Session 7
Heat and Temperature

What makes the liquid in a thermometer rise or fall in response to temperature? Which contains more heat—a boiling teakettle or a swimming pool of lukewarm water? In this session, we focus on the difference between heat and temperature and examine how both are defined in terms of particles. We also use the particle model to explain a number of everyday phenomena, from why things expand when they are heated to the role that temperature plays in changes of state.

The Video

This session opens by examining the everyday but amazing phenomenon of ice and why it feels colder to us than ice water. We then go to the Science Studio where we ask a fifth grader Joana what a thermometer will read after it has been "bundled up" in a blanket for half an hour. Another fifth grader Lydia thinks out loud about whether or not heat is matter.

Science historian Al Martinez takes us to the Saugus Iron Works in Massachusetts and recounts some of the history of the scientific understanding of heat through the processes of combustion and friction. We then take a closer look at heat transfer between different forms of matter on a particle level.

Back in the Science Studio, Lydia compares how different wood and aluminum blocks feel to the touch. But what is she measuring—heat or temperature? Then Joana takes the temperature of ice water just after the ice is removed and later on, discovers that not all liquids have the same boiling point.

Continuing in the Science Studio, third grader Sara observes a classic demonstration of the effect of heat on the volume of a solid. But what about liquids? At the Roosevelt School in Worcester, Massachusetts, science coordinator Paula Proctor and teacher Gina Robertson lead sixth graders through an investigation of the effect of heat and cold on the volume of a red liquid in a thermometer. If the liquid goes up, is its mass changing? The same experiment is then repeated in the Science Studio, where Lydia weighs the thermometer liquid before and after heating, and David, a fifth grader, conducts an experiment to determine the effect of heat on the density of air.

The session ends with a "bang" when lead forecaster Bill Babcock of the U.S. Weather Service explains how thunderstorms get started when warm, less-dense air next to the ground rises, taking water vapor with it.

Learning Goals

During this session, you will have an opportunity to build understandings of the following concepts:

- Heat is the transfer of energy between two objects with different temperatures.
- Temperature is a measure of the average energy of motion of particles.
- Heat is added when solids change state into liquids and when liquids change state into gases (e.g., in melting, evaporation, and boiling).
- Heat is removed when gases change state into liquids and when liquids change state into solids (e.g., in condensation and freezing).

On-Site Activities

Getting Ready (60 minutes)

Activity One—Problem Set and Reading Discussion (20 minutes)

1. In a small group, review the answers from the problem set for Session 6 and the concept maps that you developed for the session.
2. To prepare for this session, you were asked to notice times when you "felt" hot or cold. With the whole group, compare the feelings you noted and how and where in your body you felt them.
3. With the whole group, discuss the Leeds/CLIS article. How would you describe the distinction the authors make between heat and temperature?

Activity Two—Heat and Heat Flow (20 minutes)

Facilitators: Distribute Session 7 materials. Have a teakettle or beaker of water simmering on a hot plate.

1. In a small group, try the following experiment:
   a. Take two cups or mugs, and fill one with hot water and one with ice cubes.
   b. Compare how each feels to the touch and try to answer the following questions for each case:
      - What is the source of the heat or cold?
      - What is actually "flowing" when you feel heat or cold?
      - In what direction (toward the source or away from the source) does the transfer happen?
      - Discuss with the group what you think is happening on a microscopic and macroscopic level.
2. With the whole group, try to generalize the fundamental difference (if any) between "heat" and "cold." Are "heat" and "cold" *matter*? If not, what are they?

Activity Three—Heat versus Temperature (20 minutes)

Facilitators: Distribute the remaining Session 7 materials.

1. With your partner, try the following experiment:
   a. Touch each block (or spoon) and estimate the temperature of each material.
   b. Discuss with your partner what you think happens at a microscopic level when you touch each material.
   c. Discuss the similarities and differences between this activity and the one in Activity Two above.
2. As a group, try to state concisely the difference between heat and temperature. What does it mean to say that something is "room temperature"?

Watch the Video (60 minutes)

As you watch the video, think about the following focus questions:

1. Would your students make the same prediction that Joana does about the thermometer in a blanket?
2. In Paula Proctor's classroom, one student explains that the red liquid rises in the thermometer because it has more "heat energy." What do you think he means by this?

On-Site Activities, cont'd.

Going Further (60 minutes)

1. Scientific language is often more precise than everyday language. With your new knowledge about heat and temperature, choose whether *heat* or *temperature* is the most accurate term for the phenomena in the following situations. Discuss your answers with a partner.
   a. A thermometer reads 20 degrees Celsius.
   b. Steam rises from a teakettle.
   c. You burn yourself on a hot stove.
   d. A glass of ice water sits on your kitchen table.
   e. Your son is running a fever.
   f. A hamburger cooks on a grill.
   g. The weather report states the ocean is 76 degrees Fahrenheit.
   h. You dip your toe in the ocean on a hot day and it feels cold.
2. Is it possible to determine if something is "hot" just by looking at it?
3. As a small group, develop a level-appropriate explanation for your students as to why a glass of cold water "sweats" (collects water droplets) during the summer. Include the particle model of matter and what you have learned this session about changes of state.
4. How would you explain to one of your students why two objects, like a block of wood and a block of aluminum, are the same temperature even though the aluminum feels much colder?

Between Sessions

Homework (* = required)

* Reading Assignment

None.

* Physical Science Problem Set

(Suggested answers are listed in the Appendix.)

1. In the video, we saw that water and alcohol boil at different temperatures at sea level. How would you explain why this is so?
2. In your own words, why doesn't the temperature of melting ice go up until all the ice has melted?
3. When heating an object changes its density (as when the hot water balloons rose in the cold water), have we changed the mass, the volume, or both? Explain your answer.
4. Why do you think the traffic department uses a rubbery material instead of regular asphalt to fill in cracks in the road?

* Ongoing Concept Mapping

Develop a concept map around the idea of the microscopic picture of heat and temperature. Try to include the following concepts:

- Heat
- Flow
- Celsius
- Phase change
- Temperature
- Cold
- Fahrenheit
- Vibrating
- Thermometer
- Density

Guided Journal Entry

Reflect on the following statement: Temperature is a property of an object; heat is a property of a change. Give several everyday examples and try to restate this idea in your own words. Is this a good mnemonic to help you keep these concepts clear? If not, try to create one.

Guided Channel-TalkPhysicalSci Posting

In the winter, people sometimes talk about the cold "going right through them." Given what you have learned in this session, what might you say to someone about such a statement?

Textbook Reading Suggestions

The following are suggestions for reading topics that may provide additional background and enrichment information. These topics are likely to be addressed in any college-level physics or chemistry textbook.

- Heat
- Thermodynamics
- Phase change
- Thermal equilibrium
- Temperature
- Kinetic molecular theory of matter
- Coefficient of linear expansion

Between Sessions, cont'd.

* Preparing for the Next Session

For "Getting Ready"

Our particle model of matter is supposed to be applicable to all matter and allow us to describe matter's properties and interactions. Considering that almost everything we see is matter, we could assume that a complete model should have something to say about every phenomenon we see. Before the next session, write down any macroscopic property, behavior, or change you observe that you can connect to a microscopic description using your understanding of the particle model of matter. What phenomena are you *not* able to satisfactorily connect to the particle model? Bring examples of both to the next session.

Materials Needed for Next Time

- Styrene (Styrofoam) chips
- Aluminum pie plates
- Pieces of wool or similar cloth
- Styrene dinner plates
- Scrap paper
- Answers to "Tracking Your Understanding" Physical Science Questions from Session 1

Graduate Credit Activities

Continue your work on the annotated bibliography and action research project.

Notes