Lesson 6: Testing Heat Transfers through Different Materials

Overview

Students continue investigating heat transfers, focusing on transfer by conduction. By performing a simple experiment, students discover that heat is conducted through different materials at different rates. They put their knowledge of heat transfers to use in everyday situations.

Teacher Background

If you've ever wrapped your hands around a cup of hot chocolate, you've felt heat transfer through conduction. The heat from the hot chocolate transfers through the cup to your hand. Remember that heat is transferred from warmer matter to cooler matter. Let's examine the role the cup plays in the transfer of the heat. When the hot water is poured into the cup the cup is a different temperature than the hot chocolate. The different temperatures set the stage for a heat transfer to occur. Does the material the coffee cup is made from make a difference? Different materials conduct heat differently. Pure metals conduct heat more rapidly than mixed metals due to their closely packed molecular arrangement. Other materials such as wood, plastic, and glass do not conduct heat well. Thermal conductivity is a property – a property that refers to a material's ability to conduct heat. Different materials are given different thermal conductivity values.

Engineers apply knowledge of thermal conductivity in designing a number of items, including cooking utensils, heating systems, buildings, bridges, plastics, mechanical devices, food processing technologies, and so on. Middle school students can begin to appreciate and understand why different materials are selected for particular goods as they come to understand thermal conductivity as a property. In this lesson, students put their developing knowledge to use by considering why certain materials are used for particular items.

Key Ideas

- Different materials conduct thermal energy at different rates. Metals conduct heat rapidly. Plastic and wood do not conduct heat rapidly.
- Some materials conduct heat better than others. Knowledge of thermal conductivity differences is used to develop safe and efficient products and technologies for people.

Lesson Goals

Students will:

- recognize that a thermal conductor is a material that allows heat to readily transfer through it.
- recognize that heat is conducted at different rates through different materials.

Vocabulary

conduction: the transfer of heat through material by direct contact.

conductor: substance that allows heat to flow through it.

thermal conductivity: the rate at which heat passes through a specified material or the property of a material that indicates its ability to conduct heat. Also heat conduction is transfer of thermal energy through matter, from a region of higher temperature to a region of lower temperature and acts to equalize temperature differences.

Preparation

- Set up stations in different areas of the classroom for each sample. Place enough containers, thermometers, and measuring devices for each group at the stations as well.
- Prepare enough hot water for each student group to fill a dishpan. Hot tap water may be sufficient.

Safety

This investigation requires the use of hot tap water. Use caution to make certain that students would not be accidentally burned if water contacts their skin.

Materials

Item	Quantity
Brownie mix package (prop)	1 per class
For each group: • 4-250 mL containers • 5 thermometers • dishpan or baking tray • Enough for each group to have a 200 mL sample of: sand or crushed rock, metal BBs or pennies, glass marbles (small decorative aquarium/floral type), shredded paper or cotton balls	1 set per group
Stopwatches or access to timer that displays minutes and seconds	1 per class or 1 per student group
Hot water	enough to partially fill each group's dishpan or baking tray
Scientist's Notebook	1 per student
Student Handout 6.1 (optional): Heat Transfer through Different Materials	1 per student
Graph paper (optional)	1 per student
Temperature probes (optional)	1 or more based on availability

Time Required: 1 session

Connection to *Maine Learning Results: Parameters for Essential Instruction (MLR), National Science Education Standards (NSES), & Benchmarks for Science Literacy (BSL)*

- Heat moves in predictable ways, flowing from warmer objects to cooler ones until both reach the same temperature. NSES B (5-8)
- Describe how heat is transferred from one object to another by conduction. MLR D3(6-8) j
- Thermal energy is transferred through a material by the collisions of atoms within the material. Over time, the thermal energy tends to spread out through a material and from one material to another if they are in contact. BSL 4E/M3* (6-8)
- Design and safely conduct scientific investigations including experiments with controlled variables. MLR B1(6-8) b
- Explain why it is important to identify and control variables and replicate trials in experiments. MLR C1(6-8) b
- Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems. BSL 3C/M8**

Teaching The Lesson

Engage

1 Engage students in a "quick write."

Bring in a boxed brownie mix. Describe the following scenario: Comment to students that you noticed the directions listed different cooking times for the brownies depending on the type of baking pan used. (Consider reading the cooking directions from the box aloud to students.) Ask students to do a quick write in their scientists' notebooks in response to the following prompt: *Why do you think different cooking times are listed for different baking pans? How is this related to what you have learned about heat transfers?* Use sketches and words to explain your thinking.

Have a few students share their quick write responses. Summarize students' comments and use them to segue into the activity.

Explore

110

2 Introduce the investigation by examining different materials.

Ask students: *Have you ever been outside on a playground on a very hot sunny day and touched a metal slide or swing set? Or maybe you've walked on a paved road in your bare feet? Did you have to quickly hop from the pavement to a grassy patch because your feet were getting too hot? Do you think these objects were at different temperatures – even if it is the same temperature outside? How can this be explained in terms of heat transfer?*

Allow students to discuss their ideas. Explain that different materials transfer heat at different rates. When an object absorbs heat, the thermal energy is spread out among the molecules in the substance. The greater the amount of energy, the faster the molecules vibrate.

Give each group of four students a small sample of materials that will be tested: sand or crushed rock, metal BBs or pennies, small glass marbles, shredded paper or cotton balls. Explain that they will be using these materials to investigate whether heat is transferred at different rates through different materials.

Ask students to examine each of the items and to describe what material each item is made out of in their scientists' notebooks. Encourage students to include touch in their description of the materials.

Ask: *How do you think heat will be transferred in these materials?* (Heat is transferred through conduction – direct contact between the various items in the containers. As each sample is warmed up by the hot water bath, heat will move through the samples differently.)

3 Make predictions and review investigation procedures.

Instruct students to make a prediction and record it in their scientists' notebooks:

- *Which material do you think heat will transfer through the fastest and which material do you think heat will transfer through the slowest?* Consider providing students with the following frame (post on the board): I think ________ because________.

> **Note:** *Clarify that monitoring the change in temperature will determine the rate of transfer. For this investigation the material that has the highest final temperature will be the considered the material that transfers heat most rapidly and the material that has the lowest final temperature will be considered the slowest.*

Ask students to develop a way to record their data in their scientists' notebooks or distribute a copy of Student Handout 6.1: *Heat Transfer Through Different Materials* to each student.

Explain to students how they will test materials. Each person in the group will be responsible for obtaining a 200 mL sample of one of the materials by going to one of the material stations around the room. Demonstrate how to fill the container part way with the test material, insert the thermometer, and then continue filling the container to the 200 mL mark.

> **Note:** *Instruct students to use caution and to not push too forcefully when filling their containers so they do not break the thermometers.*

Ask students what the starting temperature is for all of the test materials. Point out to students that the starting temperatures of all of the test substances is the same – they are all room temperature. Students may have to verify this for themselves when they go to get their group's sample.

While students are collecting their preparing their test samples, place a dishpan or baking tray on each group's table. Once all students have obtained a test sample and recorded the starting temperature of their sample, direct students to place their samples in the dishpan or baking tray. When all students are seated, fill each group's pan or tray with enough hot water to raise the level just below the tops of students' samples. Instruct students to be careful not to spill any water into their sample.

Prompt students to measure and record the initial temperatures (established previously) of their samples and the hot water bath.

4 Conduct the investigation.

Have students measure and record the temperature of their samples and the hot water bath every 2 minutes for 10 minutes. Monitor students as they conduct their investigation, reminding them to use care to not splash water into their samples and to not break their thermometers.

Have each student pour their sample into the waste container at the appropriate stations. Ask students to make a bar graph of their findings (sample along the x-axis, temperature along the y-axis).

Reflect And Discuss

5 Discuss students' findings.

Gather students for a scientists' meeting. Ask students to respond to the following:

- *How did your group's results compare to your prediction? Do different materials transfer heat at different rates?* (If there were differences, discuss with students why they think there were differences. This is a good opportunity to discuss past experiences students have had and which they used as a basis for their predictions.)
- *Why is heat transferred?* (Heat is transferred due to temperature differences among the items.)
- *How did heat transfer in the investigation?* Use words and sketches (or diagrams) to explain the transfers that occurred. (Students should indicate the direction of transfer and indicate that the rate of transfers differed.)

Review students' investigation findings and discuss the heat transfers that occurred during this investigation. Explain to students that some materials are better conductors of heat than others. Ask students where they have heard the word conductor or conduction before. The word conduct is from Latin meaning "brought together." Good conductors transfer heat readily through materials and poor conductors do not transfer heat readily. Ask students to suggest materials that they are familiar with that are good conductors of heat and those that are poor conductors of heat. Explain to students that scientists actually rank or have a formula to figure out different materials' ability to conduct heat and refer to this property as *thermal conductivity*. Different materials have different thermal conductivity values.

Note: *The term "thermal conductivity" is one worth introducing, using, and discussing. However it is not expected for students to memorize this phrase.*

Revisit the brownie baking pan times listed on the mix box. Discuss the need for listing these differences in terms of thermal conductivity. Encourage students to think of other items that they may use in their kitchen. Are there certain objects that people don't want heat to readily travel through and vice versa?

(Examples might include the handles of pots, pans, and spoons) After students have made some suggestions, ask them to think of examples for other areas of their lives.

6 Summarize and bring the lesson to a close.

Revisit the question posed at the beginning of the lesson. Ask students to reflect on their learnings for the day to help them answer the question:

- *Why do you think different cooking times are listed for different baking pans?*
- *How is this related to what you have learned about heat transfers?*

Elaborate on this discussion by asking students to connect what they've learned to spoons, handles of pots and pans, and other items used in the kitchen. What types of materials are these items made out of? What are the pros and cons of various designs? Consider asking students to continue their investigation of these items or other items outside of class.

113

Extensions

Student may:

- repeat the investigation using an ice water bath or by testing other materials (i.e., rice, oil, water).
- investigate why certain materials feel cooler than others. Consider administering the task "Objects and Temperature" from *Uncovering Student Ideas in Science: 25 Formative Assessment Probes* Volume 1 (see references for full citation). Discuss the following: Why do you think some materials feel colder than others? What is going on in terms on heat transfer?
- experiment with brownie baking. Cook brownies using different types of pans, glass versus metal and compare the cooking times or cook brownies for a certain length of time and rank their "doneness."

- build a simple water heater using PBS's Design Squad's: Feel the Heat project.
- be interested in learning about another matter related to heat; the expansion and contraction of objects as the temperature changes. This "Snack" from the Exploratorium, Cool Hot Rod, demonstrates this concept: http://www.exploratorium.edu/snacks/cool_hot_rod/index.html

Connection to Maine Agencies

A Maine Energy Education Program (MEEP) is a no cost resource for schools and teachers in Maine. MEEP representatives and will come to interested schools, free of charge, to guide and support the concepts in lesson and have programs that supplement concepts in this lesson:

- School Energy Efficiency Investigation: Students use tools to see how their school uses energy and where energy is wasted. Tools include an infrared thermometer, a temperature/humidity datalogger, a light meter and a Kill A Watt meter. Students can then make recommendations on how energy can be conserved in their school. This project can be combined with the Greenhouse Gas Surveys being offered by Maine DEP.

More information can be found on the MEEP website: 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 presentation contact Nancy Chandler at 207.760.2556 or nchandler@mainepublicservice.com.

Online References and Resources

Lesson adapted from: Teach Engineering: How Much Heat Will it Hold? http://www.teachengineering.org/view_activity.php?url=http://www.teachengineering.org/collection/cub_/activities/cub_energy2/cub_energy2_lesson06_activity2.xml

Texas State Energy Conservation Office and the U.S. Department of Energy. Lesson 9: Testing Materials for Thermal Conductivity. Austin, TX. http://www.infinitepower.org/pdf/09-Lesson-Plan.pdf

Heat Transfer through Different Materials

Time	Sample Materials			
	Sand	Shredded Paper	Metal BBs	Glass Marbles
0				
2				
4				
6				
8				
10				

Heat Transfer through Different Materials

Time	Sample Materials			
	Sand	Shredded Paper	Metal BBs	Glass Marbles
0				
2				
4				
6				
8				
10				

Lesson 7: Building an Insulated Water Bottle

Overview

Students investigate the insulating properties of a variety of materials. Using their knowledge of heat transfers, students design an insulated water bottle.

Teacher Background

In the previous lesson students explored the conductivity of different materials and recognized that certain materials conduct heat better than others. In this lesson, students are asked to use their knowledge of conductivity to design a bottle that keeps water cold. This will require students to shift their focus to materials that do not transfer heat readily. These materials are known as insulators. One must use caution in thinking about conductors and insulators as definitive categories. Rather they fall along a continuum. Clearly some materials such as copper are on the conductor "end" of the continuum and materials like paper or wood are on the insulating "end" of the continuum. When selecting materials for a particular task or item, keep in mind that each material's limitation could prove to be another materials' strength- it all depends on the purpose. Thankfully, people wouldn't make mittens out of copper, an effective conductor. Wood, paper, cloth, and air are poor conductors of heat but are effective insulators.

Insulators have helped humans stay warm or cool for thousands of years. They have also been used to keep food warm and cool. Think of the mitten in the first lesson. People wear mittens when they want to slow down the transfer of body heat to the surrounding cooler environment. People use mittens as a kind of barrier between warm and cold air. Yet some mittens seem to be more effective than others at doing so. Why? Is it the thickness of the mittens, the material the mittens are made of or, could it be a combination of both? Perhaps the size of the mitten plays a part. Larger mittens enable the use of air space trapping molecules, whereas tighter fitting mittens do not. Which works better? Think about the old advice of wearing layers to keep warm. Layered clothing traps air between each layer thus cumulatively adding in the fabric's insulation effects and reducing the loss of body heat. As the mitten demonstrates, insulation is used to provide a barrier that minimizes the transfer of heat. Insulators can be used to keep items cold or hot. They do so by minimizing conduction, convection, and/or radiation.

What properties make "good insulators?" Density plays a role. The further apart atoms are from each other, the more difficult it is for a heat transfer to take place. Because of this gases such as air, which molecules are spread far apart, make better insulators in general than liquids. The molecules of liquids are further apart than solids making liquids in general better insulators than solids. By removing the atoms altogether (as in a vacuum), heat transfer by means of conduction and convection is eliminated, but radiation comes into play.

Heat transfer by radiation presents other considerations. Ever notice that many thermoses are made of reflective or shiny material? If a thermos is full of hot soup the shiny surface inside the thermos wall reflects the heat (infrared radiation) of the hot soup back to the hot soup keeping the soup hotter for longer periods of time. Why are people urged to wear white clothing in the summer as opposed to dark colors? White reflects heat and light better than dark colors and keeps the person cooler. Dark colors absorb light and heat more than light colors. Many items, such as home insulation, auto shades, space suits, hot/cold food bags, ice cream containers, etc. are also reflective and are used as insulators for that reason.

The focus of this lesson for students is, "How can knowledge of conductors and insulators be used to keep ourselves and different items warm or cool?

Key Ideas

- Different materials conduct thermal energy at different rates. Metals conduct heat rapidly. Other materials, such as plastic and wood, do not conduct heat rapidly.
- Knowledge of thermal conductivity differences is used to develop products and technologies that allow people to safely and efficiently use heat.
- Depending on how they are used, materials can be used to slow or accelerate heat transfers.

Lesson Goals

Students will:

- recognize that a thermal conductor is a material that allows heat to readily transfer through it.
- recognize that heat is conducted at different rates through different materials.
- use their knowledge of heat transfers to design an insulated water bottle.

Vocabulary

(thermal) conductor: a material that conducts heat well and quickly; metal is a good thermal conductor.

(thermal) insulator: a material used to reduce the rate of heat transfer.

Preparation

- Determine whether students will be responsible for bringing in insulating materials or whether the teacher will gather the investigation materials.
- Collect empty sports drink plastic bottles or other uniformly sized/shaped bottles. Each student will need one bottle. Have a few extra bottles on hand – one will be used as a "control."
- Consider how often temperature in the insulator bottles will be taken – some prefer every 3 minutes; others take an initial temperature at the beginning of the class and another at the end of the class.

Safety

The first part of this investigation requires the use of hot tap water by students. Double check the temperature of the school's hot water to make certain students would not be accidentally burned if water contacts their skin.

Materials

Item	Quantity
For student experiment: • 4-500 mL containers (beakers) of hot tap water (Alternatively, could use insulated take out coffee cups with covers- this eliminates the need to cover cups with plastic wrap.) • 4 thermometers • plastic wrap to cover containers and “contain” insulating material around bottles.	1 per group of 4 students
Stopwatches or access to timer that displays minutes: seconds	1 per class or 1 per student group
A variety of insulating materials: • Aluminum foil • Packing peanuts • Fiber fill • Shredded or crumpled newspaper • Sawdust • Sand • Plastic bags • Cloth (samples of cotton, wool)	Enough for class (Students could be asked to bring items from home.)
Gallon size resealable bag	1 per student pair
Large storage tube (38 quart or suitable size)	1 per class
Hot tap water in storage tub	1 per class
Thermos and/or insulated hot/cold food bag – now available in many grocery stores (prop)	1 per class
Chilled (refrigerated) water (enough for students to fill insulated bottles)	1-2 gallons per class
Scientist’s Notebook	1 per student
Student Handout 7.1: Insulation Investigation Planning Guide Student Handout 7.2: Sample Data Tables and Sample Graphs Students Handout 7.3: Keeping It Cool: Building an Insulated Water Bottle	1 per student

Time Required: 3-6 sessions

Session 1: Discuss insulation and plan in groups

Session 2: Conduct investigation

Session 3: Graph and discuss

Session 4: Plan for new insulation challenges; peer review

Session 5: Carry out the insulation challenges

Session 6: Discuss results; The Mitten Problem Redux

Connection to *Maine Learning Results: Parameters for Essential Instruction (MLR), and National Science Education Standards (NSES), and Benchmarks for Science Literacy (BSL)*

- Describe how heat is transferred from one object to another by conduction, convection, and/or radiation. MLR D3(6-8) j
- Heat moves in predictable ways, flowing from warmer objects to cooler ones until both reach the same temperature. NSES B (5-8)
- Thermal energy is transferred through a material by the collisions of atoms within the material. Over time, the thermal energy tends to spread out through a material and from one material to another if they are in contact. Thermal energy can also be transferred by means of currents in air, water, or other fluids. In addition, some thermal energy in all materials is transformed into light energy and radiated into the environment by electromagnetic waves; that light energy can be transformed back into thermal energy when the electromagnetic waves strike another material. As a result, a material tends to cool down unless some other form of energy is converted to thermal energy in the material. BSL 4E/M3* (6-8)
- Design and safely conduct scientific investigations including experiments with controlled variables. MLR B1(6-8) b
- Explain why it is important to identify and control variables and replicate trials in experiments. MLR C1(6-8) b
- Design a solution or product. MLR B2 (6-8) b
- Communicate a proposed design using drawings and simple models. MLR B2 (6-8) c
- Evaluate a completed design or product. MLR B2(6-8) e
- Suggest improvements for their own and others' designs and try out proposed modifications. MLR B2(6-8) f

Teaching The Lesson

Engage

1 Engage in introductory discussion about insulators.

Open the lesson by noting that there are a number of situations in which the transfer of heat is problematic. People have developed a number of ways to influence and regulate heat transfers by putting their knowledge of how heat is transferred into action. They develop technologies that are effective in slowing the rate of transfer or speeding up the rate of transfer. Let's consider a few examples:

> **Note:** *Consider gathering a few of the items mentioned below as props for the discussion.*

- *When it's cold outside, what do you put on before going out?* (People might wear a sweater or jacket, mittens) *Why? Where is heat coming from and where is it going?* (Clothing insulates or slows down the transfer of heat from your body to the environment.)
- *Do you think some clothing material helps keep a person's heat from transferring better than others?* (Students may suggest down, wool, fleece are insulating materials.)
- *What do you use to take a pan of brownies out of a hot oven?* (People protect their hands with an oven mitt or use a potholder.) *Why?* (The mitt prevents heat from being transferred from the hot pan to your hand.)
- Ask students to suggest other devices they may have used or are familiar with that decrease or increases the rate of heat transfers. As students make their suggestions, discuss how heat is being transferred in each of the situations. (Cookware, firefighter's clothing, wetsuits, machinery, etc.)
- *How do people influence the heat transfers that occur in their homes and other buildings? In other words, what features do buildings have that aid in temperature regulation?* (People have heating and cooling systems of various sorts; insulation, windows, etc.)

Explain that in this lesson students will be exploring insulators. Discuss with students what an insulator is, how it is different than a conductor, and ask students to give examples of insulators they are familiar with. Students can think of insulators as materials that slow the rate of heat transfer.

Note: *As students share what they know about insulating materials listen carefully to gauge whether students (still) believe that certain materials are inherently warm or cold. As this lesson proceeds, consider having students monitor the temperature of the insulating materials throughout the investigation (beginning, middle, end) to help students overcome this persistent idea.*

Alternately, divide students into groups of 4 and have them discuss what they think will make a good insulator and why. Assign each student the task of bringing in one of the items chosen for testing. Have groups plan what each student is bringing in so there are no repeat test materials within a group. Wood shavings, scarves, dirt, mud, dog hair, horse hair, wool, aluminum foil, toilet paper, and mittens are items students may choose to test. Discourage students from bringing in housing insulation. Eliciting the help of students in gathering materials piques students' curiosity.

Explore

2 Introduce the investigation.

Explain that they will be planning and carrying out an investigation that explores the effectiveness of different types of materials as insulators. Each student group of 4 will select 3 different materials to insulate containers filled with 500 mL of hot tap water to determine which material has the best insulating properties. One container will serve as the control.

Alternately, student groups can be (randomly) assigned insulation types to test as a way to make certain all insulation types are investigated.

A variety of insulating materials should be available to students. Label each type. As students begin planning their investigation, encourage students to examine the different materials before deciding which materials their group would like to compare and before students make their predications.

Distribute a copy of Student Handout 7.1: Insulation Investigation Planning Guide to each student. Allow students time to plan their investigation using the guide. Direct students to record their investigation plan in their scientists' notebooks. Assist students as needed. Note any common questions or difficulties that arise as students are planning and address appropriately in the discussion that follows.

3 Review investigation plans.

Before students begin, discuss the following:

- *What variables are there in this investigation?* (insulation materials)
- *Which variables are you changing?* (Students should only change the different insulation materials- everything else should remain the same in order for this to be a fair test: the container size, the amount of water, starting temperatures, taking temperature readings – all should remain constant.)
- *How will you know if the material is having an effect- slowing down the transfer of energy?* (Students should recognize that a control container is needed; one container that has not been insulated should be monitored as well and will be used for comparison.)
- *How often should temperature readings be taken during the investigation?* (Recommend that students take readings every 1-2 minutes.)
- *How will you record your observations?* (tables, graphs, observations) Alternatively, guide students in creating data tables and graphs or provide students with the sample data table found on Student Handout 7.2: Sample Data Table and Sample Graphs.

> **Note:** *Make certain that students have made a prediction prior to beginning their investigation. Give students a few minutes to make necessary edits to their plans.*

4 Conduct the investigation.

Instruct students as to how to obtain the necessary investigation materials including how to safely access and measure hot tap water. Demonstrate for students how to unwrap or nest the insulating materials around the outside of the container. As students conduct their investigation, circulate among students, monitor student progress and ask questions that focus on student understanding.

Reflect And Discuss

5 Review, analyze, and discuss data.

Ask students to create a graph of their findings and write a conclusion supported with evidence in their scientists' notebooks. Gather students together for a scientists' meeting. Discuss the following:

- *What conclusions did you make?*
- *Were there differences in data?*
- *Were there differences in the way different groups conducted their investigation?*
- *Based on the data, which insulation slowed the transfer of heat the most? Which insulation slowed the transfer of heat the least?*

- *What is the source of heat in the investigation?* (Discuss the idea that the insulator is not a heat source. Be sure students recognize that insulators slow heat transfers. Ask students what temperature the insulating material is and/or monitor the temperature of the insulating materials as well to help students overcome the idea that some materials are inherently “hot” or “cold.”)
- *If you could do the investigation again, what materials would you try?*
- *What new questions do you have about insulators and heat transfers*

6 Present new insulation challenge

Show students a thermos and/or an insulated (hot/cold food) bag that are available at many grocery stores. Ask students what they think these items would be used for. Students may not have thought about the possibility of using them to keep food like iced tea or frozen food cold on one day and then the next day use them to keep something like soup or pizza hot. *How is this possible?* Pass around the items and allow students to closely examine the materials from which these are made. While the items are being passed around the class, ask students to write about how they think these items can be used to keep things both cold and hot in their scientists' notebooks.

Once the items have been examined, ask if students think the insulating materials they investigated earlier could also be used to keep something cold.

Give each student a copy of Student Handout 7.3: Keeping it Cool: Building an Insulated Water Bottle and review the criteria. Make sure the students know ahead of time that their insulated water bottles will be placed in water – that might affect the choice of insulating materials. Explain that students will be working in pairs to plan, construct, and test an insulated water bottle. Ask student to bring their materials to school and consider giving students a 20 minute time limit to construct their bottles.

7 Construct insulated bottles.

Give students 20 minutes to construct their insulated water bottles following their plans. Students should wrap each bottle in plastic wrap to keep chosen insulation snug. Then put the bottle in plastic bag.

8 Examine peer's designs.

Ask students to place their insulated water bottle on their desks or in a designated area. Give each student pair a pad of sticky notes. Allow students a few minutes to examine the bottles created by their peers. As they examine the designs of their peers, ask students to write down a constructive comment, a suggestion, or question about the design and stick it on the desk next to the bottle. After students have had a chance to examine the different designs, share some of the comments that have been written on the notes with the class. Be sensitive to students' feelings when sharing comments and consider paraphrasing, posing comment as a question, or eliminating comments if they are inappropriate.

> **Note:** *Take time to discuss the purpose of share ideas and the need to maintain respect for each other while writing and reading comments.*

9 Test insulated water bottles.

Fill a container, large enough for all insulated bottles to fit inside, with hot tap water. The hot water tub will simulate a hot day. Have each pair fill their water bottle with a uniform amount of refrigerated (chilled) water. Fill an extra bottle with the same amount of refrigerated temperature water to serve as the control. Have students take and record the starting temperature of the refrigerated water. Have students test their insulated bottles by placing their bottles in the hot water tub.

After 3 minutes have students check and record the temperature and again every 3 minutes. Alternatively, have students take an initial temperature at the start of class and then take the temperature at the end of class. Have students calculate the total temperature change in their scientists' notebooks.

Prepare and post a class data chart on the board, on an overhead, or a computer data collection program. Have students add their data to the class data chart.

10 Review findings and reflect on designs.

Review class data and discuss findings with students as before. Consider asking students to reflect upon some or all the following prompts before meeting.

- *What conclusions did you make?*
- *Describe how your bottle work compared with others in your class.*
- *Based on the class data, which types of insulated bottle designs slowed the transfer of heat the most?*
- *Why did you design the bottle the way you did? Use your knowledge of heat transfers to explain.*
- *If you could redesign your bottle, what changes would you make and why?*
- *What new questions do you have about insulators and heat transfers?*

11 Revisit *The Mitten Problem* Redux.

Provide each student with Student Handout 7.4, *The Mitten Problem* Redux. Ask students to complete the task. Collect and review students' ideas.

Extensions

Student may:

- investigate early refrigeration methods ("ice box"). Ice houses and root cellars were commonplace in earlier times.
- View how ice was harvested from Maine lakes by the Sebago Ice Company. This 5 minute narrated clip, *Ice Harvest*, has uneven but discernable audio. Ice Harvest Sampler, 1930s-1940s, footage provided by Northeast Historic Film, www.oldfilm.org To view movie clip go to: http://windowsonmaine.library.umaine.edu/fullrecord.aspx?objectId=6-2400 click on "Moving Image"
- view *How Do You Keep Lemonade Cool?*, a video clip adapted from *FETCH!*™ which shows two cast members teaming up to take on a design challenge: Make a lemonade stand that keeps lemonade cool and is sturdy and transportable. Teachers may like to show this to students in conjunction with their insulated bottle challenge. http://www.teachersdomain.org/asset/eng06_vid_lemonade stand/
- read *A Chilling Story: How Things Cool Down* (1991) by Eve and Albert Stwertka. This book describes cooling by heat transfer, cooling by evaporation, and cooling by expansion. It also has chapters describing how refrigeration and air conditioning works.

Connection to Maine Agencies

A Maine Energy Education Program (MEEP) is a no cost resource for schools and teachers in Maine. MEEP representatives and will come to interested schools, free of charge, to guide and support the concepts in lesson and have programs that supplement concepts in this lesson:

- **School Energy Efficiency Investigation:** Students use tools to see how their school uses energy and where energy is wasted. Tools include an infrared thermometer, a temperature/humidity datalogger, a light meter and a Kill A Watt meter. Students can then make recommendations on how energy can be conserved in their school. This project can be combined with the Greenhouse Gas Surveys being offered by Maine DEP.

More information can be found on the MEEP website: 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 presentation contact Nancy Chandler at 207.760.2556 or nchandler@maine publicservice.com.

Online References and Resources

Lesson adapted from **Utah Education Network** in partnership with the Utah State Office of Education and the **Utah System of Higher Education**, Insulation ExperimentationLesson.
http://www.uen.org/Lessonplan/preview.cgi?LPid=21569

Chicago Science Group. (2007). *Science Companion: Energy*. Lesson 7: Building a Better Water Bottle. USA: Chicago Science Group and Pearson Education, Inc.
http://www.sciencecompanion.com

Houck, C. (2000-5). *Insulators, Conductors, and Energy Transfer*. Beacon Learning Center, U.S. DOE Technology Innovation Challenge Grant.

How Stuff Works: How Thermoses (Vacuum Flasks) Work:
http://www.howstuffworks.com/thermos.htm

Explanation of Insulation R-values: http://www.school-for-champions.com/science/thermal_insulation.htm

Article: Gas Filled Cold Weather Clothing Wins Awards BYU student's clothing invention: http://inventorspot.com/articles/gas_filled_clothing_wins_awards_13558

Article: Surviving Olympic Heat
ClimaCool clothing
http://www.sciencenewsforkids.org/articles/20040630/Feature1.asp

Insulation Investigation Planning Guide

Consider the following as you plan your investigation. Record your investigation plan in your scientists' notebook.

1. Write down the investigation question: Which insulator will keep the container of hot tap water hot the longest?

2. What prior knowledge do you have about insulators that will help you answer this question? Remember what you have learned about how heat moves and how heat transfers occur (conduction, convection, and radiation).

3. Make a prediction based on your prior knowledge.
   I think …… because ……

4. What are the variables in this investigation?

5. What is the control?

6. How will you "insulate" your container with the materials you have chosen to test?

7. Each container should contain the same amount of hot tap water. Why is it important to take the temperature immediately after filling each insulated container? Is it important that the containers are sealed with a cover? Why or why not?

8. How often should the temperature be recorded for each of the containers? When will you stop recording the temperature?

Consider the following during your investigation. Record your ideas in your scientists' notebook. Use words, pictures, graphs, or tables to help explain your ideas and findings.

1. How does the temperature change over time?

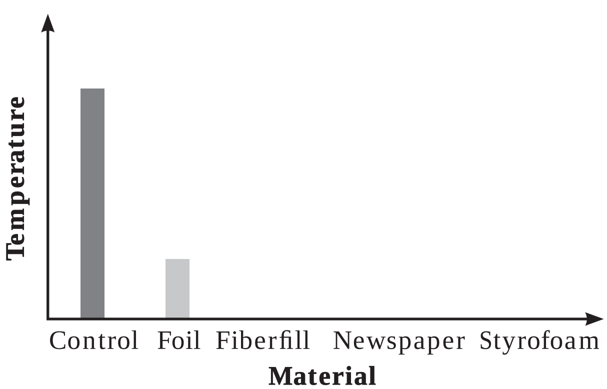
2. Record your data. How did you make sure all results are accurate?

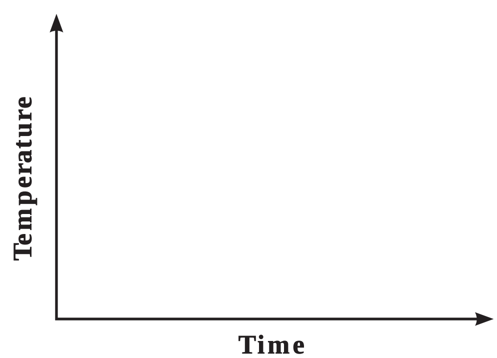
3. Write a conclusion based on your results. Which material has the best insulating properties and which was the worst? How do you know? What is your evidence?

Sample Data Table

Temperature (°C)	Control	Aluminum foil	Fiber fill	Shredded newspaper	Styrofoam peanuts
(Starting Time) 0 min					
1 min					
2 min					
3 min					
4 min					
5 min					
6 min					
7 min					
8 min					
9 min					
10 min					
Change in Temperature					

Sample Graphs





Keeping It Cool: Building an Insulated Water Bottle

Task

Using your knowledge of heat transfers and insulators, plan and build an insulated water bottle. The insulated bottles will be placed in hot water.

Criteria

- Students must use the water bottle issued to them in class. Each student will be provided with the bottles that are the same size and shape.
- Only materials available in class or brought from home can be used. (Do not purchase materials for this investigation.)

> **Note:** *Materials that are a safety hazard are not permitted. (Fiberglass is an example of an unsafe material.)*

- Insulated bottles must fit inside a gallon sized resealable bag.
- Design sketches must be included in your scientists' notebooks.

Keeping It Cool: Building an Insulated Water Bottle

Task

Using your knowledge of heat transfers and insulators, plan and build an insulated water bottle. The insulated bottles will be placed in hot water.

Criteria

- Students must use the water bottle issued to them in class. Each student will be provided with the bottles that are the same size and shape.
- Only materials available in class or brought from home can be used. (Do not purchase materials for this investigation.)

> **Note:** *Materials that are a safety hazard are not permitted. (Fiberglass is an example of an unsafe material.)*

- Insulated bottles must fit inside a gallon sized resealable bag.
- Design sketches must be included in your scientists' notebooks.

The Mitten Problem Redux

Canyon mittens by madelinetosh
http://www.flickr.com/photos/madelinetosh/2058039634/

Using what you have learned about heat and heat transfers, explain why you think the temperature reading on the thermometer placed inside the mitten was the same as the temperature reading on the thermometer left outside the mitten. Include a drawing to illustrate your thinking.

The Mitten Problem Redux

Canyon mittens by madelinetosh
http://www.flickr.com/photos/madelinetosh/2058039634/

Using what you have learned about heat and heat transfers, explain why you think the temperature reading on the thermometer placed inside the mitten was the same as the temperature reading on the thermometer left outside the mitten. Include a drawing to illustrate your thinking.

Lesson 8: Energy Warms Maine

Overview

What sources of heat are available to keep Maine homes warm? In this lesson, students are introduced to Maine residents who are asking for the students' help in recommending a home heating fuel before the upcoming winter.

Teacher Background

Energy is continually needed to heat a home. Heat naturally "escapes" from our homes as it transfers to the surrounding cooler environment. To maintain people's comfort and safety in winter months, heat must be continually supplied. 47%-67% of energy used in homes is used for heat. Choosing how to heat one's home is an important decision and one that is based on a number of factors. No one fuel is the perfect choice for everyone as all solutions have benefits and drawbacks.

Maine people have been burning wood to keep themselves warm for hundreds of years. Maine is the most heavily forested state in the lower 48 states making wood abundant and accessible. Another reason wood is an attractive fuel choice for Maine people is that it is an example of a renewable resource. Renewable resources are *"energy sources that can be replenished in a short period of time"* (Energy Information Agency). The burning of wood, however, does have drawbacks. The type of stove used as well as the type of wood burned plays a role in how clean or polluting the burning of wood is. There are a variety of wood burning stoves that are being used by Maine homeowners. Some of these stoves burn wood more efficiently than others. The burning of wood can cause high concentrations of particulate matter in the smoke that is released into the air. This can cause respiratory and heart problems to people exposed to the wood smoke. Other environmental impacts that are a concern with wood fuel are related to wood harvesting techniques.

The majority of Maine people use heating oil to heat their homes. Oil, coal, natural gas, and propane are examples of fossil fuels and are *nonrenewable* resources. Fossil fuels were formed many millions of years ago from organisms, made up of carbon molecules, that died, decomposed, and were buried long before dinosaurs even roamed the Earth. The majority of fossil fuels were formed during the Carboniferous Period (360-286 million years ago). Carboniferous gets its name from carbon, the basic element of life and fossil fuels. There is a limited amount of fossil fuels, which is why these fuels are considered *non*renewable resources. Nonrenewable resources are "*energy sources that we are using up and cannot recreate in a short period of time*" (Energy Information Agency). To the homeowner oil, coal, propane, and natural gas may appear to be "cleaner" sources of home heating but this is not necessarily the case. The carbon released during the burning of oil, coal, propane, and natural gas was previously trapped deep underground. By burning coal, oil, propane, and natural gas the trapped carbon is released into the atmosphere as carbon dioxide. This contributes to the problem of climate change. There are other air pollutants that come from the burning of fossil fuels such as particulate matter, sulfur dioxide, and nitrogen oxides. There are also large environmental impacts from the "harvesting" of these resources.

Electricity is also used to heat Maine homes, schools, and businesses. The use of electricity for heating has declined in recent years due to the increased costs. Unlike resources such as wood, oil, natural gas, and propane, electricity is considered a "secondary" energy resource. Electricity is created using renewable energy sources like hydro and geothermal power, tidal, solar, and wind power, and nonrenewable resources such as coal, oil, propane, and natural gas. One major fossil fuel, coal, is largely responsible for much of the electricity created and used in the United States. Some of the coal that is mined for electricity was formed 65 millions of years ago during the late Cretaceous Period while dinosaurs roamed the Earth. The burning of coal contributes large amounts of pollutants to the air that are responsible for acid rain as well as climate change. Other environmental impacts from the mining of coal from deep within the earth include mountain top mining that has destroyed many acres of mountain land, polluting both land and water.

It is estimated that in 2008, over 3000 Maine homes used solar energy (passive or active solar systems) in their homes. Passive solar design technologies make use of the sun's energy for the heating and cooling of living spaces by combining the orientation of windows for maximizing solar gain and the use of building materials that store heat for long periods of time and slowly release the heat into the home. With this approach, the building materials making up the home are designed to purposefully absorb, reflect, and transmit solar radiation. A common example is a solarium built on the southeast side of a building. Also available are active solar technologies, which convert solar energy into usable heat. This process requires the use of electrical or mechanical equipment such as pumps and fans. Active solar technologies also allow the storage of energy for future heating needs. Examples of this kind of technology include air heat collectors and radiant floor heating systems. Air heat collectors absorb solar heat in collectors and move hot air into a building. Whereas radiant floor heating systems move water through pipes installed in floors. Photovoltaics are active solar technology devices that convert the heat energy into electricity. Energy from the sun is a renewable resource. An obstacle for home owners is that some of the equipment needed to harvest, convert, and store the sun's energy into energy that can be used for heating and electricity can be expensive to install but can save money for many years to come. Since there is no combustion this is a very clean energy source.

Alternative methods of heating our homes are being examined and are becoming popular. Technologies continue to be developed and improved for existing heating systems. Methods such as geothermal heating – collecting heat in a liquid that is moved through underground piping systems or wells and is then transferred into buildings with the use of air-too-air heat exchangers utilizing heat transfers from the Earth's interior – are gaining in popularity in Maine.

With rising fuel costs and the urgency to lower the carbon dioxide impact on the planet, Maine people are working toward finding the most energy-efficient methods to heat their homes, schools, and businesses.

Key Ideas

- Energy in fuels used to heat our homes can be traced back to the sun.
- People use resources – both renewable and nonrenewable – to maintain and improve their existence.
- Perfectly designed solutions do not exist. All solutions have trade-offs, such as safety, cost, efficiency, aesthetics, and environmental impacts. Solutions have constraints.

Lesson Goals

Students will:

- identify different fuels used for heating Maine homes.
- describe several factors that need to be considered when selecting a fuel for heating.
- describe the benefits and challenges of using various fuels to heat Maine homes.

Vocabulary

resource: naturally occurring substances that are considered valuable.

nonrenewable resource: a resource such as a fossil fuel that does not replenish as part of natural ecological cycles.

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

Preparation

- Become familiar with the types of fuels used to heat homes in Maine. Review Student Handouts 8.2: Fuel Information Sheets and determine how many fuels students will take under consideration. To make the task more manageable, consider using the Fuel Information Sheets for Wood (Biomass), Natural Gas, Heating Oil, Electricity, and Propane or the fuels commonly used in your area and are familiar to your students. Presently these five are the most commonly used fuels for heat in Maine. If students will be doing additional research on fuels, gather appropriate resources and/or preview websites if using with students.
- Review the terminology in the Fuel Information Sheets and identify terms that may be unfamiliar to or difficult for students. Renewable, nonrenewable, efficient, rural, suburban, refined, emissions, and versatile may be words that need to be pre-taught or clarified.
- Determine how groups will be organized (self-selected or assigned small groups) to carry out the research in this lesson.

Materials

Item	Quantity
Scientist's Notebook	1 per student
Student Handouts 8.1: Consumer Profiles Student Handout 8.2: Fuel Information Sheets Student Handout 8.3: Fuel Recommendation Guidelines and Rubric Student Handout 8.4: Consumer Profile and Fuel Information Sheet Group Discussion Guide (optional)	1 per student
Access to the internet (optional)	1 per class or student

Time Required: 1-2 sessions

Connection to *Maine Learning Results: Parameters for Essential Instruction (MLR)*, and *Benchmarks for Science Literacy (BSL)*

- Identify personal choices that can either positively or negatively impact society including population, ecosystem sustainability, personal health, and environmental quality. MLR C3(6-8) b
- Identify factors that influence the development and use of science and technology. MLR C3 (6-8) c
- Different ways of obtaining, transforming, and distributing energy have different environmental consequences. Benchmarks 8C/M2
- In many instances, manufacturing and other technological activities are performed at a site close to an energy resource. Some forms of energy are transported easily, others are not. BSL 8C/M3
- Some resources are not renewable or renew very slowly. Fuels already accumulated in the earth, for instance, will become more difficult to obtain as the most readily available resources run out. How long the resources will last, however, is difficult to predict. The ultimate limit may be the prohibitive cost of obtaining them. BSL 8C/M10** (SFAA)
- By burning fuels, people are releasing large amounts of carbon dioxide into the atmosphere and transforming chemical energy into thermal energy which spreads throughout the environment. BSL 8C/M11**

Teaching The Lesson

Engage

1 Engage students in a discussion about heat in Maine.

Review with students their current understanding about heat and use this to segue into a class discussion on the topic of heat on a much larger scale – heat use in Maine. Begin by asking students: *How does energy warm Maine? In other words, what sources of heat are available and/or are used by Maine people?*

As students respond to this question, make a class list on the board or on a piece of chart paper. During the discussion help students make the connection between various fuels and the sun. Ask students to reflect on the list and then discuss the following with students:

- *How much of the energy used in homes is used for heat?* (Almost half- anywhere from 47%-65% of the energy used in homes is used for heat.)
- 140 *What do you think the most commonly used fuel for heat is in Maine today?* (Do not provide an answer – simply gather students' ideas. Consider asking students to suggest percentages of use for each fuel type that they suggest.)
- *What types of fuels do you think people that lived in Maine long ago (half century, century, millennium) used? Why?*
- *Do all Maine people use the same types of fuel to heat their homes? Why or why not?*

Continue the introductory exploratory conversation by asking:

- *What do you know about the types of fuels used to heat Maine homes?*
- *Where do you think these fuels come from?*
- *How do you think people decide which fuels to use?*

The purpose of this introductory discussion is to engage students in thinking about the different ways Maine people heat their homes rather than seeking out definitive answers.

Explore

2 **Introduce consumer profiles.**

Arrange students in groups of 4. Provide each student with one copy of Student Handout 8.1: Consumer Profiles. Introduce the following scenario: Explain to students that the individuals described in the handout are faced with selecting a fuel to heat their homes this winter. They are new to Maine and do not know much about the fuel types available in this area. Their neighbors and the people at the town office knew that this class had been studying heat and wondered if they could help them choose. The individuals described in the handout want to make the best decision they can – deciding which fuel(s) to use to heat their homes is important!

Revisit the idea that people choose different fuels for different reasons. Discuss with students the idea that it is unlikely that one fuel will be the perfect solution for everyone, noting that individual selection is based on a number of factors, some of which they have already discussed. Ask students if there are other factors people consider when making fuel choices that haven't already been discussed.

Instruct students to "get to know" the individuals by reading the information on Student Handout 8.1. Alternately, read profiles aloud as students listen. Ask students to highlight or underline any details that they think will be important to consider when recommending a fuel for this person. Ask students to discuss at their tables some of the things they learned about the individuals, noting what they felt were the important pieces of information to keep in mind. It may be helpful for students to think about each person's needs vs. wants. Ask students to work with their group to think about fuel choice questions that they would like to ask one of the individuals described in the handouts. The purpose of the questions should be designed to aid in suggesting a fuel choice for the person described in their handout. Have students share some of their questions with the class.

> **Note:** *Determine whether students will self-select the individual profile they will be focusing on or if profiles will be assigned to different groups.*

3 **Introduce fuel information sheets.**

Give each group one set of Student Handout 8.2: Fuel Information Sheets. Discuss the following with students:

- In Maine, we use different types of fuels to heat our homes. The fuel information sheets represent the most common types used in our state (as of 2008).

• Some fuels are readily available to consumers.

• Some fuels provide heat at a low cost; others are more expensive. Some of the fuels are renewable; others are nonrenewable. (Discuss what is meant by each of these terms, using the background teacher notes as a guide. Post these words with picture examples if possible, on the board for students to reference.)

• Some fuels affect the environment more than others.

• Some fuels are more efficient than others.

> **Note:** *Consider brainstorming with students what "efficient" means. Fuel efficiency is measured in complex ways. The idea here is to discuss the common usage of the word and not introduce the use of formulas to calculate efficiency.*

Encourage students to divide up the fuel information sheets among their group members so that each student becomes an "expert" on one or two of the fuels. Instruct students to review the information found in their fuel handout.

> **Note:** *One way to adapt the activity for low and non readers is to pair students up with the fuel information sheets so that there would be two students per fuel.*
>
> *There is space at the bottom of each of the information sheets for students or the teacher to add to the information about each fuel type. Students (or the teacher ahead of time) could conduct additional research about their fuel type and add it to the list on the handout. (Ex: current cost, local shortages, etc.)*

Provide each student with a copy of Student Handout 8.4: Consumer Profile and Fuel Information Sheet Group Discussion Guide (optional). Students will share the information about their fuel with other group members and use the information to recommend a fuel for their individual. If there are items on the bulleted list that students do not understand, encourage them to find out more by doing additional research. The Energy Story at http://energyquest.ca.gov/story/chapter08.html contains a wealth of information.

As students are discussing information in their groups, encourage them to jot down notes about the advantages and disadvantages of the different fuel choices in conjunction with the individual's profile. Consider brainstorming and/or modeling how students might keep the information they are collecting organized. (Ex: listing pros and cons in a data chart.)

As students work, circulate among groups monitoring progress, posing questions, and supporting students as needed.

Reflect And Discuss

4 Discuss recommendations.

After students have considered the consumer profiles and consulted the information about different fuel types, bring students together for a class discussion. As student groups share their recommendations ensure students support their recommendations with reasoning.

5 Introduce analysis task.

Explain that students will continue to work in their group to create a one-page product that clearly explains the group's recommended fuel choice for one of the individuals introduced in the student handout. Provide each student with a copy of Student Handout 8.3. For their product, students may choose to write a letter to the individual, create a graphic (ex: Venn diagram, comparison chart, etc.), or script a phone conversation that describes the recommended fuel choice as well as why the group recommends it.

Be sure to review the assignment details and scoring rubric found on the handout with students.

6 Reflect and bring lesson to a close.

Ask students if there are other ways people in Maine keep their homes warm that were not included as choices. As students share what they know, discuss how they think these methods are related to and/or are different from those featured in this lesson. For example, students may suggest that coal, wind, and solar power may be used to heat homes. While coal can be burned in furnaces to create heat for homes, wind and some methods of solar energy are used to generate electricity which can then be used for heat. Students may also be familiar with geothermal heating methods. Geothermal heat comes from deep within the Earth. Despite our seasonal changes in temperature, the temperature 10-30 feet below the ground remains fairly constant year round. In Maine, people typically access geothermal heat through wells. They pump the heat up from the well, concentrate it, and circulate it around their homes.

As students suggest different ways people heat their homes, help them recognize or question the "heat" connections. Consider giving students time to investigate some additional sources. The Chewonki Foundation has developed an interactive website for their poster "Pathways to a Sustainable Future" that students may find helpful in thinking about the connections between sources of energy traditionally used for heat. Several types of renewable energy and their connection to heat are described: http://www.chewonki.org/Pathways/interactive_poster/default.shtml

Ask students to find out how they heat their homes. This information will be used at the start of Lesson 9.

Bring the lesson to a close by asking students if they know what type of heat source they use in their homes. Ask students if they think the types of fuels available to Maine people will remain the same or if they think these will change and why.

Extensions

Students may:

- visit "The Energy Story" to learn more about fossil fuels- coal, oil, and natural gas. http://www.energyquest.ca.gov/story/chapter08.html
- visit the Chewonki Foundation's: Pathways to a Sustainable Future Renewable Energy Poster. This interactive poster allows students to learn more about stainable energy and includes a number of follow up activities. http://www.chewonki.org/Pathways/interactive_poster/default.shtml
- play MEEP's Global Energy Game Balance the 3 E's: Energy, Economics and Environment, and win! (6th-adult). Downloadable gameboard and instructions available at: http://www.maine.gov/dep/air/education/teachers.htm
- read Energy Information Administration **Energy for Kids** Page that describes renewable and not renewable energy sources and while not specific to thermal energy includes information about energy used to heat homes. http://www.eia.doe.gov/kids/energyfacts/
- investigate historical weather events in Maine that students' parents, grandparents, aunts and uncles may remember. Students can interview older relatives and gather information on such weather events. Students could ask and record such questions such as, how did the weather event affect their ability to stay warm? Did they lose power? Did they have a wood burning stove and wood to burn? How did they cook and get water? Students could put together a "History Booklet" or "Hall/Wall Display Imagery" of how their relatives coped with such events.

  One example of a large weather event that affected many of Maine's citizens was the Ice Storm of 1998. Many students were just babies or not yet born during what is considered to be one of Maine's most memorable ices storms in recent history. Many people found their homes and communities without electricity for days (even weeks!) and had to rely on alternative methods to keep their homes warm. During this event, many Maine families learned the importance of having a back up heating system – one that would work in the absence of electricity. Students may find the following websites about the Ice Storm of 1998 interesting.

WMTW TV Channel 8 News Clip Ice Storm 1998 (you tube)
http://video.google.com/videosearch?q=ice%20storm%201998%20Maine%20news&ie=utf-8&oe=utf-8&rls=org.mozilla:en-US:official&client=firefox-a&um=1&sa=N&tab=iv#

Kids From Maine Talk About Surviving The Ice Storm Of '98
http://www.fema.gov/kids/me98_01.htm

MPBN: Ice Storm Remembered.
Audio broadcast reflecting back on experiences during 1998 Ice Storm. http://www.mpbn.net/News/MaineNews/tabid/181/ctl/ViewItem/mid/1858/ItemId/7130/Default.aspx

- participate in NEED's *Great Energy Debate*. Students evaluate the advantages and disadvantages of the major energy sources in an innovative debate format:
  http://www.need.org/Guides-Grade.php

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 onthe education section of the site. To schedule a presentation contact Nancy Chandler at 207.760.2556 or nchandler@maine publicservice.com.

Online resources and references

Lesson adapted from NEED Project, PO Box 10101, Manassas, VA, *The Great Energy Debate Game*. http://www.need.org/needpdf/Great%20Energy%20Debate%20Game.pdf.

Chewonki Foundation: Pathways to a Sustainable Future Renewable Energy Poster. http://www.chewonki.org/Pathways/interactive_poster/default.shtml

Heating fuel comparison calculator: http://www.efficiencymaine.com/pdf/heatfuelcomparisoncalculator.xls

University of Maine Cooperative Extension. (Nov. 2008). Comparing Values of Various Heating Fuels. http://www.umext.maine.edu/energy/Homeheating/comparingfuelheat.htm

University of Maine Cooperative Extension:
Home Heating Alternatives.
http://www.umext.maine.edu/energy/homeheat.htm

StrastoSphere. (2007). *Advantages and Disadvantages of Various Fuels*. http://chestofbooks.com/food/household/A-Manual-Of-Home-Making/Advantages-And-Disadvantages-Of-Various-Fuels.html

Maine Solar House
(site maintained by homeowners Bill and Debbi Lord)
http://www.solarhouse.com/

Heimer Engineering:
Heating The Heating System, Boiler, and Furnace
http://www.heimer.com/information/heating_system.html

Consumer Profiles

Ellsworth Ella

Ella is an 83-year-old grandmother of nine. She and her feline companion, Jake, have recently moved into a small one bedroom first floor apartment in town. Ella has led an active life and is in reasonably good health. Over the past few months she has discovered that she has developed allergies to dust and some days it is difficult for her to move due to her arthritis. Ella is retired but keeps busy volunteering at the library. When she is at home, she wraps up in her favorite afghan to enjoy reading a good book or painting in her cozy living room.

Rockwood Ray

Ray has lived in warmer climates all of his life. This will be his first winter in Maine. Ray and his family of five recently purchased an old uninsulated farmhouse that sits on 25 acres of forested land. The two-story house has a large front porch, several “backhouses,” and a barn – just what he and his wife have always dreamed of. Ray knows that the house needs some renovations and is considering installing a new heating system. Several different heating systems have been used in the house in the past as there are cast iron radiators, electric baseboards, and original fireplaces throughout the home.

Auburn Anne

Anne and her husband live within the city limits in a multi-level 2000 square foot home. As a member of a busy pediatric practice, Anne has somewhat irregular working hours due being “on call” - tending to sick patients and other medical emergencies at all hours. Anne’s husband is a freelance wildlife photographer and is often away on assignments for days at a time. When they are not working, the couple primarily uses public transportation, their bicycles, or their hybrid car to get around town.

Presque Isle Pete

Pete is about to graduate from Unity College, an environmental school where he studied natural resources. He and his girlfriend Sherry want to live in the rural area of Maine where he grew up. They’ve both found jobs in a nearby city and only drive 10 miles to get home to their ramshackle cabin in the woods. Pete and his friends have some carpentry skills and they’d like to build a small energy efficient house on his 10 acre partly wooded lot which was previously part of an old hay field. They would like to grow a garden for food and keep their energy expenses low with little or no environmental impact.

Fryeberg Felicia

Felicia is an outdoor recreation leader/educator and travels a lot for her job taking high school and college kids on outdoor camping adventures. She owns a small 3-bedroom house where she lives with a couple of friends. They are all very busy twenty-somethings who don't want to be bothered taking time to do chores around the house and property. The idea of sharing the house is to keep expenses low and have plenty of time for fun and adventure. The house is currently heated with wood and no one has the time or patience to gather a wood supply or keep the wood stove going. They've decided to find a less time intensive yet dependable energy source that won't cost too much for the home.

Jonesport Jarvis

Jarvis and his wife Joanne are in their thirties and live in a suburban area of Maine. They have three children who keep them very busy traveling back and forth to extra-curricular activities. Their eldest boy has developed allergies to pollen, pet dander and dust and has been sick a lot with asthma attacks. The middle child is fond of animals and has several pets in the house. Their daughter is still a toddler who crawls and runs around playing on the floor a lot. Keeping up with the family expenses and dealing with children's health issues is a primary concern. Their oil furnace just died and they've been temporarily been using electric and kerosene heaters to keep warm. They need to find an alternative-heating source that will be safe, clean and dependable for their home. So far they've saved $15,000 and are hoping they can find an affordable renewable energy option for their home

Fuel Information Sheet

Wood (Biomass)

- Maine has 17 million acres of forest.
- Wood is a renewable energy source; we can grow more trees and manage forested areas.
- Wood must be transported to where it is used.
- Wood requires storage space and proper "seasoning."
- The amount of energy stored in wood is less than the amount of energy stored in an equivalent amount of a fossil fuel.
- Labor is involved in preparing wood for use - cutting, splitting, and stacking.
- Many people enjoy the warmth of a fire and find them aesthetically pleasing.
- Wood burning stoves and furnaces often generate uneven heating.
- Supplementary devices (fans, grates) are sometimes added to aid in distributing heat to greater areas in the home.
- Wood provides intense heat. Many wood burning furnaces or stoves need to be manually replenished every few hours to provide heat throughout the day.
- Wood can be used as a fuel because trees capture and store radiant energy from the sun through a process called photosynthesis.
- Fire burning equipment must be properly installed and regularly cleaned to reduce the risk of fire.
- For some, wood has a low cost, especially if it's available from the homeowners own woodlot.
- Burning wood produces smoke, particulate matter, and other harmful emissions.
- Many Maine families use wood as a primary heat source.
- Scientists are developing trees that can be grown to full size in less than half the time of the average tree.
- Outdoor wood boilers (owb's) are furnaces that are installed outdoors to keep the wood mess outside the home. They burn 4-foot long logs that last half the day – but the low temperatures and slow burning in the firebox create lots of air pollution problems.
- Certified wood stoves for indoor use can use 1-2 foot pieces of wood that can be burned in fast, hot fires which result in less air pollution.
- Pellet stoves have become a popular way to burn wood. Wood pellets are made from dry sawdust compressed under high pressure and pushed through a die. Pellets usually come from the byproduct of sawmills and are very easily transportable due to their size (about half and inch) and their weight.
- Pellet stoves require electricity for their operation, pellets come in bags that require storage and lower grade or pellets that are unused for long periods of time can disintegrate into sawdust.

Fuel Information Sheet

Natural Gas

- Natural gas was formed by the decomposition of tiny sea plants and animals that lived millions of years ago.
- Natural gas is a clean burning fossil fuel.
- The chemical name for natural gas is methane.
- More than half the homes in the United States use natural gas for heat.
- Natural gas is odorless. Chemicals are added to the gas to give it an odor.
- Natural gas is found in oil fields and coal beds. Natural gas is not found in Maine.
- When burned, natural gas provides immediate heat.
- Natural gas is a nonrenewable resource.
- The invention of high-pressure pipelines has made it possible to ship natural gas all over the United States.
- 150 If leaks occur in natural gas pipelines, fires and explosions can result.
- Natural gas is readily available to consumers as a public utility in urban areas and in bottles in other areas.
- In addition to using natural gas to heat their homes, many people use natural gas for their dryers and ovens.

Fuel Information Sheet

Heating Oil (Petroleum)

- The word petroleum comes from the word *petro* meaning rock and the word *oleum* meaning oil.
- Petroleum was formed over millions of years from the remains of plants and microorganisms.
- Petroleum is a nonrenewable resource.
- There is an immediate release of heat when burned.
- In recent years the cost of oil has risen.
- A small storage space is needed.
- Safe storage is difficult.
- Heating oil has a high heat value.
- Petroleum is a hydrocarbon; a chemical compound that contains hydrogen and carbon.
- 80% of Maine homes use oil-based heating systems.
- The United States imports about 2/3 of the petroleum it uses from other countries.
- Petroleum straight from the ground (crude oil) is not usable. Crude oil must be refined into heating oil and other products.
- Harmful emissions are produced when petroleum products are burned.
- Oil must be transported by pipeline, truck, or tanker to where it is refined and/or used.
- If oil is spilled into the water or onto the land, it can cause damage to the environment.
- The United States has petroleum reserves in Alaska and offshore but there is a high cost and environmental price to pay for it. The drilling for oil in these areas is also controversial.

Fuel Information Sheet

Electricity

- Electricity is a secondary energy source. It must be generated for use.
- Coal generates about half the electricity in the United States. When burned, coal produces the highest amount of carbon dioxide of all fossil fuels.
- When coal is burned sulfur dioxide is given off. Sulfur dioxide is a major cause of acid rain and is a contributor to several respiratory diseases.
- In Maine, hydroelectric dams and wind generate a small but growing percentage of our electricity.
- Electric heat is versatile; it can be used to warm individual spaces and/or for entire homes.
- Homeowners can easily add additional electric heat to new areas of their homes (additions, basements, workshops, garages).
- Unlike heating systems that require piping which limits where these systems can go, electric heating systems can be installed just about any place in the home.
- Nearly all homes already have electricity in place.
- Alternative energy sources such as solar and wind can be used to generate electricity that can be used to heat homes.
- Electric heating systems operate cleanly, are long-lasting, and are low maintenance.
- No onsite fuel storage is required.
- Electric heating systems do not require the ventilation needed to burn a fuel.
- Electric heat is expensive.

Fuel Information Sheet

Propane

- Propane is a clean burning fossil fuel.
- Propane exists in liquid and gas forms. Propane is stored as a liquid in pressurized tanks because it takes up less space, making it very portable.
- Propane is mostly used in rural areas that do not have natural gas service. Homes and businesses use it for heating, hot water, cooking, and clothes dryers.
- Half of America's farms rely on propane to dry crops, power tractors, heat greenhouses, and warm chicken houses.
- Like natural gas, propane is colorless and odorless. A chemical is added to propane as a safety measure.
- Propane is a nonrenewable energy source.
- The 2000 Olympic Games torch burned a mix of propane and butane, which provides a lower emission and better luminosity and consumes less fuel.
- Propane is usually more expensive than natural gas, heating oil, or kerosene. Propane supplies and price are tied to oil and natural gas supplies and costs.
- Propane heaters come in a variety of shapes and sizes allowing flexible placement in tight spaces. Small portable space heaters are designed to heat one room or area of the home at a time providing heat to only the areas that need it and offering greater energy efficiency.
- Propane gas stoves and fireplaces heat more evenly and more efficiently than wood-burning ones.
- Propane is a less expensive alternative to electricity.

Fuel Information Sheet

Solar

- The sun radiates more energy in one second than people have used since time began. It takes the sun's energy just over 8 minutes to travel the 93 million miles to the Earth.
- The sun is made up of helium and hydrogen gas. It produces radiant energy in a process called nuclear fusion.
- Solar energy systems have no ongoing fuel costs.
- Energy from the sun is renewable.
- There is a high initial cost of installation and high ongoing maintenance cost.
- Harnessing energy from the sun is difficult because the energy that reaches the Earth is widely spread out.
- In northern areas there may not be enough sun during winter months to make this practical as it may require supplemental heating. Often supplemental heating is supplied as expensive electric heat.
- Solar energy systems do not require fuels to be stored in the traditional sense. Solar systems often have batteries for storing energy.
- Solar energy systems do not produce emissions of greenhouse gases or particulate matter.
- The amount of solar radiation that reaches an area depends on the time of day, season of the year, cloud coverage, and geographic location.
- Passive solar homes do not need special equipment.
- Passive solar technologies are means of using sunlight for useful energy without use of active mechanical systems.
- Active solar technologies convert solar energy into usable heat, cause air-movement for ventilation or cooling, or store heat for the future and require the use of electrical or mechanical equipment, such as pumps and fans, to increase the usable heat in a system.
- Photovoltaic or solar cells convert radiant energy into electricity.

Fuel Information Sheet

Geothermal

- Geothermal energy can be used to heat homes in several ways: through direct use in heating systems (these use hot water from springs or reservoirs near the surface), by electrical generation (which is then used for heat), and by geothermal heat pumps (using stable ground or water temperatures near the earth's surface to control building temperatures above ground). The last method is the one used by some Maine people to heat their homes.
- Geothermal energy is generated in the earth's core, about 4,000 miles below the surface. Temperatures hotter than the sun's surface are continuously produced inside the earth.
- Examples of geothermal energy are hot springs, volcanoes, and geysers.
- Geothermal energy is renewable.
- People in Maine typically access geothermal heat through their wells.
- Despite our seasonal changes in temperature, the temperature 10-30 feet below the ground remains fairly constant year round. Geothermal heat pumps use the Earth's constant temperatures to heat and cool buildings by transferring heat from the ground (or water) into buildings in winter and reverse the process in the summer.
- Geothermal heat pumps do not have ongoing fuel costs.
- According to the U.S. Environmental Protection Agency (EPA), geothermal heat pumps are the most energy-efficient, environmentally clean, and cost-effective systems for temperature control.
- Most homes still use traditional furnaces and air conditioners; geothermal heat pumps are becoming more popular.

Fuel Recommendation Guidelines and Rubric

Create a one-page product that clearly explains the recommended fuel choice for one of the individuals introduced in the student handout. You may choose to write a letter to the individual, create a graphic (ex: Venn diagram, comparison chart, brochure, informational sheet), or script a phone conversation (or some other idea you may have) that:

- explains which fuel the group recommends for the individual.
- describes the recommended fuel choice.
- makes a case for the recommended fuel choice using supporting details.

Sample Summary Rubric

	Exceeds Standard (4)	**Meets Standard** (3)	**Partially Meets Standard** (2)	**Does Not Meet Standard** (1)
Recommendation Statement	Strongly and clearly makes a recommendation. Clearly identifies the issue.	Clearly states a recommendation. Some references to the issue.	Recommendation is not clearly stated. Little or no reference to the issue.	Recommendation is not easily understood and does not reference the issue.
Reasons and Support	Provides four or more strong, accurate relevant details, reasons, and/or examples in support of the recommendation.	Provides three relevant, accurate details, reasons, and/or examples in support of the recommendation.	Provides two relevant, accurate details, reasons, and/or examples in support of the recommendation.	Provides one or no relevant, accurate details, reasons, and/or examples in support of the recommendation.
Conclusion	Summarizes recommendation in a strong concluding statement.	Summarizes recommendation in a concluding statement.	Concluding statement is a weak summary of recommendation	Concluding statement makes no reference to recommendation.
Organization	Sentences and paragraphs are complete, well written and varied.	Sentence and paragraph structure is generally correct.	Sentence and paragraph structure is inconsistent.	Little or no evidence of sentence or paragraph structure.
Mechanics and Grammar	Contains no punctuation, spelling, or grammatical errors.	Contains few errors in punctuation, spelling or grammar that do not interfere with meaning.	Contains several punctuation, spelling and/or grammatical errors that interfere with meaning.	Contains numerous punctuation, spelling, and/or grammatical errors that make the piece illegible.

Consumer Profile and Fuel Information Sheet Group Discussion Guide

1 Each person should briefly tell about the fuels that they studied.

2 Each person should tell what the pros/cons are for each fuel.

3 Does anybody have a fuel source that would absolutely not be appropriate for your consumer? Explain why this fuel would not be a good choice for them.

4 Does anybody have a fuel source that would definitely be a possibility for the consumer to consider purchasing? Discuss why you feel this fuel is a good choice.

5 Which would be the best fuel for your consumer? Why?

Consumer Profile and Fuel Information Sheet Group Discussion Guide

1 Each person should briefly tell about the fuels that they studied.

2 Each person should tell what the pros/cons are for each fuel.

3 Does anybody have a fuel source that would absolutely not be appropriate for your consumer? Explain why this fuel would not be a good choice for them.

4 Does anybody have a fuel source that would definitely be a possibility for the consumer to consider purchasing? Discuss why you feel this fuel is a good choice.

5 Which would be the best fuel for your consumer? Why?