Heat and Temperature

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Sci Ed 491

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Concepts Addressed in the Unit: Heat and Temperature

The concepts of this unit are heat and temperature. The national and state science standards require an understanding of these concepts because they are of universal importance in all fields of science. The field of thermodynamics has specific definitions of these quantities, but simpler, conceptual definitions serve the needs of this mini unit. Temperature is a measure of average kinetic energy of a substance. Heat is the disorderly motion of molecules in a substance.

Rationale of the Unit

Heat and temperature are important concepts in all areas of science and in students' day-to-day lives. People deal with heat and temperature in their everyday experiences, yet many people hold serious misconceptions about them. Investigating heat and temperature provides a way for students to explore energy interactions and to see how thermal energy is transferred. Through their investigations, students can learn the larger concept of conservation of energy, which is a central concept in the study of science. The concepts in this unit are fundamental to understanding the physical properties of matter. This mini-unit could easily fit within a larger unit in a middle school or 9^{th} grade science class dealing with physical properties of matter or conservation of energy and mass.

In order to elicit preconceptions and basic understanding, we chose to begin the unit with a pre-assessment. Students will complete a quiz, which the teachers can then use to guide their instruction on subsequent days. The first lesson of the unit deals with thermal energy and the transfer of heat, and students will learn that thermal energy transfers can cause changes in temperature. With the second lesson, students will explore the concept of temperature and develop an understanding of temperature as a measure of molecular motion. Students will also investigate the relationship between heat and temperature. The final lesson of the unit focuses on the idea that heat can also cause phase changes. Students will recognize that temperature does not change during a phase change. The unit will end with a post-assessment where students complete the same quiz that they started the unit with and write a reflection on how their thinking has changed. We have chosen to incorporate numerous activities and short experiments to allow the students to construct their understanding about temperature and heat and to allow teachers many opportunities to assess learning.

The lessons in this mini-unit address important state and national standards, as shown in Tables 1 and 2.

TABLE 1. National Science Standards Address in the Heat & Temperature Unit

Science Literacy Benchmarks: Project 2061 (AAAS, 2001)	**Lesson Number**		
	1	**2**	**3**
Benchmark 1) B. Scientific Inquiry • …. scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.	X	X	X
Benchmark 4) D. Structure of Matter • Atoms and molecules are perpetually in motion. Increased temperature means greater average energy of motion, so most substances expand when heated. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules 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.	X	X	X
Benchmark 4) E. Energy Transformations • Energy cannot be created or destroyed, but only changed from one form into another. • Most of what goes on in the universe….involves some form of energy being transformed into another. Energy in the form of heat is almost always one of the products of an energy transformation. • Energy appears in different forms. Heat energy is in the disorderly motion of molecules………	X	X	X
Benchmark 11) B. Models • Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly….. • Mathematical models can be displayed on a computer and then modified to see what happens. • Different models can be used to represent the same thing.	X	X	X
Benchmark 11) C. Constancy and Change • Physical and biological systems tend to change until they become stable and then remain that way unless their surroundings change. • A system may stay the same because nothing is happening or because things are happening but exactly counterbalance one another.	X	X	X
Benchmark 12) C. Manipulation and Observation • Read analog and digital meters on instruments used to make direct measurements of length, volume, weight, elapsed time, rates, and temperature, and choose appropriate units for reporting various magnitudes.	X	X	X
National Science Education Standards **Physical Science Content Standard B for Levels 5-8** (NRC, 1995)	**Lesson Number**		
	1	**2**	**3**
Transfer of Energy • Energy is a property of many substances and is associated with heat ….. • Energy is transferred in many ways. • Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature. • In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat …… might be involved in such transfers.	X	X	X
Properties and Changes of Properties of Matter • A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample.	X	X	X

TABLE 2. Washington State Science Essential Academic Learning Requirements (EALRs) and Grade Level Expectations (GLEs) Addressed in the Heat & Temperature Unit

EALR 1 Systems: The student knows and applies scientific concepts and principles to understand the properties, structures and changes in physical, earth/space, and living systems.

EALR 1.1 Properties: Understand how properties are used to identify, describe, and categorize substances, materials, and objects; and how characteristics are used to categorize living things.

- GLE 1.1.1: Understand how to use physical and chemical properties to sort and identify substances.
- GLE 1.1.4: Understand that energy is a property of matter, objects, and systems and comes in many forms (i.e., heat [thermal] energy, sound energy, light energy, electrical energy, kinetic energy, potential energy, and chemical energy).

EALR 1.3 Changes: Understand how interactions within and among systems cause changes in matter and energy

- GLE 1.3.3: Understand that matter is conserved during physical and chemical changes.

EALR 2. Inquiry: The student knows and applies the scientific ideas, skills, processes of investigation, and the nature of science.

EALR 2.1 Investigating Systems: Develop the knowledge and skills necessary to do scientific inquiry.

- GLE 2.1.1: Understand how to generate a question that can be answered through scientific investigation.

"Harris, as reported by Hewson and Hamlyn, suggests that the subject of heat is one of the most confused in science" (Driver et al, 1994). In response to that confusion, we have developed this mini-unit keeping not only the standards in mind, but also common preconceptions.

Listed below are many of the common preconceptions that must be considered when teaching the topics of heat and temperature (Driver et al, 1994; AAAS, 2001).

Children:

- think of heat as a substance
- do not necessarily think of hot and cold as part of the same continuum; think cold is the opposite of heat
- view temperature as a mixture of heat and cold inside the object or as a measure of the amount of heat possessed by that object, with no distinction between the intensity of heat and the amount of heat possessed
- think temperature of a body is related to its size or volume
- think heat is hot, but temperature can be cold or hot
- see no difference between heat and temperature
- the sensations of hotness and coldness are due to something leaving the hot or cold object and entering the body
- have difficulty appreciating the intrinsic motion of particles in solids, liquids and gases

To avoid reinforcing the preconception that heat is a substance that has fluid-like properties, we have decided not to use the word "flow" in this unit and to use "transfer" instead. We have addressed the other common preconceptions within the activities and assessments in our lessons.

Unit Calendar

Day 0: On the day before beginning this unit, the pre-assessment quiz will be given at the end of the period. This will allow the teacher to review the pre-assessments before beginning the unit.

Lesson Plan 1	Lesson Plan 2
Activities: Pre-assessment questions Hot water in cold water experiment: graphing temperature data, introduction to energy transfer diagrams Post-assessment questions **Objectives**: 1. Students will be introduced to heat transfer through a conduction experiment. 2. Students will use energy transfer charts to explain conduction. **Assessment**: Groups will be given a conduction situation. They will draw an energy transfer diagram for that situation and present their diagram to the rest of the class.	**Activities**: Take-home worksheet reviewed as pre-assessment: Cooling curves of water worksheet discussion Food coloring experiment; cooling curves of water worksheet; computer simulator worksheet **Objectives**: 1. Students will measure heat energy transfer by change in temperature. 2. Students will develop a working definition of temperature by observation of liquid motion. 3. Students will use a computer simulation to examine effect of heat on gas kinetic energy. **Assessment**: Worksheets for water cooling curves, dye in water activity and gas simulation.
Lesson Plan 3	**Lesson Plan 4**
Activities: Pre-assessment questions Phase changes and cooling curves experiment: graphing cooling curves in Excel, energy transfer diagram Post-assessment assignment **Objectives**: 1. Students will observe that during a phase change, there is no temperature change. 2. Students will be able to account for the differences between the cooling curves for different substances. **Assessment**: Students will be given a substance and its melting and boiling points. They will draw the cooling curve and energy transfer diagram for their substance.	**Activities**: The post-assessment quiz (same as the pre-assessment quiz) will be given. Students will write about any changes to the ideas they had when they began the unit. **Objectives**: 1. Students will demonstrate understanding of the unit objectives by successfully completing the post-assessment quiz. 2. Students will reflect on their learning by writing a reflection. **Assessment**: Post-assessment quiz and reflective write-up

Name ___________________________ Date _________

Heat and Temperature Quiz

1. What is heat?

2. What is temperature?

3. True or False. If you don't stir a liquid or a gas, then they are not moving. Explain your reasoning.

4. You have two identical beakers of water, A and B. If twice a much heat is transferred (added) to beaker A, which beaker will have the highest temperature? Explain.

5. In what way(s) can we observe a transfer of heat?

6. Which contains more thermal energy, an iceberg or a liter of hot water? Explain.

7. Do cold objects contain heat energy? Explain.

8. What is happening to temperature while ice is melting to become (liquid) water? Explain.

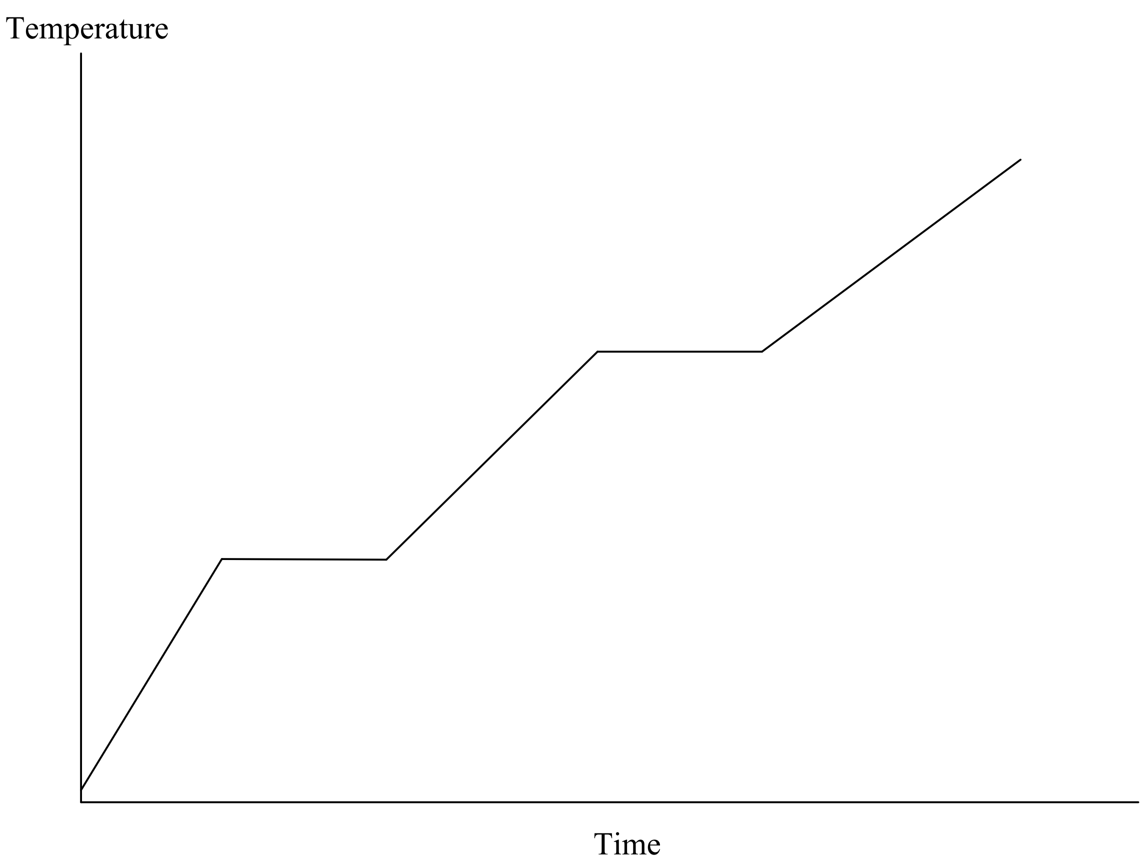
9. Does a cup of water boil at a different temperature than a large soup pot of water? Explain.

10. There is a pot of boiling water on a stove. Someone turns the burner knob from medium to high. What happens to the temperature of the water?

11. A. You are outside on a cold day and sit down on a metal bench. What does it feel like and why?

B. You get up from the bench after sitting for a while. You place your hand where you have just been sitting. Predict what it would feel like and explain your reasoning.

12. For the following graph, properly label the where each state of matter exists and where the melting and boiling points are on the graph.



Lesson Plan 1
Heat Energy Transfer

Objectives:

1. Students will demonstrate an understanding of the transfer of energy in a thermal conduction situation through the use of energy transfer charts and by correctly answering questions about a new conduction situation.
2. Students will demonstrate an ability to use energy transfer charts to describe energy interactions by drawing accurate energy transfer charts for a new conduction situation.

Materials:

- Flasks (50 mL, one per group)
- Beakers (250 mL, one per group)
- Hot water
- Cold water
- Thermometers (2 per group)
- Whiteboards (1 per group)
- Foam Rubber Sleeve for Beaker (1 per group)
- Clock or Stopwatch (1 per group)

Procedure:

Pre-assessment:

1. Ask students the following question: “Does an interaction occur when warm and cold objects touch each other?”
2. Tell students to write a response to the question and explain their reasoning in their journal.
3. Have students discuss their responses with the people around them.
4. Bring class together as a group and discuss responses. List possible outcomes on the board.

Introduction:

1. Introduce experiment by relating to pre-assessment discussion.
2. Tell students that they will be performing an experiment to test their ideas about the pre-assessment question. Let them know that they will have an opportunity after the experiment to revisit their initial ideas.
3. Allow students to form groups of 2-3.

Experiment:

1. Hand out directions and tell groups to gather their materials.
2. Allow students to perform experiment and gather temperature data. Students will record temperature data in the table on their worksheet.

Graphing, Analyzing Data, and Energy Transfer Charts:

1. Students will graph their data.
2. Have students answer questions on their worksheet that require them to analyze their data and form conclusions.
3. Introduce the idea of an energy transfer chart. Students will fill in the energy transfer chart on their worksheet that describes the transfer of energy in the experiment they just conducted.
4. Students will answer questions on the worksheet related to their energy transfer charts.

Assessment:

1. Assign each group one of the following situations:
    A. A flask of cold water is placed in a beaker of ice.
    B. A flask of cold water (5° C) is placed in a beaker of cold water (5° C).
    C. A flask of cold water is placed in a beaker of hot water.
    D. You hold a cup of hot chocolate in your hands on a cold winter day.
    E. Your friend holds an ice pack on her sprained ankle.
2. Direct groups to draw an energy transfer chart on their whiteboard that describes their situation. The charts should describe the transfer of energy and the observations that allow us to detect the energy transfer. Tell them that they will be presenting their charts to the rest of the class.
3. Give students time to work. Walk around the room monitoring progress and providing assistance.
4. Ask for volunteers or chose groups to present. Give each group a couple of minutes to describe their situation and present their energy transfer chart. Allow time for other students to ask questions.

Safety:

Follow general lab safety procedures regarding glassware. Depending upon the temperature of the hot water, burns may be a safety issue.

Reference:

Constructing Ideas in Physical Science (http://cipsproject.sdsu.edu/main.html)

Name________________________________ Date_________________

Hot Water in Cold Water Experiment

Experiment Question:
What happens when a flask of hot water is placed inside a beaker of cold water?

Prediction:
Write a hypothesis in regards to the experiment question.

Materials (per group):
- Flask (50 mL)
- Beaker (250 mL)
- Hot water
- Cold water
- 2 Thermometers
- Whiteboard
- Foam rubber sleeve for beaker
- Clock or stopwatch

Directions:
1. With the flask and beaker empty, place the flask inside the beaker. Use a ring stand and clamps to create a set-up where one thermometer is in the beaker and the other is in the flask.
2. Remove the flask from the beaker. Fill the flask with hot water. Use the thermometer to measure the temperature of the water. Record the temperature in the data table (at time = 0).
3. Fill your beaker with cold water. Measure and record the temperature (at time = 0).
4. Place the flask into the beaker without combining the hot and cold water.
5. Position the ring stand set-up so that one thermometer is in the water in the flask and one thermometer is in the water in the beaker.
6. Record the temperature of both the water in the flask and the water in the beaker one minute after putting the flask in the beaker.
7. Take and record temperature measurements every minute.

Data Table:

Time (minutes)	Temperature (°C) of Water in Flask	Temperature (°C) of Water in Beaker

Graphing:

Graph your temperature data on graph paper for the water in the flask and the water in the beaker. Use different colors to distinguish between the two.

Questions:

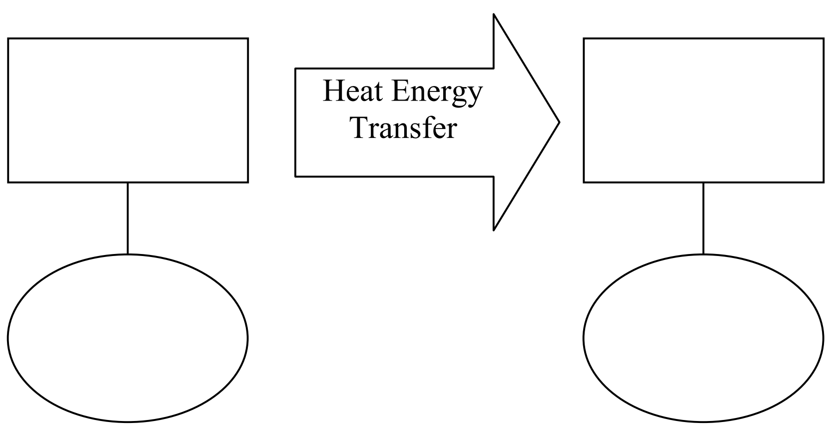
1. Answer the experiment question. Use evidence.

2. Does the evidence support your prediction? Explain. Resolve any inconsistencies by discussing with your group members.

3. So what happened in terms of energy? Was there a transfer of energy? If so, describe the transfer. How were you able to observe the transfer?

Energy Transfer Charts:

An energy transfer chart is a useful tool for describing any transfer, including heat transfer. Thermal energy is defined as the total energy of molecular motion in a substance, and when this energy is transferred, it is called heat. In the rectangles below, write the names of things involved in the energy transfer in your experiment. (Hint: Pay attention to the direction of the arrow!) In the ovals below, write the specific observations that allowed you to detect the changes in energy.



Questions:

1. Which object is giving heat? How do you know?

2. Which object is receiving heat? How do you know?

3. Does the thermal energy of an object depend upon the amount of substance? How much heat would be transferred by a drop of boiling water dropped on your skin compared to a pot of boiling water poured on your skin? How does this relate to the definition of thermal energy?

4. Draw energy transfer charts for each of the following situations:

   F. A flask of cold water is placed in a beaker of ice.

   G. A flask of cold water (5° C) is placed in a beaker of cold water (5° C).

   H. A flask of cold water is placed in a beaker of hot water.

   I. You hold a cup of hot chocolate in your hands on a cold winter day.

   J. Your friend holds an ice pack on her sprained ankle.

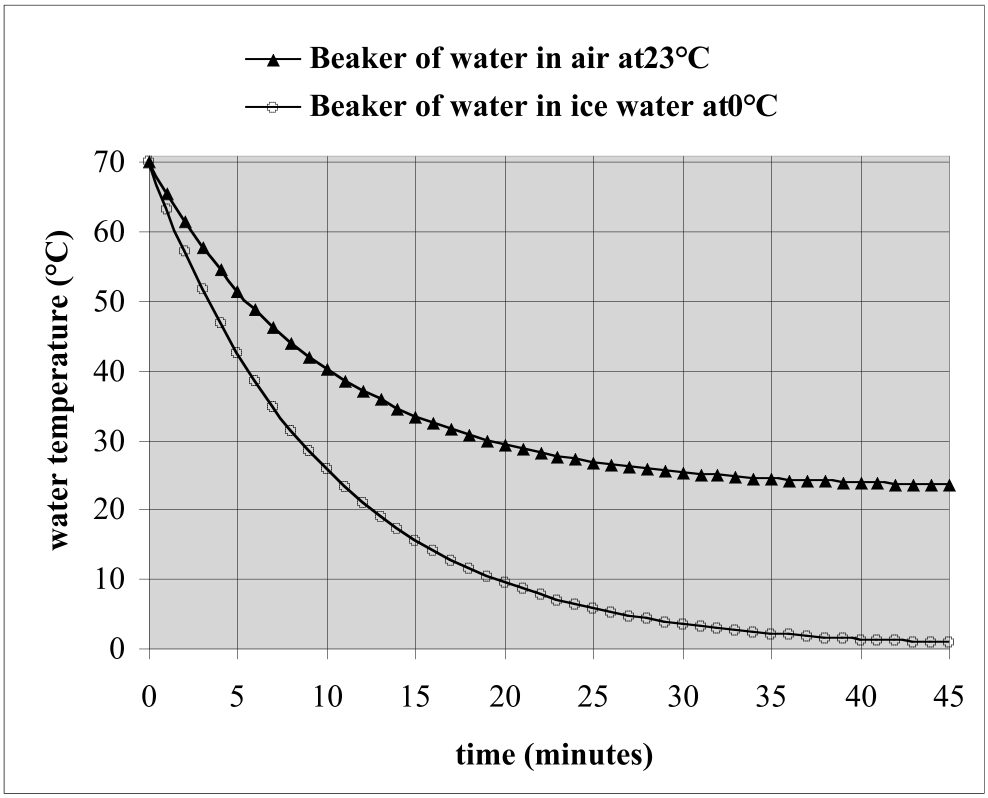
5. Do cold objects contain heat energy? Explain.

6. A person touches a large chunk of ice with their hand and remarks, “This is making me cold.” Explain what this person is feeling. Is the ice transferring “cold” to the person? Is there a heat transfer occurring? Explain.

Worksheet for Cooling Curves of Water **Name**________________________________

Experimental Description

Two identical beakers with exactly the same amount of warm water were prepared. The first beaker was allowed to cool by sitting in a classroom with an air temperature of 23°C. The second beaker was placed in a large bucket of ice water at 0°C. The temperature of each was measured every minute for 45 minutes. The data are shown below.



Use this graph to answer the following questions.

1) Which beaker of water starts off at higher temperature?

2) Which beaker of water ends up at higher temperature?

3) Which beaker of water had a larger temperature drop overall?

4) After 10 minutes, what are the temperatures of the two beakers of water?

5) After 10 minutes, what was the drop in temperature of the two beakers of water?

After 10 minutes, which beaker transferred more heat? How do you know?

Lesson Plan 2
What is Temperature?

Lesson Objectives:
1. Students will learn that thermal energy transfers can be measured by changes in temperature
2. From observations of behavior of dye in water at different temperatures, students will construct a model relating higher temperatures to greater motion in the liquid state and therefore to higher kinetic energy.
3. Students will use computer simulations of the behavior of gases to see the effect of heat addition and higher temperatures on the kinetic energy of gases.

Materials needed per group of three:
- 3 clear jars or beakers (approx. 500mL)
- near boiling water
- hot water
- cold water
- food coloring
- computer with internet access and Java loaded
- Dye in Water Activity Worksheet (1 per student)
- Simulation Experiments for the Kinetic Energy of Gases Worksheet (1 per student)

Pre-assessment:
1. Divide the class into working groups of 2-3 students.
2. Discuss the take-home worksheet about the cooling curves for water.
3. Elicit ideas about how the transfer of heat was measured: temperature.
4. Discuss the class' general ideas about what temperature is?

Introduction:
1. Introduce experiment by relating to pre-assessment discussion.
2. Tell students that they will be performing an experiment to test their ideas about the pre-assessment question. Let them know that they will have an opportunity after the experiment to revisit their initial ideas.

Experimental Activity:
1. Hand out directions and tell groups to gather their materials.
2. Allow students to perform experiment and make observations about the rate at which dye spreads out in water at different temperatures.

Activity Discussion and Assessment:
1. Student groups present their observations and explanations to the class.
2. Discuss the apparent relationship between higher temperature and motion in the liquid. Relate this to kinetic energy.
3. Ask students if they think the same may apply to solids and gases?

Simulation Activity:

1. Hand out directions and worksheet and have groups log into the simulation website.
2. Allow students to perform simulations experiment and make observations about temperature, kinetic energy, collisions, heating and cooling.

Simulation Discussion and Assessment:

1. Students present their observations.
2. Discuss the apparent relationship between higher temperature and motion of individual molecules in the gas state. Relate this to kinetic energy.
3. Allow students to reassess their conclusions on their worksheet before turning them in for grading.

Safety:

Follow general lab safety procedures regarding glassware. Burns from the hot water are the greatest danger.

References:

- Heat and temperature:
  http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/thermal/

- Kinetic theory of gases simulation:
  http://www.falstad.com/gas

Dye Dispersion and Temperature Activity

Overview:

This activity deals with temperature and kinetic energy. Temperature is a measure of the average kinetic energy of the particles in a sample of matter, which is a very abstract concept. This demo provides concrete visual aids to help students grasp this abstract concept. The first part of the demo, which involves adding food coloring to a bowls of water at three temperatures, illustrates the kinetic nature of temperature because the food coloring molecules disperse more quickly in the hotter water where the molecules are moving more quickly. The food coloring activity still does not provide students a picture of what is happening at the molecular level. That is addressed with the computer simulation of gas behavior at different temperatures.

Materials (per group of three students):

- 3 clear jars or beakers (approx. 500mL)
- near boiling water
- hot water
- cold water
- food coloring
- Dye in Water Activity Worksheet (1 per student)

Groups:

The class is to be divided into groups of 2-3 students.

Experiment:

1. Students will fill separate beakers with water at 3 temperatures, and set them up next to one another.
2. Have students record the temperature of the water in each beaker.
3. Have students place 2 drops of food coloring into the cold water, then the warm water, and then the hot water.
4. Allow students to observe for several minutes.
5. Students write down their observations.
6. Students, in their small groups, come up with an explanation based on their observations, and present it to the rest of the class.

Safety Issues:

Be careful with hot water around students.

Questions for Discussion:

1) Elicit general observations.
2) Did the trends surprise you?
3) What can you say about higher temperature and spread of the dye?
4) What do you think temperature is really measuring?
5) What type of energy is motion related to?
6) Why does the same object feel “hotter” when its temperature is higher?
7) How would you define temperature?

Name________________________________ Date_________________

Dye in Water Activity Worksheet

Experiment Question:
What happens when you add food coloring to water at different temperatures?

Prediction:
Write a hypothesis in regards to the experiment question.

Materials for each group:

- 3 clear jars or beakers (approx. 500mL)
- near boiling water
- hot water
- cold water
- food coloring

Directions:

1. Fill separate beakers with about 300mL of water at 3 different temperatures, and set them up next to one another. <u>Be careful with the hot water!</u>
2. Record the temperature of the water in each beaker.
3. Place 2 drops of food coloring into the cold water, then the warm water, and then the hot water.
4. Observe what is happening for several minutes.
5. Write down your observations in your lab notebook.
6. Suggest an explanation for your observations.

Questions for Discussion:

1) Summarize your observations.

2) Did the trends surprise you?

3) What can you say about higher temperature and spread of the dye?

4) What do you think temperature is really measuring?

5) What type of energy is motion related to?

6) Why does the same object feel “hotter” when its temperature is higher?

7) How would you define temperature?

Introduction: Simulator for the Kinetic Energy of Gases
Java Applet Source: www.falstad.com/gas

You have discovered that "temperature" is a measure of the average kinetic energy of a material. With this computer simulation you will apply the same ideas to individual gas molecules and see how adding or removing thermal energy affects the motion and kinetic energy of gases.

This java applet is a simulation that demonstrates the "kinetic theory of gases." This theory works for gases at temperatures and pressures like those in this classroom.

Familiarize yourself with the layout of the simulator

The simulator is a 2-dimensional chamber with four walls and gas molecules moving around inside. The molecules shown in this simulation are all the same substance (such as nitrogen gas), but the individual molecules have different kinetic energies that you can see because of their different speeds. Notice that the color of each molecule indicates the amount of kinetic energy it has at that moment.

Slower (lower kinetic energy) **Faster (higher kinetic energy)**
blue————purple————red————orange———yellow————white

At the bottom of the chamber you'll see the heater (shown as a wavy line). When you increase the "**Heater Temperature**" control, see how the wall temperature changes color to reflect the change in temperature. The **Heater Temperature** slider controls the heater at the bottom of the screen; if the temperature is high, the heater is more likely to give a large kinetic energy boost to molecules that hit it. If the temperature is low, the heater becomes a refrigerator; it removes kinetic energy from the system.

At the bottom of the screen is a **velocity histogram** showing the distribution of velocities of the molecules. Again, color is used to indicate velocity; velocities increase as you go to the right on the graph. The height of the velocity bars shows the number of molecules that have that velocity. The scale of the graph changes constantly so watch the colors to orient yourself. The temperature of the gas depends on the average velocity of the gas molecules. This can be determined from the velocity distribution represented by the histogram.

Press "**Reset**" to reset the positions and velocities of the molecules to random values.

Pressing "**Reset to Equal**" will cause the velocities to all be the same, although they won't stay that way for long.

Pressing "**Reset to Extreme**" will reset half of the molecules to a high kinetic energy (the yellow gas molecules) and half of the molecules to a low kinetic energy (blue molecules). Again, they won't stay that way for more than a fraction of a second.

"**Set Wall Temp**" will set the temperature of the walls to be the same as that of the heater.

Simulation Experiments for the Kinetic Energy of Gases

Note: For all of your simulations keep the **Volume** slide set to maximum and **Gravity** set to minimum.

1) Set **Heater Temperature** to the minimum. Press **Set Wall Temperature** and then **Reset**. You can keep pressing **Reset** to watch the molecules and to answer the questions below.
   - Do all the molecules have the same speed (or kinetic energy)?
   - Do you observe any collisions? What happens when molecules collide?
   - On average, what is happening to the speed of the molecules over time?

2) After the molecules have slowed down in step 1, increase the **Heater Temperature** to about 10% on of the scale and press **Set Wall Temp.**
   - What changes do you observe?
   - On average, what is happening to the speed of the molecules over time?

3) Increase the **Heater Temperature** to about 20% on of the scale and press **Set Wall Temp.**
   - What changes do you observe?
   - On average, what is happening to the speed of the molecules?
   - Have the number of collisions changed in steps 1, 2 and 3? If so, how?

4) Increase the **Heater Temperature** to about 50% of the scale and press **Reset** and then **Set Wall Temp.**
   - If the wall temperature is higher than the temperature of the gas inside the chamber, what happens?

5) Decrease the **Heater Temperature** to 0% of the scale and press **Reset** and then **Set Wall Temp.**
   - If the wall temperature is lower than the temperature of the gas inside the chamber, what happens?

6) What if you injected hot gas into the container? What would you expect to happen? Simulate it by hitting "**Reset to Extreme**." This initially gives half the molecules a relatively high temperature (high kinetic energy) and half a low temperature (low kinetic energy).
   - Record your observations

7) When you increase the heat added to a system, what happens to the amount of disorder in the system? *Write a plan to examine this, and check with your teacher before continuing.*

8) Set the **Heater Temperature** to about 20% of the scale and press **Reset** and then **Set Wall Temp.** Observe the behavior of the gas molecules. Now repeat the same simulation but with the **Heater Temperature** set to 80% of the scale.

   - How long does it take before the system seems to stabilize?

   - When a system is no longer changing temperature, it is at "thermal equilibrium." Do all molecules have the same kinetic energy at thermal equilibrium? What is your evidence?

Kinetic Energy of Gases: Post-Assessment

1) When you add thermal energy (add heat) to a system, what happens to the kinetic energy of the molecules within the system? Draw an energy diagram showing the direction of heat transfer for this case.

2) When you remove thermal energy or cool the system, what happens to the kinetic energy of the molecules within the system? Draw an energy diagram showing the direction of heat transfer for this case.

3) Do you think that heat is a substance made up of particles like a gas or a liquid? Give some reasons for your answer.

4) When you add heat to a system what happens to the amount of disorder in the system?

5) Propose a theory to explain how heat is transferred in a substance using your observations with this simulator.

6) Gases seem calm, but are they really? Imagine a 1-liter container full of gas at room temperature and pressure. The kinetic theory of gases allows you to calculate the frequency of collisions. In every liter of air, about a billion billion billion collisions between gas molecules happening every second!!

7) How has your thinking about heat changed?

8) How has your thinking about temperature changed?

Lesson Plan 3
Temperature and Phase Changes

Objectives:
1. Students will be able to graph a cooling curve.
2. From observing the cooling curve of wax, students will be able to see that during a phase change, there is no temperature change.
3. Students will be able to account for the differences they observe between the cooling curves for water and wax.

Materials needed per group of 4:
- hot plate
- 2 test tubes (15 mm x 125 mm)
- heat resistant beaker
- paraffin wax
- 2 ring stands
- 2 test tube clamps
- hot tap water
- 2 thermometers in #3 stoppers to fit test tubes
- computer with Excel

Materials needed per student:
- lab notebook
- safety goggles
- Phase Changes and Cooling Curves handout

Safety Concerns:
Make sure students are careful when handling the hot plate or hot water. Remind them to keep all paper (and anything else flammable) away from the hot plate. Also remind students of proper procedure in handling glassware.

Background for teacher:
Students will heat a test tube of paraffin and a test tube of water to the same temperature – where all the wax has melted. Students will then take the temperature of both test tubes every 30 seconds for 5 minutes. From this information, students will be able to graph (in Excel) phase change diagrams for both substances.

Pre-assessment:
Have students answer the following questions in their lab notebooks individually.

What is a phase change?

What happens to temperature during a phase change?

After the students have answered the questions in their notebooks, have them share their ideas with a partner. Once the partners have finished, bring the class together to share ideas as a group.

Transition into the lab activity.

Activity:
Teacher notes:
Have students get into the same groups of four as on day one to work on the activity: Phase Changes and Cooling Curves. Assist as needed with set up. Watch for any misuse of the hot plate and glassware. Make sure each student has a specific role in the group as stated in the handout. Assist as needed with graphing. After students have finished graphing their data, make sure they answer the questions on the handout.

Post-Assessment:
As a homework assignment, have students draw their own energy curve and energy transfer diagrams for one of the substances below, given its melting and boiling points.

Substance	Melting Point Temperature – *t* (°C)	Boiling Point Temperature – *t* (°C)
Aluminum	659	2,327
Copper	1,083	2,595
Ethyl alcohol	114	78.3
Gold	1,063	2,600
Hydrogen	259	253
Lead	328	1,750
Mercury	39	357
Nitrogen	210	196
Oxygen	219	183
Silver	962	1,950
Water	0	100

Sources:
Lesson: http://onlineclassroom.bnl.org/teachers/lesson_plans/phase_change_lab.html
Chart: http://www.engineeringtoolbox.com/melting-boiling-temperatures-d_392.html

Phase Changes and Cooling Curves Experiment

Objectives:
Students will be able to graph a cooling curve from data they collect. They will be able to account for differences between different cooling curves and identify what is happening to temperature during a phase change.

Materials needed per group of 4:
- hot plate
- 2 test tubes (15 mm x 125 mm)
- heat resistant beaker
- paraffin wax
- 2 ring stands
- 2 test tube clamps
- hot tap water
- 2 thermometers in #3 stoppers to fit test tubes
- computer with Excel

Materials needed per student:
- lab notebook
- safety goggles
- this handout

CAUTION: Be careful when handling the hot plate or hot water. Keep all papers away from the hot plate.

Procedure:

1. In your group of four you will each have a specific job. Two of you will be reading temperatures, one will be recording the temperatures, and the fourth will keep track of time. Work together to get the materials needed above assembled as stated below. Make sure your safety goggles are on at this point.
2. Set up the ring stands around the hot plate so that the test tubes will both fit into the beaker when it is placed on the hot plate.
3. Fill one test tube _ full with paraffin and the other test tube _ full with hot tap water. Place a stopper with a thermometer through it on the end of each test tube. Attach each test tube with a clamp to a ring stand. Place both test tubes in a beaker of water. The beaker should be on top of the hot plate.
4. Heat both test tubes in the beaker of water until the wax melts. Both tubes should be at the same temperature. Turn the hot plate off and record that temperature.
5. Record the temperature of the wax and the water every 30 seconds for 5 minutes. Make a note of the temperature the wax begins to solidify. You can record the temperatures on a separate sheet of paper; you will be putting the data in an excel file to graph it.
6. During the activity be sure to write down any observations you make about what is occurring.

Graphing in Excel:
Set up your columns to look like this:

Time (sec)	Temp Wax (C°)	Temp Water (C°)
30		
60		
90		
120		
150		
180		
210		
240		
270		
300		

After filling in your temperature date for the wax and water, you can create a chart.

Creating a chart:

1. Highlight the area that contains your data.
2. Go to the Insert menu and choose Chart. You will be taken to the Chart Wizard.
3. Choose XY Scatter from the Chart Type menu. Under Sub-type choose the one that shows both the data points and smooth lines going through them. Click Next.
4. On this step your data range should match the area that your data is in (the area you highlighted). Click Next.
5. For Chart Title type Cooling Curves by: (the first names of everyone in your group). The X axis should be Time and the Y axis should be Temperature. Click Next.
6. Place your chart as an object in the same sheet that your data is in. Click Finish.
7. Print a copy of your data and chart for each person in your group (make sure they both fit on one page). Tape the copy in your notebooks and answer the following questions about your chart.

Questions:
Answer these questions together as a group, but write them down in each of your notebooks.

1. Describe the two curves. How are they similar? How are they different?

2. What is occurring in the region where the wax temp remained constant?

3. When the temperature of the wax was constant, it was still higher than the surrounding water bath. What was causing the heat?

4. Think back to the first two questions you answered in class: What is a phase change? What happens to temperature during a phase change? Has this activity changed your thoughts on these questions? Explain.

5. Draw an energy transfer diagram for the two systems in the activity.

6. List any questions you now have after completing the activity.

Lesson Plan 4
Assessment and Reflection

Objectives:

1. Students will demonstrate understanding of the unit objectives by successfully completing the post-assessment quiz.
2. Students will reflect on their learning by writing a reflection.

Materials:

- Quizzes (1 per student)

Post-assessment:

1. Pass out quizzes.
2. Allow students time to complete quiz.
3. As a class, discuss correct answers to quiz questions.

Reflection:

1. Hand back pre-assessments and give students time to compare with post-assessment.
2. Post directions and questions for the written reflection. Students will write 1-2 pages responding to the following questions:
    - What have you learned about heat?
    - What have you learned about temperature?
    - How has your thinking about heat changed?
    - How has your thinking about temperature changed?
3. Allow students time to write their reflections.

Resources and References

Preconceptions:

Atlas of Science Literacy, Project 2061, American Association for the Advancement of Science, National Science Teachers Association, Washington, DC, 2001.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science*. London: Routledge Falmer.

National Science Standards:

National Science Education Standards, National Research Council (1996) http://www.nap.edu/readingroom/books/nses/html

Project 2061, American Association for the Advancement of Science (2001) Project 2061. http://www.project2061.org

Lesson Plan 1:

Constructing ideas in physical science. It's About Time, Inc. http://cipsproject.sdsu.edu/main.html

Lesson Plan 2:

Heat and temperature: http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/thermal/

Kinetic theory of gases simulation: http://www.falstad.com/gas

Lesson Plan 3:

http://onlineclassroom.bnl.org/teachers/lesson_plans/phase_change_lab.html
http://www.engineeringtoolbox.com/melting-boiling-temperatures-d_392.html