Lesson 1: *The Mitten Problem*

Overview

In this introductory lesson, students are presented with a formative assessment probe, *The Mitten Problem*, to elicit their current thinking about sources of heat energy. Students then design and conduct a follow up investigation to further develop their conceptual understanding of heat as a form of energy.

Teacher Background

How are a cup of boiling water, an iceberg, a wool sweater, and a woodstove similar? How are they different? Perhaps the first thing that comes to mind when one thinks of these items is a particular temperature such as hot or cold. People often think of objects in terms of temperature, being "warm," "cool," "hot," or "cold." Does this thinking indicate a misconception? Likewise, through early experiences, students develop intuitive notions about energy, including heat. Children often think of heat as an intrinsic property of a material or object. In other words, students often think of materials as being inherently hot or cold or as containing a certain amount of "hotness" or "coldness." Although heat is a form of energy and not a substance, it is often described as one. "Put on a warm sweater!" and "If you're cold, wrap up in a warm blanket!" are phrases many caring adults have said to children. Is this language misleading? Could these sort of innocent reminders contribute to children thinking that the sweater and blanket themselves are warm? Or are they made of materials with effective insulating properties? Why does a wool sweater feel warmer than a cotton sweater? The sweater, like the mitten used in this lesson, is not in and of itself "warm." The sweater does not give off heat, it is not a heat source, and it does not have a higher starting temperature than its surroundings. Often what is overlooked in this situation is that the person wearing the sweater gives off heat. Wool has insulating properties that are more effective in slowing the transfer of heat energy than cotton so the wool "holds in" the body's warmth more effectively than the cotton, thus making the person feel warmer.

This lesson begins with *The Mitten Problem*, an engaging and motivating question posed as a formative assessment probe. *The Mitten Problem* is designed to elicit students' initial ideas about heat using a familiar experience. While this probe specifically targets ideas related to sources of heat, this simple investigation provides a stimulating and familiar context for students to explore and express their developing understanding about heat sources and insulators.

So what do a cup of boiling water, an iceberg, a wool sweater, and a woodstove have in common? All of theses substances are examples of matter and all have thermal energy.

> **Note:** *Students will be using thermometers during this and subsequent investigations. Determine if students are skilled in using thermometers and if not, provide needed instruction.*

Key Idea

• Objects and substances are not inherently "warm" or "cold."

Lesson Goals

Students will:

• explore their current ideas about heat.

• be able to differentiate between a heat source and objects or substances affected by a heat source.

Vocabulary

heat: the flow of thermal energy from a warm area to a cooler one.

heat source: anything that produces heat.

Preparation

• Gather an assortment of mittens.

• Inspect thermometers. Use thermometers with enough precision as to not confuse students. Consider borrowing laboratory quality thermometers or using temperature probes.

• Make overhead of thermometer diagram.

Assess students' prior experiences with reading and handling thermometers. If necessary, provide students with a mini-lesson on how to read thermometers. Discuss precision and limitations of the instruments being used. Simple lesson ideas can be found at: http://www.bbc.co.uk/schools/scienceclips/teachersresources/ages8_9/tr_keeping_warm_offlp.shtml

Safety

Ask students to use caution in handling thermometers. Use only thermometers that contain alcohol (not mercury) and those that cannot easily be broken. Many classroom thermometers are affixed to a metal or plastic backing to prevent breakage and laboratory thermometers often come with a plastic or rubber ring that prevents cylindrical thermometers from rolling off table tops. Give students instructions before the lesson about safe procedures to follow should a thermometer break. Have a dust pan and broom ready in case of breakage.

Materials

Item	**Quantity**
The Mitten by Jan Brett	1 per class
Student Handout 1.1: *The Mitten Problem*	1 per student
Thermometers	2 for initial demonstration 2 per student pairs (or 1 per student)
An assortment of mittens	1 pair minimally per student pair
Scientist's Notebook	1 per student
Teacher Resource 1.1: Thermometer diagram (optional)	1 per class

Time Required: 2 sessions

Session 1: Read book, do probe and mitten investigation demonstration

Session 2: Plan and carry out investigation, hold scientists' meeting

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

- Energy appears in different forms. Heat energy is the disorderly motion of molecules. BSL 4E(6-8)
- Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature. NSES B(5-8) 8

Teaching The Lesson

Engage

1 Read *The Mitten*.

Open this lesson by initiating a discussion about mittens, using the children's story *The Mitten* by Jan Brett. Say something like: *How many of you have read the story "The Mitten" before? By looking at the cover, what do you think this story is going to be about?* This will get everyone involved and will not exclude those students who may not have heard the story before. (Several have undoubtedly heard this simple, classic story before.) Explain that this tale relates to a problem you will be asking students to investigate today. Read *The Mitten* to students. At the conclusion of the story, ask students why they thought the animals climbed into the mitten. (To keep warm.) Ask, "*Do you think their strategy would work? Why or why not?*"

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2 Administer "*The Mitten Problem*" probe.

Provide each student with a copy of Student Handout 1.1: *The Mitten Problem*. Ask students not to put their names on their papers. Either read the probe aloud to the class or instruct students to individually read the probe and select a response that best matches their thinking about the problem. Make certain that students complete the last portion of the probe by explaining their reasoning. Give appropriate support to students who need help with their writing.

> **Note:** *Make certain that students know why they are doing this activity. The probe allows everyone's ideas to be shared. Reinforce how important it is to consider all ideas and set the expectation that as ideas are shared it is done so respectfully.*

3 Collect, distribute and review student responses.

After all students have committed to a response based on their current ideas, ask them to crumple their papers into a ball and upon a given signal, toss the paper balls around the room until instructed to stop. (A few seconds of tossing is sufficient to "mix" papers around the room!) Have students pick up or hold on to one paper, and make certain all students have a paper. Facilitate a discussion about *The Mitten Problem* by asking students to share the ideas and thinking that are on the "caught" paper (as opposed to sharing their own ideas). Model how to respectfully share the responses of others by giving students the following example: "This person selected Response A: The thermometer inside the mitten will have a lower temperature reading than the thermometer on the table. The reason the person gave was that mittens have large holes that let cold air in and make the thermometer reading drop."

> **Note:** *Commit and Toss, the strategy used above, is a technique used to get a quick sense of the different ideas students have about a particular idea. It is a safe, fun, and engaging way for all students to make their ideas known anonymously to the teacher and to other students in the class without individual students being identified as having correct or incorrect ideas. It also helps students recognize that there are a variety of ideas in the room and allows students to privately compare their ideas to those of others in the class. The Commit and Toss strategy "incorporates an essential component of conceptual change teaching and learning- committing to an outcome based on students' own ideas." This strategy comes from the resource Science Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning, pages 65-68 by Page Keeley.*

Explore

4 Initiate an investigation.

After various student responses have been discussed, ask students what they could do to find out if the temperature reading of a thermometer would increase, decrease, or remain the same inside the mitten. Students most likely will suggest how they would carry out an investigation.

Carry out this initial inquiry of the question above as a demonstration in a place visible to all students:

- Post the guiding question on a white board or chalk board for students to see and refer to: *How can we find out if the temperature reading of a thermometer will increase, decrease, or remain the same if the thermometer is placed inside a mitten?*
- Show students the materials available for the investigation: two thermometers and a mitten. Ask students if they can think of anything else that might be needed to carry out this investigation.
- Ask students what information is important to monitor and keep track of during the investigation. Ask students how they will determine if the mitten has an effect on the thermometer's temperature reading? This will remind students that they need to note and record in their scientists' notebooks the starting temperature of each thermometer (room temperature).

Note: *You may wish to use an overhead copy of the thermometer visual aid to record the starting temperature by coloring in the thermometer to the appropriate reading.*

- Put one thermometer in the mitten and leave the other thermometer uncovered on the table. Ask why they think two thermometers are needed. (The unwrapped thermometer is the "control" in the investigation and without that we would have no way to determine if the mitten was having an effect on the thermometer reading.
- Ask students to describe their thinking using diagrams or sketches to answer the following in their scientists' notebooks: *What do you think will happen to the temperature reading of this thermometer if we put the thermometer inside this mitten?*

  Note: *You may wish to note the start time and the end time of the investigation. Run the investigation for a fairly short period of time – about 3-5 minutes.*
- After students have been given the opportunity to record their thoughts, ask students to share with a partner.

5 Examine results.

Read the thermometers or ask a student volunteer to compare the temperature readings on the two thermometers. Ask students to record the temperatures in their scientists' notebooks. Students may be surprised to learn that the thermometer readings are the same. Ask students to record in their notebooks their thoughts and ideas about what they observed. Have students share some of their thoughts with the class.

Note: *Students commonly believe that some materials, such as blankets and sweaters, are intrinsically warm and that some, such as metals, are cold. (Driver et al. 1994). Students may suggest a variety of reasons for the temperature readings that they observed. Students may believe that the thermometer needed to be left wrapped up inside the mitten for a longer period of time; they may say the thermometer needed to be wrapped up in more layers or more snugly to "warm up" the thermometer; or they may suggest the thermometer is broken. Whatever reasons students give at this point should not be discounted or corrected.*

6 Plan student-designed investigation.

Tell students that they will be working in pairs to conduct their own investigation to further explore their ideas about why the temperature reading inside the mitten was the same as the temperature reading outside the mitten. Use the following guiding questions to help students focus and plan their own investigations:

- *What is the focus of your investigation?* Students should focus on one aspect to investigate, for example: length of time thermometer is left in mitten, number of layers (bundling or wrappings), using different types of mittens, or faulty equipment, etc. Student pairs in the class can choose to investigate different aspects of the problem, but each student pair should work together to investigate only one variable.

> **Note:** *Pushing students to focus on one aspect of the thermometer problem will help them determine what information should be monitored and recorded during their investigation.*

- If students think the temperature will increase if it is left wrapped up in the mitten for a longer period of time, ask them to predict how long they think it will it take.
- If students think that the thermometer was not wrapped tightly enough or covered in enough layers, ask them to predict how many more layers or suggest how it could be wrapped differently.
- Ask students who think using different kinds of mittens will result in a higher temperature reading to predict how much hotter they think it will be in the different types of mittens.

> **Note:** *Keep investigations simple. Students may want to take the mitten experiment outside, especially during the winter or place the mitten in a refrigerator or freezer. In doing so, students may inadvertently collect data that reinforces the misconception that mittens are a source of heat. Two potential problems arise: 1) students see a higher mitten temperature because the thermometers are not left long enough; 2) mittens are insulators and external factors such as wind and sunlight affect the readings. Advise students to design experiments that DO NOT involve putting the mitten in a new environment.*
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> **Note:** *It may be wise to give students a time limit for carrying out their investigations.*

Ask students to record their investigation question and prediction and to design a data table for their investigation in their scientists' notebooks. Students may include pictures of how the investigation is going to be carried out. Visit each student pair to make certain they have a clear plan in mind before providing materials for them to investigate their question. Remember that the purpose of this informal investigation is to explore initial ideas about heat rather than writing extremely detailed procedures or constructing complex data tables.

7 Provide materials for students' investigations.

Each pair of students will need two thermometers and a mitten. Allow students to carry out their investigation. Remind students to record their findings in their notebooks. Circulate among student pairs as they work. Ask guiding questions, make note of current thinking, and observe investigative behaviors.

Reflect And Discuss

8 Consider results and draw conclusion.

Ask student pairs to:

- review their findings
- write a concluding statement supported with evidence for their investigation in their notebooks. Consider providing the following scaffold for this step:
  After 5 minutes in the mitten, the temperature of the mitten was ______
- record a least one new question they have as a result of their investigation.

9 Hold a scientists' meeting.

Pair each student investigative team with another investigative team. Ask students to use the information in their notebooks to summarize how they carried out their investigation and share their findings and new questions with one another. Again, circulate among groups, listening to their conversations.

10 Debrief the experience as a large group.

Ask students to bring their notebooks and sit in a large circle for a science discussion. Start the discussion by summarizing students' experiences thus far: *We began investigating what would happen to the temperature reading of a thermometer that was placed inside a mitten. Our initial investigation showed that the thermometer placed inside the mitten had the same temperature as a thermometer that was not placed in a mitten. This seemed surprising! Each of you then conducted a follow up investigation to test your ideas and to find out more. The focus of this discussion will be to share your current ideas based on your findings from your investigations and to share your new questions.*

Invite students to share their current ideas but insist that they support what they say with evidence. Encourage students to cite evidence from their own investigation or from their peers. Use this discussion to inquire more deeply about students' ideas concerning heat. Keep a list of the new questions students have about heat.

At this point, do not confirm that the mitten will not change the temperature reading of the thermometer because the mitten does not generate its own heat. This is an introductory lesson. It is not expected that students attribute the unchanged temperature readings to the mitten not being a generator or source of heat now. Heat is a very challenging concept and students will need numerous experiences to build an understanding of thermal energy.

11 Bring lesson to a close.

Acknowledge that this initial experience may bring forth more questions than answers and that the questions students have about heat will continue to be explored in the next few lessons.

> **Note:** *Some students may believe that certain objects and substances are intrinsically "warm" or "cold." Therefore, in spite of the first hand experiences with their own investigations, they may have great difficulty in recognizing that blankets, hats, and mittens are not generators of heat and that this explains the unchanged thermometer readings. While it is tempting to tell students that items generally thought of as "warm" (blankets, hats, and mittens) are not generators of heat and, therefore, are not capable of changing the temperature reading on a thermometer, it is best to bring the discussion to a point where students are able to agree on a tentative explanation as to why the temperature reading did not change. Students can revisit and reevaluate this thinking as they have more experiences with what heat is and how heat is transferred.*

Extensions

Student may:

- extend their mitten experiments by testing for a longer period of time.
- test other items they perceive as "warm." (Gloves, hats, scarves, jackets, blankets, etc.)
- visit WGBH's *Surviving Winter*. This media-rich activity explores the various physical and behavioral adaptations that animals rely on to help them survive changing environmental conditions, such as the arrival of winter. http://www.teachersdomain.org/resource/adlit08.sci.sawinter
- learn more about Chester Greenwood , a Maine inventor of Ear Muffs.

  http://www.visitmaine.com/article/at_chester_greenwood_day_its/?vm=l26qngdu6o8i22dr8lk4lnsrc3

  http://inventors.about.com/library/inventors/blgreenwood.htm

  http://www.ideafinder.com/history/inventions/earmuff.htm
- learn more about weather in Maine.

Connection to Maine Agencies

A Maine Energy Education Program (MEEP) representative and will come to interested schools, free of charge, to guide and support the concepts in lesson. For more information go to the MEEP website: 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 presentation contact Nancy Chandler at 207.760.2556 or nchandler@mainepublicservice.com.

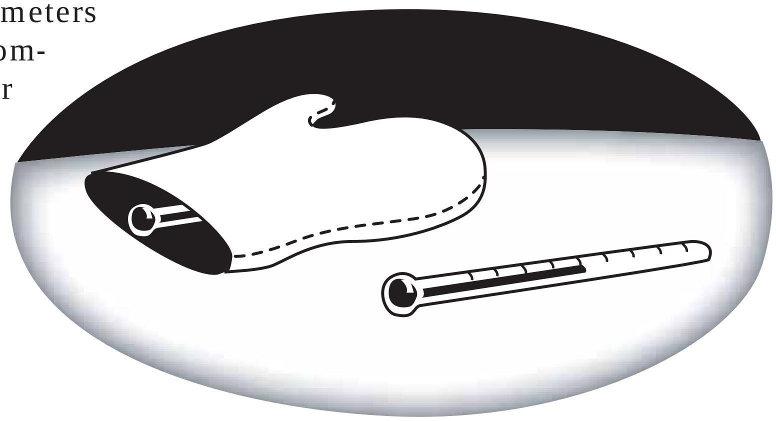
Online References and Resources

Annenberg Media. (1997-2009). Essential Science Series: Physical Science, Workshop 7
http://www.learner.org/resources/series200.html

The Mitten Problem

Sarah's science class is investigating heat energy. They wonder what would happen to the temperature reading on a thermometer if they put the thermometer inside a mitten.

Sarah's group obtained two thermometers and a mitten. They put one thermometer inside the mitten and the other thermometer on the table next to the mitten. An hour later they compared the readings on the two thermometers. The temperature inside the room remained the same during their experiment.



What do you think Sarah's group will discover from their investigation?
Circle the response that best matches your thinking:

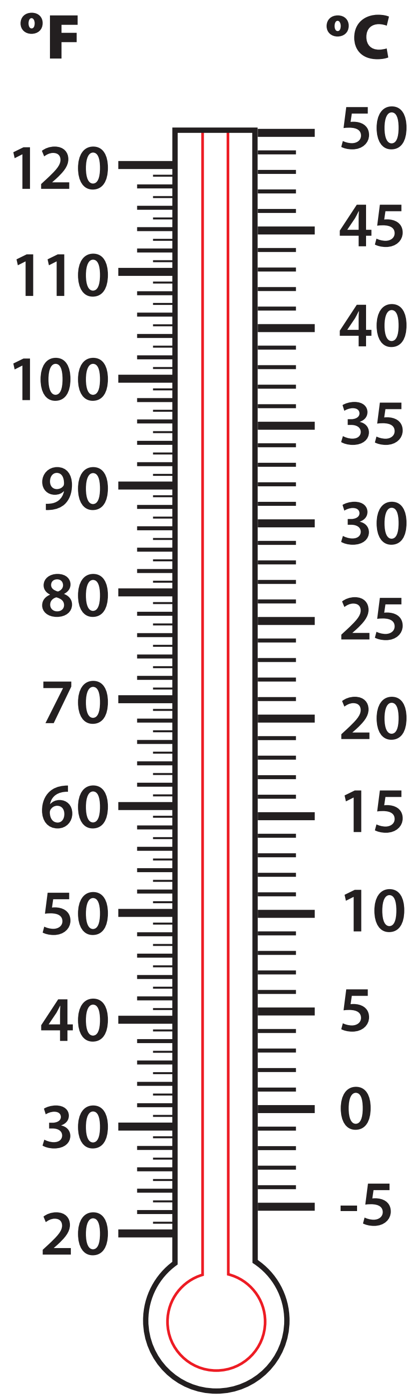
A The thermometer inside the mitten will have a lower temperature reading than the thermometer on the table.

B The thermometer inside the mitten will have a higher temperature reading than the thermometer on the table.

C Both thermometers will have the same temperature reading.

☞ Describe your thinking. Provide an explanation for your answer.

Thermometer Diagram



Lesson 2: Molecules on the Move

Overview

Through direct observations and computer simulations students are introduced to the concept that heat is the transfer of thermal energy. Students will investigate the relationship between thermal energy and molecular motion.

Teacher Background

We are, in some ways, quite familiar with heat. Whether we realize it or not, heat plays a role in just about everything that happens: warming our food, heating our homes, keeping our hands warm on a chilly autumn day, warming the Earth, building mountains, and creating weather systems... the list goes on. Very simply put, heat is a form of energy, and energy makes things happen. We have all certainly felt heat and have observed its effects on matter. If asked to explain heat, however, many would find it challenging.

Let's use a familiar scenario to help us understand the fundamentals of heat. Picture this: An ice cube is placed in a bowl of very hot soup. The ice cube begins to melt. What is happening? Is heat involved? Is heat moving? Which way is it moving? In common terms we say that the bowl of soup is "hot" and the ice cube is "cold." But scientists would think of the ice-cube-in-a-bowl-of-soup scenario in terms of differences in thermal energies.

What is thermal energy and how is thermal energy related to heat? Thermal energy refers to the collective energies of the molecules that make up all matter. The ice cube and the soup are both made up of molecules. Like all molecules, the molecules that make up the ice cube and the soup are in constant motion and the energies of this molecular motion is what scientists refer to "thermal energy."

Temperature is a way of measuring a substance's thermal energy. Molecules move more rapidly at higher temperatures. Keep in mind that since thermal energy refers to the collective molecular energies, the amount of thermal energy a substance has is also dependent on the amount matter. This explains why a bathtub of warm water or an ocean of cold water has more thermal energy than a cup of boiling water even though the temperature reading is lower and the molecules are moving slower.

How is thermal energy related to heat? Strictly speaking, heat is thermal energy that is "in transit" or "on the move." Said another way, heat is thermal energy that is moving from one system to another or heat is moving thermal energy. Thermal energy is transferred when there are temperature differences and transfers from warmer substances to cooler ones. The transfer of heat stops when both substances reach the same temperature. In the ice-cube-in-the-soup scenario, the heat is moving from the soup to the ice cube.

What should middle school students know about heat? Connecting thermal energy to the motion of molecules is a grade-level expectation in middle and high school standards. However, development of this concept must occur over time in numerous contexts and through many experiences and discussions. Developing an understanding of heat requires students to synthesize a number of abstract concepts that are likely to be relatively new to adolescents. It is not intended that students discriminate between thermal energy and heat. The major emphasis of this instructional unit is on heat transfers, placing in the forefront the examination of where heat comes from and where it goes.

For teachers interested in taking their understanding of heat and thermal energy to a deeper level, the following online tutorial is recommended:

NSTA Science Objects: Energy: Thermal Energy, Heat, and Temperature at http://www.nsta.org.

Key Ideas

- Matter is made up of particles (atoms or molecules) that are moving.
- The arrangement and motion of the particles of matter differs depending on temperature. At higher temperatures, particles have greater energy and are more spread out. At lower temperatures, particles have less energy and are more compact.
- Heat is a form of energy that is related to the random motion of molecules.
- Models are used by scientists to explain ideas.

Lesson Goals

Students will:

- describe the motion of particles (atoms or molecules) of matter at different temperatures and in different states.
- recognize the random motion of molecules as thermal energy. When that thermal energy is transferred from one object to another, the amount of energy transferred is called heat.
- be introduced to the idea that all matter has thermal energy.
- consider the benefits and limitations of models.

Vocabulary

heat: the flow of thermal energy from a warm area to a cooler one.

thermal energy: the collective energies of molecular motion of a substance. (The higher the temperature, the faster the atoms and molecules that make up the substance are moving and thus the more thermal energy the substance has. Thermal energy of a substance takes into account the amount of matter. The greater the amount of matter, the more thermal energy a substance has. This is why an iceberg contains more thermal energy than a cup of boiling water.) .

Preparation

- Practice the food coloring in hot and cold water demonstration. Make certain that the water is completely still before placing a drop of dark-colored food coloring into each container of water simultaneously. If the food coloring does not move through the samples of hot and cold water at noticeably different rates, use hotter hot water and colder cold water.
- Fold each index card in half to make freestanding labels for the "hot" and "cold" water samples used in the demonstration. Write "hot" and "cold" on each card.
- Preview and become familiar with how to navigate the websites used to introduce students to the different particle motions of different states of matter. Direct links to the website can be found on the *PowerSleuth* website under *Energy Heats Maine* Lesson 2. Consider organizing a classroom webpage such as portaportal.com for these and other *Energy Heats Maine* links of interest.

Safety

This investigation requires the use of hot water. Use caution when using hot water with students. Double check the temperature of the school's hot water to make certain that students would not be accidently burned if water contacts their skin.

Materials

Item	Quantity
10 oz or larger clear cups or containers that can hold hot water	2
Food coloring (a dark color)	1 bottle
Index cards (to label "hot" and "cold" water samples)	2
LCD projector and computer	1 per class
Student laptops (if available)	1 per 1-2 students
Scientist's Notebook	1 per student
Student Handout 2.1: *Molecules on the Move* (optional)	1 per student

Time Required: 2 sessions

Connection to *Benchmarks for Science Literacy (BSL)*

- Atoms and molecules are perpetually in motion. Increased temperature means greater average energy of motion, so most substances expand when heated. BSL 4D/M3ab (6-8)
- In solids, the atoms or molecules are closely locked in position and can only vibrate. In liquids, they have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions. Benchmarks 4D/M3cd (6-8)
- Models are very useful for communicating ideas about objects, events, and processes. When using a model to communicate about something, it is important to keep in mind how it is different from the thing being modeled. Benchmarks 11B/E4**(3-5)

Teaching The Lesson

Engage

1 Conduct food coloring in water demonstration.

Place two clear containers in a place visible to all students. Fill one container with hot water and another with the same amount of cold water. Label and take the temperature of the two water samples. Be certain that the "hot" or "cold" labels are placed as to not block students' view of the demonstration. Ask students to make a prediction of what they think will happen when a drop of food coloring is released into the different containers of water.

When the water is completely still, put a drop of dark-colored food coloring into the center of each container simultaneously. Ask students to observe and record in their scientists' notebooks what they see happening during the demonstration. Repeat the demonstration a second time if necessary. Students may be interested in timing how long it takes for the color to uniformly disperse.

> **Note:** *Alternatively, students could do this activity at their tables with a partner.*

2 Discuss students' observations.

Ask students to describe what happened during the demonstration. (Students should notice that the food coloring spread out faster in the hot water container than it did in the cold water container.) Ask students if they have any ideas about why this happened and what questions they have about the demonstration. Jot down students' ideas and questions on the board or on chart paper.

3 Elicit students' prior knowledge of molecular (particle) movement.

Explain to students that all substances (all matter), including water, are made up of tiny invisible particles (atoms and molecules). These particles are so small that they can't be seen even by using powerful light microscopes.

> **Note:** *Scanning tunneling microscopes (STM) have allowed scientists' to "see" atoms by locating the atoms position and making an outline of the atom. This type of microscope does not magnify objects in the same way that light microscopes do. For more information visit: http://science.howstuffworks.com/atom10.htm*

Place a cup of water in a place that is visible to all students. Say something like: *Let's imagine that we could use some sort of tool that would allow us to see the tiny, tiny parts – the individual molecules - of water. What would these tiny parts of water look like?* Ask students to draw and describe their ideas in their scientists' notebooks. After a few moments, have students share their ideas with their neighbors.

Ask students to consider what they might see if they were able to see these tiny parts of water as the temperature changed. For example, ask students: *If I were to take the same water that you drew a picture of a moment ago and cooled it down so much that it eventually froze and then looked at it, do you think the parts of the frozen water would look the same or different as the liquid water?* Ask students to draw and describe their ideas about what frozen water (ice) would look like in their scientists' notebooks.

When students have completed this, ask students to do the same for water in its gas form (water vapor). When they are finished, have students share and discuss their ideas at their tables. Circulate around the room, taking note and listening to students' ideas.

> **Note:** *Upper elementary students may not be familiar with "atoms" and "molecules" unless they have had prior experiences with matter. Even if students have heard of the words, it is likely that their understanding may not be scientific. It is not the intent of this unit to develop an in depth understanding of matter and in particular, atoms and molecules. If students are unfamiliar with these terms, simply refer to these tiny parts of matter as particles rather than introduce unnecessary vocabulary prematurely. If students are familiar with the terms atoms and molecules use them.*
>
> *It is also not expected that students have knowledge that the particles (atoms and molecules) that make substances up are constantly moving. Asking students to draw what they think they would see if they COULD see the particles that make up a familiar substance (water) serves to get students thinking about what they might look like. It is highly unlikely, unless students have had prior experiences with states of mater, that they will include molecular movement in their drawings and descriptions. Students without prior instruction may also lack an understanding or even an awareness of states of matter especially matter as a gas.*
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> *This brief exercise is meant to help students develop the idea that particles (atoms and molecules) that make up matter are in constant motion and help them link this idea to thermal energy and heat (the flow of thermal energy).*

Explore

4 View computer simulations of molecular movement of materials at different temperatures.

Discuss with students the idea that scientists often use models to represent ideas or processes for a number of reasons. (Refer to the drawings students made earlier as these are a type of model.) Ask students why they think scientists would make models of the smaller individual parts – the particles of substances? What might these models help scientists explore?

> **Note:** *If students are unaware of the use of models consider using a globe or other familiar example of a model. Most students understand that globes are used to represent the Earth. What they may not recognize is that it is a "model" and like all models it was designed to show certain aspects of the Earth and has strengths and weaknesses. Ask students to discuss the globe's strengths and weaknesses. (Strengths – Since we have the entire Earth in the classroom this model allows users to visualize the Earth in a semi-realistic way, allows users to communicate about the Earth using the same frame of reference. Weaknesses – size is obviously off, colors can't be accurate for each season of the year, etc.)*

Explain to students that they will be examining three computer models of some familiar substances. Make sure that students understand that these are models and that people cannot see directly the individual particles that make up substances. Students may wonder how people can make models of things they have never seen. Explain that models are often developed to show or represent ideas and effective models show ideas that are supported by evidence. Reiterate that models have their strengths and limitations in representing but in this situation models allow us to think about how molecules might be moving.

Using an LCD projector, display the web resource from the Miami Science Museum to the class: http://www.miamisci.org/af/sln/phases/index.html

> **Note:** *The representation shows the arrangement and motion of elements or molecules in gas, liquid, and solid phases. Even though the representation includes a thermometer, it does not explicitly discuss the energy levels of the molecules in each phase. It also does not clarify that molecules are not shaped or colored as depicted.*

Orient students to the simulation by reading the introductory caption on the top of the web page. Explain to students that we'll begin by putting water into the "molecule chamber" (click on water – nothing will appear in the box yet) and selecting a state to view. Point out the thermometer on the left hand side of the molecule chamber and ask students: *If we would like to "see" what the parts of water look like when water is a solid (ice), what temperature would I need to select on the thermometer?* Click on the base of the thermometer. The chamber should fill with blue particles. Ask students to describe what they see in the chamber and comment on how this is similar to or different from what they drew earlier in their scientists' notebooks. Students should notice the arrangement and motions of the molecules. (Solids have particles that vibrate in "place.")

Ask students, given the molecular motion they observed in solid water or ice, if they would like to predict what they think they will see when they look at liquid water? Click midway up the thermometer to view water in its liquid phase. Ask students: *What happens to the molecules as the temperature changes?* Students should notice that the arrangement and motion is different for water in its liquid state. (Liquids have particles that are loosely bound and slide past one another in a random motion.)

Follow a similar line of questioning and observations for water in the gas phase. Students should notice that the gas molecules can move around freely and interact – usually by bumping into one another – when they come close to one another. (Gases have particles that are further apart with more space between them and they move more rapidly than when in their liquid or solid phase. Students may think that there are more molecules in ice than water and more in water than in water vapor as opposed to molecules in the gas just being more spread out.)

Introduce students to two additional simulations described below. Depending on availability, students could view these sites in pairs on individually on laptops. As these simulations are introduced to students, orient them to the sites by pointing out key features and sharing navigation tips. Encourage students to jot down some notes about what they observe or read on these sites in their scientists' notebooks. Ask students to think about how increasing or decreasing the temperature affects the energy of the particles. (Optional: Provide each student with a copy of Student Handout 2.1: *Molecules on the Move* to focus their observations.)

- Harcourt School Publishers: http://www.harcourtschool.com/activity/states_of_matter/index.html

  Explain to students that in this model, the substance is not identified and point out the temperature gauge (the +/- bar to the right of the purple sample).

- Vision Learning: http://web.visionlearning.com/custom/chemistry/animations/CHE1.1-an-threestates.shtml

  This animation provides another model in a slightly more sophisticated way of the relative molecular motions of water in its various states. Students may ask why water particles in this model look like small Mickey Mouse heads. This model shows how the elements making up water, hydrogen and oxygen, are attached and arranged. This is added detail is one that students do not need to be concerned with at this point. Ask students to focus on the differences in the motions and arrangement of the particles in the models.

Reflect And Discuss

5 Revisit students' drawings.

Ask students to revisit and reflect upon the drawings they made earlier of water in each of the three states. Ask students to respond to the following prompt(s) in their scientists' notebooks:

- *How are your ideas about the movement of the molecules of water similar to the computer models?*
- *How are your ideas about the movement of the molecules of water different from the computer models?*
- *Make new pictures showing your new ideas of how the molecules of water move at each of the following temperatures: ice (0°C), water (20°C), and water vapor (100°C). Use words to describe your new models.*

6 Connect models to food coloring demonstration.

Remind students of the food coloring in hot/cold water demonstration from the beginning of the lesson. Pose the following to students: *Using what you know about the movement of water molecules at different temperatures, explain why the food coloring moved differently in the two samples.*

Allow students a few moments to discuss their ideas with a partner and then construct an explanation based on their observations. All students should write an explanation in their scientists' notebook. Students may wish to use pictures to help describe their thinking. Have a few student volunteers share their ideas.

> **Note:** *Students should include the following in their explanations: All matter has smaller parts that are constantly in motion. Substances at higher temperatures have more energy and therefore the molecules in them move around much more rapidly. When the food coloring is added to hot water, the particles of water bump into the food coloring particles at a faster rate and more frequently than when the food coloring is put into the colder water. This causes the food coloring to spread out much more rapidly in the hot water than in the cold water.*

7 Relate particle motion to heat and thermal energy.

Explain to students that all matter is made up of small particles and these particles are always moving. Emphasize the idea that all matter is made up of tiny moving particles by discussing a few examples: particles making up the table are moving even though we can't see movement in the table; particles making up icebergs are slowly jiggling; particles making up a cold liquid drink are moving; particles making up a glass window are also moving as is the air inside a basketball; the particles making up an apple are moving, etc. Explain that substances are made of smaller parts that are moving. It is this particle motion that moved the food coloring through the two containers of water. Students may think that the "release" of the food coloring made the particles move, so they may not be convinced. Consider leaving the sample undisturbed and discussing why the food coloring eventually spreads through the entire sample, long after the "push" or dropping in of color is not longer taking place.

Explain that scientists refer to the collective motion of particles in matter as thermal energy. The amount of thermal energy a substance has depends on its temperature and amount.

Dissect the word thermal by asking students if they have ever heard of the word thermal before. Ask students to suggest words that they've heard of that contain "therm" or "thermal." Students may suggest terms such as: thermos, thermal underwear, thermal pajamas, thermostat, thermometer, thermal blanket, thermal insulation, thermal pane windows, geothermal, thermo pack, thermodynamic, thermoregulation, isotherm, hypothermia, thermochemistry, endotherm, ectotherm, endothermic, exothermic, etc. Explain that the root of thermal is "therme"- a Greek word referring to heat. It may be fun to post their "therm" words on a white board or large sheet of paper so they can see as well as hear the root word.

Set the stage for upcoming lessons about heat by asking students why they think the word "thermal" was used to describe the collective energies of particles in a substance. Students will develop the idea in upcoming lessons that heat is thermal energy that flows.

> **Note:** *Physicists distinguish heat from thermal energy. Heat is thermal energy that is "in transit" – thermal energy that is moving from one system to another. Heat is moving energy. As noted earlier, thermal energy is transferred when there are temperature differences and transfers from warmer substances to cooler ones. The transfer of heat stops when both substances reach the same temperature. Teachers should not be overly concerned about students distinguishing between thermal energy and heat. The idea here is to help students recognize that there is a connection between*

thermal energy and heat and more importantly, that heat is related to the motion of particles. These ideas are addressed in upcoming lessons. Students' understandings about heat will develop over time.

8 Bring lesson to a close.

Challenge students to find additional words that contain the root "therme." Consider creating a "therme" board for students to post the words they come up with throughout the unit.

Extensions

Student may:

- explore Physics Central: Physics in your Glass: Racing Molecules www.physicscentral.com/experiment/physicsathome/glass.cfm. This site describes the molecular motion of water in its various states and explains the differential movement of food coloring though warm and cold water. Included is a "Try this" section that encourages users to try the food coloring experiment with vegetable oil, adding soap, and adding salt.
- investigate how thermometers work.
- build their own thermometer: http://www.pbs.org/wgbh/nova/teachers/activities/3501_zero.html

Connection to Maine Agencies

A Maine Energy Education Program (MEEP) representative and will come to interested schools, free of charge, to guide and support the concepts in lesson. For more information go to the MEEP website: 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 presentation contact Nancy Chandler at 207.760.2556 or nchandler@maine publicservice.com.

Online References and Resources

- Berkheimer, G., Anderson, C., Blakeslee, T. et al. (1988) *Matter and Molecules.* East Lansing, MI: Institute for Research on Teaching, Michigan State University. http://ed-web3.educ.msu.edu/reports/matter-molecules/default.htm
- National Science Teachers Association. *Science Objects: Energy: Thermal Energy, Heat, and Temperature.* www.nsta.org

Molecules on the Move

Review the websites as instructed by your teacher and answer the questions.

1 How does increasing or decreasing the temperature affect the energy of the particles?

2 Explain why it is not necessary that the substance is identified in all of the models.

3 How does the motion of molecules differ between each state of matter?

4 How does the arrangement of molecules differ between each state of matter?

5 Draw water molecules at 0, 20, and 100 degrees Celsius.

Lesson 3: Mixing Water

Overview

Students design and carry out an investigation to monitor the temperature of water when equal volumes of hot and cold water are mixed.

Teacher Background

It's a beautiful cold winter day in Maine. It's snowing hard and school is canceled. The kids just came in from playing in the snow and it's time for some hot chocolate! Imagine serving a cup of hot chocolate to those "chilled to the bones" children. The hot chocolate is too hot; it requires the addition of cold water to lower the temperature. How much cold water should be mixed with the cocoa to bring the temperature down to one that is suitable? Is there a way to predict the resulting temperature in advance? When the hot chocolate and cold water are mixed, what is going on in terms of heat?

In this lesson students examine the nature of heat and how heat is transferred. In this investigation students mix equal volumes of hot and cold water and discover that the resulting temperature is the midpoint between the starting temperatures of the two samples. While this investigation may seem simple on the surface, the concepts involved are somewhat sophisticated and abstract. Transfer of heat occurs when interacting substances or systems are at different temperatures. When samples of cold and hot water are mixed together, an energy transfer occurs. Transfer occurs until the interacting substances or systems reach the same temperature and transfer only occurs in one direction – from warmer substances to cooler ones. A change in the temperature of a substance is due to the change in the average molecular motion of the molecules.

While students may readily grasp the mathematical relationships in this exercise, students may have difficulty explaining what happens in terms of the flow of heat from warmer substances to colder substances. This is especially challenging for students that think of "hot" and "cold" as substances. When the cooler water and the warmer water are mixed together, a transfer of the energy occurs between the particles as they come into contact with each other. Heat transfers from the more energized molecules in the warmer water to the less energized molecules in the colder water until the two have the same average energy (temperature). Since the two samples are the same volume, the temperature at which transfer stops is the midpoint of the two starting temperatures. In actuality, the temperature may be slightly less due to a small amount of heat energy that is transferred to the containers and surrounding environment. While it is not expected that students incorporate directionality (warm to cold) into their thinking about heat transfers at this point, this exercise sets the stage for this concept in the next lesson.

Key Ideas

- Heat can be transferred from one place, object, or system to another.
- Mixing water of two different temperatures results in a sample of water with an intermediate temperature that is predictable given the starting and ending temperatures.

Lesson Goals

Students will:
- explain resulting temperatures in terms of the change in thermal energy.
- describe how heat spreads from one place to another including how cooler materials can become warmer and vice versa.

Vocabulary

heat: the flow of thermal energy from a warm area to a cooler one.

thermal energy: the collective energies of molecular motion of a substance. (The higher the temperature, the faster the atoms and molecules that make up the substance are moving and thus the more thermal energy the substance has. Thermal energy of a substance takes into account the amount of matter. The greater the amount of matter, the more thermal energy a substance has. This is why an iceberg contains more thermal energy than a cup of boiling water.)

Preparation

- Prepare enough hot (approximately 50°C) and cold (approximately 10°C) water for students to work in pairs. A pitcher of ice water will be about 5°C. This can be brought to about 10°C by adding tap water just before students need to use it. Make sure however that students do not have any ice in the samples of cold water when they are doing their investigation. Likewise, an insulated container (old insulated coffee pot or thermos) with 60°C water gathered just before the lesson begins will drop about 10°C before it is time for students to do their investigation. Another reliable method for preparing cold water is to fill a gallon jug about 1⁄2 way with water and freeze it overnight. Add enough cold water to fill the jug. The ice chills the water for more than 90 minutes.

- Determine how materials will be managed – especially how students will efficiently and safely obtain hot and cold water samples.
- Prepare a few temperature examples and answers for the mathematical portion of this lesson (see Step 5 in the Reflect and Discuss section).
- Make an overhead or class chart for Student Handout 3.1.

Safety

This investigation requires the use of hot tap water. Check the temperature of the school's tap water to make certain that students would not be accidently burned if water contacts their skin.

Materials

Item	Quantity
Cups, foam or insulated paper	3 per student pair plus one set for teacher demo
Graduated cylinders	2 per student pair
Thermometers	2 per student pair
Pipette	1 per student pair
Scientist's Notebook	1 per student
Hot and cold water	Enough for pairs of students to conduct investigation
Cloth towels or sponges to wipe up spills	1 per student pair and a few extras on hand
Dust pan and brush	1 for class
Student Handout 3.1: Mixing Water Class Data	2 copies per student
Overhead of Student Handout 3.1	2
Temperature probes, if available (optional)	

Time Required: 2 sessions

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

- Describe several different types of energy forms including heat energy, chemical energy, and mechanical energy. MLR D3(6-8) h
- When warmer things are put with cooler ones, the warmer things get cooler and the cooler things get warmer until they all are the same temperature. BSL 4E/E2a* (3-5)
- 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. BSL 4E/M3* (6-8)

Teaching The Lesson

Engage

1 Introduce the mixing water investigation.

Explain to students that they will be using their knowledge of thermal energy in an investigation. Remind students that thermal energy is the collective energies of molecular motion of a substance.

Hold up two cups of water, one half-filled with hot water and one half-filled with cold water. Ask students: *If I could see the motion of the individual molecules in each of these samples, what do you think the difference in their motion would be?* (Students should recognize that the sample at the higher temperature would have greater molecular motion.)

Pose the following to the class: *I have been wondering….what would happen if equal volumes of hot water were mixed with an equal volume of cold water?* Ask students to use sketches and/or diagrams to describe in their scientists' notebooks what they think will happen when equal volumes of hot and cold water are mixed. Circulate around the room as students make this entry in their scientists' notebooks. Ask a few student volunteers to share their ideas. 51

Ask students to predict the ending temperature of the mixed water sample. Make sure students support their prediction with a reason. Activate students thinking by asking: *Would the ending temperature be higher or lower or the same as the starting hot/cold water samples?* Have a student volunteer take the temperature of each of the water samples. Record the temperature of each sample on the board. Have students record their prediction in their scientists' notebooks.

Alternatively, have students make their predictions interactively. Make a line in the room representing the temperature scale. 50°C to 10° Celsius. Have students stand where they think the final temperature would be after mixing and say why they think this.

2 Plan a "mixing" experiment.

Post the following focus question on the board: When the hot and cold water samples are mixed what do you think the resulting temperature will be in comparison to the beginning temperatures? With this question in mind have students work in pairs to design a simple experiment to test their ideas. Before students begin planning, show them the materials that are available for them to use:

- 3 cups, foam or insulated paper
- 2 graduated cylinders
- 2 thermometers
- pipette
- hot and cold water

Give students (5-10) minutes to record a plan for an experiment in their notebooks. After each pair has their preliminary ideas recorded, bring the class together to briefly discuss those plans. Jot some of these ideas on the board. While it is not critical that each pair follow the exact same plan, make sure student pairs take into consideration the following points:

- Use equal volumes of hot and cold water in the investigation. The volume students decide to use does not matter as long as students use the same for both the hot and cold. Somewhere between 50 and 100 mL is manageable. Students should specify a volume of water.
- Decide how to record data.
- Measure and record the starting temperatures before mixing.
- Mix the hot and cold water in the 3rd insulated cup.
- Measure the resulting temperature by placing both thermometers in the mixing cup.
- Repeat their experiment (time permitting).

Encourage students to make amendments to their procedures if they've overlooked something brought forth in the discussion. Give them a few minutes to make edits.

Explore

3 **Conduct the investigation.**

Before students carry out their investigative plans, instruct them in material use and management. Include the following:

• Safe access and transport of hot and cold water.

• Proper use and storage of thermometer.

• Accurate measurement of water volume using the graduated cylinder and pipette.

• Clean up procedures.

While students are conducting investigation, circulate around the room, monitoring students' measuring and temperature reading skills and their ability to record their results accurately and efficiently.

> **Note:** *To help monitor student lab work consider using what is referred to as "Traffic Light Cups." This strategy encourages students to monitor their progress and to use the cups as a visual cue when they require teacher assistance. Each lab group gets a set of green, yellow, and red large plastic stackable party cups. The 3 cups are stacked on top of each other with the green cup on top. If the students need immediate help, they put the red cup on top as a signal. Teacher sees the visual cue and attends to the group. Students use a yellow cup to signal they need some help but they can keep working until they get it. A green cup means they are able to keep working and that they feel they are doing fine without assistance. It is important to monitor and check in with each group no matter what color is displayed when opportunities arise as some groups may feel they are doing fine when in fact they need some guidance. This strategy allows the teacher to attend to groups who feel they are in most need. This monitoring strategy is from Science Formative Assessments by Page Keeley*

Reflect And Discuss

4 **Compile and review results.**

Create a class data table by asking one student from each pair to write their results on a transparency copy of Student Handout 3.1: Mixing Water. Students can enter class data on their own copy of Student Handout 3.1 or develop their own chart in their scientists' notebooks.

After the class data has been compiled, discuss the following with students:

- *What do you notice about the data?* (Accept reasonable answers.)
- *Is there a pattern between the starting temperatures and the ending temperatures?* (Students should notice that the ending temperature is between the two starting temperatures. More precisely, the ending temperature is exactly halfway between the cold and hot water starting temperatures.)
- Assist students in developing an equation that captures the pattern shown in the data:

$$\frac{Temp_{h}\ (hot)\ +\ Temp_{c}\ (cold)}{2} = Temp_{f}\ (final)$$

- Ask students if they could use this equation to accurately predict the final ending temperature given starting temperatures for different samples of hot and cold water. Give students a few examples to practice using the formula. Be sure to emphasize that for the sake of simplicity, the volumes of hot and cold water used must be the same.

> **Note:** *Teachers should supply numbers easily added and divided by 2 so that the focus of the lesson is not math, but the science concept.*

5 Discuss findings by asking students to draw motion of mixing molecules.

Ask students to imagine again that they could see the molecules in action as the water mixing was occurring. Ask students to draw a series of pictures (supported with words) that illustrates what they think was going on with respect to the motion of the molecules before, during, and after mixing. After students have had the opportunity to draw their ideas individually, have students discuss their drawings in small groups followed by a large group discussion.

Students should recognize that the “hot” water particles would be moving more rapidly (had higher energy) and the “cold” water particles would be moving more slowly (had lower energy). In other words, students should be able to recognize that the speed of the particle motions (energies) changed in the samples of hot and cold water as a result of mixing. It is not expected that students understand the mechanism behind the change but that the speeds (energies) changed. When the hot and cold water mixed “warm” water resulted.

> **Note:** *Students may wonder why the resulting “warm” water temperature is slightly below the midpoint temperature. Ask students why they think this happened and guide students into recognizing that some of the “hot” water's energy is transferred to the cup and surrounding environment.*

As students are discussing their ideas, consider aiding their understanding by drawing a series of diagrams on the board that show the same number of particles in two samples but in the hot water sample, use short arrows to show the rapid movement of particles in the sample. In the cold water sample, use arrows to show slower movement of particles. Remind students that matter is made up of particles; particles are always moving and because of this, all matter has thermal energy- even matter we think of as "cold."

6 Introduce an additional "mixing" challenge.

Say to students: *In this investigation we used equal volumes of water. Do you think that the same thing would happen if we used unequal volumes? For example, if I added 100 mL of cold water with 10 mL of hot water will I get a temperature that is half way between the two starting temperatures or something else?*

Allow students time to carry out additional investigations using unequal volumes of hot and cold water. Ask students to work under the same guidelines as they did before which included predicting the final temperature and recording their findings on the class data chart.

7 Bring lesson to a close.

Discuss with students their findings as before and bring the lesson to a close by creating a summarizing statement (bulleted list) of what students learned from their investigations.

> **Note:** *It is not expected or even encouraged that students incorporate directionality into their thinking about heat transfers at this point. The next lesson provides students with the opportunity to examine the idea that heat is transferred from warmer to cooler substances.*

Extensions

Student may:

- investigate what would happen if the mixed water sample was allowed to sit for two hours. What is going on in terms of molecules?
- investigate if it makes a difference whether the cold water sample is poured into hot water sample and vice versa.
- try out a virtual mixing experiment at: Concord Consortium. (2005-06). ITSI DIY: Show Activity 126: Temperature of Mixing Water. http://itsidiy.concord.org/activities/126

Connection to Maine Agencies

A Maine Energy Education Program (MEEP) representative and will come to interested schools, free of charge, to guide and support the concepts in lesson. For more information go to the MEEP website: 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 presentation contact Nancy Chandler at 207.760.2556 or nchandler@mainepublicservice.com.

Online References and Resources

National Science Teachers Association. *Science Objects: Energy: Thermal Energy, Heat, & Temperature*. www.nsta.org

Mixing Water Class Data

Group	Volume of hot/cold water samples (mL)	Temperature of the hot water (°C)	Temperature of the cold water (°C)	Prediction (°C)	Final Temperature (°C)
	/				
	/				
	/				
	/				
	/				
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	/				
	/				
	/				

Lesson 4: Where is Heat Coming From and Where is It Going?

Overview

In this investigation, students expand their understanding of thermal energy transfers by focusing on the directionality of heat transfers. Students collect temperature data from two interacting containers of water and from their results infer that heat is transferred from warmer matter to cooler matter until both substances reach the same temperature.

Teacher Background

In the previous lesson, students focused on the idea that thermal energy changes. This investigation adds another layer to students' understanding by examining the direction of heat transfers- from warmer matter to cooler matter.

The idea that heat transfers from warmer substances to cooler substances is a challenging idea for students for a number of reasons. One reason is, as noted previously, many students believe certain materials are inherently "warm" or "cold" or view "hot" and "cold" as entities of objects. Another reason is that many everyday experiences with "cold and hot" lead students to think that energy moves from cooler areas to warmer areas. For example, most children have been told by their parents to shut the door to keep the cold air out. What they should be saying is close to door to **keep the heated air in!** If we stand in front of a door open to a cold outdoors or open a refrigerator we feel the cold air "escaping." It's these types of common experiences that lead children to logically conclude, "I feel cold, so cold must be moving."

Let's consider a few questions involving heat transfers. What is the source of heat for our planet? We all know the source of heat for Earth is the Sun, but how does the warmth of the Sun get to the Earth? Another question about heat transfers to ponder is, what happens to a glass of ice water that is left out in a warm room for a long time? From experience we know that the water will no longer have ice in it and will no longer be "cold." But how did it warm up? Heat from the surrounding warmer air transferred into the glass and then to the water, warming the ice cube and causing it to melt. Another example of a heat transfer occurs when a person is taking a nice warm bath. Why does the temperature of the bath water cool after a while? The cooling of the bath water occurs in much the same way as in the glass of ice water. Heat is transferred from the warmer water in the tub to the tub and then to the surrounding air in the bathroom because their temperatures are cooler than that of the bath water. That cools off the tub water. These things happen because warm matter does not keep its heat if near colder matter. Heat naturally transfers when there are temperature differences, from warmer areas to colder areas, until the interacting matter reaches the same temperature. Heat transfers occur all the time!

Students may struggle with the idea that heat **moves from** warm matter to cool matter and may frequently revert back to their intuitive notions about heat. Focusing on and discussing everyday experiences that students encounter regularly will go far in helping students conceptually grasp the nature of heat and how it is transferred. A simple yet effective question to continuously ask throughout this and the next few lessons is, "Where is heat coming from and where is it going?" Reflecting on and discussing this simple question not only reinforces the notion that heat moves but will help students see the pattern of heat moving from warmer substance to cooler substances. *Benchmarks for Science Literacy* and the *Maine Learning Results* state "when warmer things are put with cooler ones, the warm ones lose heat and the cool ones gain it until they are the same temperature." While this is a Grade 3-5 expectation, it is worth maintaining a focus on this idea throughout this lesson because a conceptual understanding of this key idea lays the foundation for an understanding of energy transfers and conservation of energy; both middle school expectations. Note that this lesson was deliberately designed to investigate "heat" using something that students often think about as "cold" so that they may begin to recognize that "hot" and "cold" are relative terms.

While this lesson examines heat transfer macroscopically, some students may bring their knowledge of molecular motion and heat to these activities. As objects warm up their kinetic molecular movement increases. Along with this increase in molecular movement is an increase of energy. Since the notion that energy moves from a more energetic state to the less energetic state is a high school grade level expectation a conceptual understanding of this is not expected at this time. Rather, this lesson focuses on macroscopic recognition of transfers of heat from warmer matter to cooler matter.

Key Ideas

- Energy can move from one place, object, or system to another.
- Substances heat or cool as a result of energy transfer.
- Energy always transfers from warmer matter to cooler matter until both reach the same temperature.

Lesson Goals

Students will:

- explain resulting temperatures in terms of energy transfer.
- explain how heat moves from one place to another including how cooler materials can become warmer and vice versa.
- describe conditions necessary for heat transfer; namely that heat is transferred 1) when there is a difference in temperatures between interacting matter, and 2) from warmer matter to cooler matter until both reach the same temperature.

Vocabulary

heat transfer: the transfer of thermal energy between substances due to a difference in their temperatures.

Preparation

- Collect clear 2-L plastic bottles. Remove the top tapered portion of the bottles (screw top and neck) by cutting along the top edge of the bottle's label. Remove the label and discard the top portion of the bottle.
- Prepare enough warm water (with a starting temperature of approximately 35°C – tap water often reaches this temperature) and ice water for students working in pairs.
- Preview and pre-register for the website used in this lesson. Become familiar with how the simulation works and how to navigate the site. http://www.fossweb.com/modulesMS/kit_multimedia/ChemicalInteractions/conduction/conduction.html

  > **Note:** *In order to use the site, teachers need to register in advance. Teachers receive a user name and password via email which can be shared with students to access the animation. Passwords expire July 1 of each year but are renewable.*

- Determine students' graphing abilities and pre-teach necessary skills.

Safety

Make certain that students know how to safely use and handle thermometers. Review thermometer safety with students, making sure students know what to do if breakage occurs. Bottle edges are sharp. Instruct students to use caution when placing plastic bags inside to avoid puncture.

Materials

Item	Quantity
Table lamp with a 100 watt incandescent bulb	1 per class
Cooler (optional, a prop)	1 per class
Thermometers	2 per pair
Temperature probes (optional – if available, could be used in conjunction with student thermometers)	Based on availability
2-L clear plastic bottles with top portion removed	1 per pair
Quart size freezer bags (heavy duty)	1 per pair
Blue food coloring	1 bottle per class
Warm and ice water	Enough for pairs of students to conduct investigation
Cups or beakers (500 mL)	2 per pair
Access to clock with minute hand, timer, or stopwatches	1 per class or 1 per student pair
Scientists' Notebook	1 per student
Student Handout 4.1 (optional): Temperature Changes	1 per student
Graph paper	1 per student
Colored pencils	Each student needs two different colors
Access to internet	Individual, pairs, or whole class depending on availability

Time Required: 2-3 sessions

Session 1: Heat idea discussion, lamp demonstration, introduce model cooler, prep for investigation.
Session 2: Carry out investigation, reflect and discuss results.
Session 3: Carry out virtual heat flow investigations.

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

- Energy appears in different forms. Heat energy is the disorderly motion of molecules. BSL 4E(6-8)
- Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature. NSES B(5-8) 8

Teaching The Lesson

Engage

1 Discuss people's ideas about heat.

Ask students: *Where do you think people get their ideas about heat?* Direct students to write down a "heat" or "cold" experience they've had. Give students an example to get them thinking: *When I went out to the garage this morning, I felt the cold hit my face!* Discuss how these experiences shape their ides about heat.

2 Introduce another "heat" experience.

Display in an area visible to all students, a lamp with an incandescent light bulb in it. **Do not turn the light on.** Ask a student volunteer to hold their hand near the light bulb. After a few seconds have the student share with the class how his or her hands feel. (Students should not feel any difference in their hands.)

Turn on the lamp. Have the student hold his or her hands near the incandescent light bulb again.

> **Safety Note:** *Use extreme CAUTION! Do not let any students touch the lamp. Touching a light bulb can cause serious burns.*

After a few seconds, have the student share with the class how his or her hands feel now. (Hands should feel slightly warmer.)

3 Discuss observations.

Discuss with students the following:

- *How did our student volunteer's hands get warm?* (The heat from the bulb warmed the student's hand.)
- *Does heat move?* (Yes, in the experience with the lamp, heat moved from the bulb to the person's hands.)
- *Does heat move in a particular way?* (Students may know that heat moves from something at a higher temperature to something at a lower temperature. The point of this question is to have students begin to think about how heat moves, not to provide a correct answer.)
- *How could you tell if something was gaining heat?* (Students may say that you could feel it or the object could glow, melt, or increase in temperature. Students may suggest using a tool such as a thermometer to see if the object's temperature was increasing.)

- Would you say the lamp is giving off heat? Why? Where does the heat come from? Students will most likely recognize that electricity makes the lamp work and may say that the lamp gives off both heat and light. Some students may explain that the heat comes from the movement of electricity through the lamp.

Explore

4 Present students with the following scenario.

Share the following scenario with students: *Have you ever used a cooler or ice chest to keep your food cold on a hot summer day?* (Many students will be familiar with this situation however some may not have had this experience. Consider bring in a cooler to show students. Ask them what they think it is for and/or demonstrate by putting food inside beforehand and showing them that it is still cool.)

Would you say "heat" is involved in the keeping the food cool? Ask students to talk to a neighboring student about their thoughts. After a few moments, have students share some of their thoughts with the class. (The idea of the "cooler" may initially challenge students' idea of "heat" if they revert to the common, everyday use of word "heat." Students who are beginning to relate "heat" to molecular activity may be able to articulate that all matter has "heat." The movement or transfer of heat is involved in keeping items cold in a cooler and terms such as "hot" and "cold" are relative and somewhat arbitrary.)

As with the light bulb demonstration, ask students to think about how they think heat is moving in the food and cooler example. It may help them to think about the movement of heat in terms of what's gaining heat and what's losing heat. Or in terms of where the heat comes from and where goes.

> **Note:** *Students may think that the "coldness" moves rather than heat and may struggle with the idea that heat moves from objects and materials that are at higher temperature to those that are at a lower temperature until equilibrium is reached. Some students may also think that both heat and cold are transferred at the same time.*

5 Introduce students to a model “cooler” investigation.

Gather the materials for the cooler investigation, and explain to the students that they will be investigating how heat moves using a simple model “cooler.” Show students the materials they will be using and explain how they will be using them:

- 2-L bottle (with the top portion removed) filled with a mixture of ice cubes and water.
- quart-sized bag filled with warm water to represent the “food” that is being kept cool in the cooler.

Say to students: *Since we are interested in trying to figure out how heat moves, let's think about things that are important to monitor during this investigation. What measurements and/or observations do you think we should record that will help us understand how heat moves?*

Students may suggest monitoring the temperatures of both the ice water in the “cooler” and the “food” in the bag. Students may suggest noting the temperature in the room. Students should recognize that in order for this to be a fair test, equal volumes of hot and ice water should be used the model. 500 mL (2 cups) of water is a manageable amount to use during this investigation.

> **Note:** *Each student pair will have two thermometers; one that is kept inside the sealed “food” bag and the other that is kept in the cooler of ice water. One thermometer could be left out for the class to measure room temperature.*

Suggest that students add a drop of blue food coloring to the the "food bag." This will help students recognize that the water, the matter, is not changing positions during this investigation and reaffirm that the heat is what moves. Consider adding the food coloring to the class supply of the water representing the food as students are introduced to the location of the warm and ice water and the other investigation supplies. As the food coloring is added, explain to students: *Sometimes people think that heat is a substance – matter – but it is not. Heat is a form of energy. Energy is not matter. Coloring the water will remind us that the heat is moving and that no water is moving in and out of the bag, otherwise the food coloring would show up in the ice water as well. It also will let us know if our food bag springs a leak during our investigation.*

> **Note**: *A leak in the bag would invalidate the investigation because students would be mixing water as in Lesson 3 and this would not help students infer which way heat moves.*

There is no absolute way to prove that heat moves in this activity because energy cannot be seen, but with teacher guidance, students can infer from this activity that heat moves.

6 Make predictions and plan for data collection.

Before students begin, ask them to record the following in their scientists' notebooks:

- **Focus Question:** *Where do you think the heat is coming from and where do you think it is going?*
- **Prediction:** *I think* _________ *because* _________. Make sure that students support their prediction with reasoning that involves "where they think heat is coming from and where they think it is going" in the "*because*" portion of their prediction. For example, students might state "*I think* the temperature of the food will be lower and the temperature of the ice water will be higher *because* the heat is moving from the ice to the food. (This is not correct, but a student may think this.) It may be helpful for students to think about which one of the containers is holding something at a higher temperature and which container is holding something at a lower temperature. Check to see that students have included reasoning in their predictions.

  > **Note**: *If students struggle at making a prediction supported by reasoning involving heat transfers, consider having students work in small groups to craft their predictions or assisting students in crafting a class prediction. Another possibility would be to present several predictions supported by reasoning to students and allowing them to choose the prediction that fits their current thinking.*

- Sketch of "cooler" components.
- Preparation for data collection. Ask students to design a chart to record temperature change over time. Alternately, provide students with Student Handout 4.1: Temperature Changes and ask students to paste this in their notebooks.

7 Conduct the investigation.

Provide students with instructions as to how materials should be managed and used including:

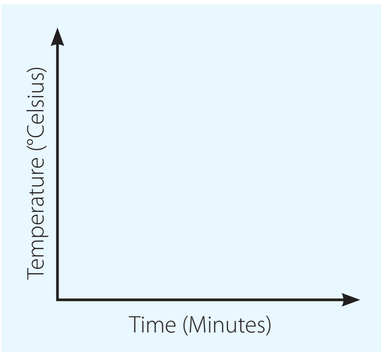
- Access and safe transportation of water.
- Proper use and storage of thermometer.
- Clean up procedures.

While students are conducting their investigation, circulate among groups, monitoring students' work. Students may stop monitoring the temperature once both samples have reached the same temperature. This takes approximately 10-15 minutes.

Reflect And Discuss

8 Graph and review results.

Ask students to create a double line graph (time on x axis, temperature on y axis, plot lines using two different colors) of the data they collected during the investigation. Depending on students familiarity with graphing, consider asking students what kind of graph they would construct and/or why use a double line graph in this case. The following site contains a graphing tutorial to help students think about the types of graphs to use and why: http://nces.ed.gov/nceskids/help/user_guide/graph/whentouse.asp



Support students as needed in constructing this graph. If students prefer to construct their graphs on a separate sheet of graph paper, have students paste their graphs into their scientists' notebooks. If students have access to and familiarity with computer graphing programs, consider using these instead.

Ask students to examine their completed graphs and write about what their graph and the investigation told them about heat transfer. Consider giving students the following prompts to guide their responses:

- *What does the graph tell us about how heat moves or is transferred?*
- *Where did heat come from and where did it go? Use a picture to help explain your ideas.*
- *How do you know? What evidence do you have that supports your claim?*

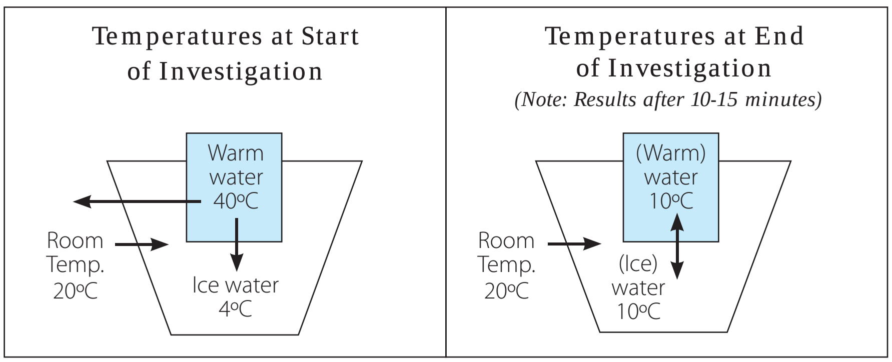
Support students as necessary and consider working through these questions as a large group.

9 Conduct a scientists' meeting.

Ask students to gather in a circle and bring their scientists' notebooks with them. Engage students in a discussion with the following questions:

- *How did heat move during this investigation? Where did it come from and where did it go? What is your evidence that supports what you're claiming?* (Encourage students to share the pictures (drawings) they used to explain their thinking. Heat moved from the warmer water representing the "food" to colder ice water. Students should have noticed that the temperature of the warmer water decreased while the temperature of the ice water increased until both samples of water reached the same temperature.) **Be certain to emphasize that the transfer was from warm to cold. This is the where inference comes in to play. Discussion will be important here since students can't actually see the heat moving from warm to cool.**

- *How can you be sure that it was not the water that moved during this investigation?* (Students should notice that the ice water did not turn blue. This shows us that energy moved, not matter.)
- *How close do objects or substances have to be for heat to be transferred from one to the other? In other words, do substances have to be in direct contact with (touching) one another for heat to be transferred?* (Remind students of the light bulb experience and our Sun.)
- *What happened to the room temperature? How do you think that the room temperature affected the temperature changes in the warm water or ice water samples?* (Guide students in discussing this last point. Students may recognize that heat was transferred from the room to the ice water. It may be helpful to use diagrams to help students understand the directionality of the heat transfers involved. Using a diagram like the one shown below, show students how arrows can be used to indicate the direction of heat transfer between samples. Emphasize that heat moves from warm to cool not the other way around.)



10 Introduce virtual energy flow investigations.

Explain to students that they will be using a website that allows them to examine heat flow virtual containers at different starting temperatures. Show students how to use the website by working through one example together as a class. The opening screen shows two containers, an inner and outer container. The opening screen also shows the temperatures of the water samples in the inner container, the outer container, and room temperature in the upper left hand corner. The user must drag and drop the temperatures to the correct places on the diagram. Once this has been done correctly, the shaded boxes appear over the picture and arrows appear in the top left hand corner. The user must click and drag arrows to show the direction heat flows. Once completed, the user clicks on the check me button. If the arrows have been arranged correctly, another scenario appears. If the arrows are not appropriately placed, the user must correct them before moving to the next scenario. http://www.fossweb.com/modulesMS/kit_multimedia/ChemicalInteractions/conduction/conduction.html

Note: *In order to use the website, teachers need to register in advance. They will receive a user name and password via email which can be shared with students to access the animation. Passwords expire July 1 of each year but are renewable.*

Give students time to complete several scenarios. Consider asking students to record their arrow placement for a certain number of scenarios in their scientists' notebooks using a simple chart, such as the one shown below:

Room Temperature in °C	Direction of Heat Transfer (Arrow)	Outer Tub Temperature in °C	Direction of Heat Transfer (Arrow)	Inner Tub Temperature in °C	Direction of Heat Transfer (Arrow)	Check
30°C	←	60°C	→	0°C	↓	

70

As students work, circulate around the room assisting students as needed. Ask students to write a short summary in their notebooks about what they learned about heat flow the investigations.

Alternatively, this exercise could be done as a class using an LCD projector.

11 Bring lesson to a close.

Ask a few students to share their understanding about the movement of heat from the investigations. Students should have captured the idea that heat moves from warmer places to cooler places in their written summaries.

Extensions

Student may:

- explore electronic cooling devices such as refrigerators and air conditioners.
- examine mood rings, mood beads, and other interesting "toys" that change color due to heat transfers (color changing paper, putty, mugs/glasses, foam, T-shirts) http://www.teachersource.com/Chemistry/Thermochromic/Heat_SensitivePaper.aspx
- investigate different temperature scales (Celsius, Fahrenheit, and Kelvin)
- research the relationship between heat, weather, and climate. Extreme Weather (NASA Lesson Plan: Hurricanes as Heat Engines) http://mynasadata.larc.nasa.gov/preview_lesson.php?&passid=50

Connection to Maine Agencies

A Maine Energy Education Program (MEEP) representative and will come to interested schools, free of charge, to guide and support the concepts in lesson. For more information go to the MEEP website: 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 presentation contact Nancy Chandler at 207.760.2556 or nchandler@maine publicservice.com.

Online References and Resources

Chicago Science Group. (2007). *Science Companion: Energy*. Lesson 5: Hot Water, Cold Water: Transferring Heat Energy. USA: Chicago Science Group and Pearson Education, Inc. http://www.sciencecompainion.com

Temperature Changes

Time in minutes	Temperature of "food" in °C	Temperature of ice water in °C	Observations
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			