Volume 31, Number 2, page 74-76