Conduction, Convection, and Radiation: An Introduction

Summary

Teacher demonstrations help students understand heat and the methods of transfer - conduction, convection and radiation.

Group Size

Large Groups

Materials

Invitation to Learn
- Ball and ring set
- Hot plate
- Science journals

Heat is made up of molecules
- Hot and cold water
- Hot plate
- Saucepan
- 3 clear glass cups
- Food coloring
- Measuring cup
- Science journals

Conduction
- Bag of beans
- Carton of BBs
- Plastic cups
- Hot plate
- Compound bar
- Science journals

Convection
- *Paper Spinner Directions*
- Tissue paper
- Aluminum pie tin
- Lighter or matches
- Hot plate
- Science journals

Radiation
- Colored patches of cloth
- A pane of glass
- Infrared temperature gun
- *Hogle Zoo Heat!*
- Overhead projector
- *Test Yourself: Conduction, Convection, and Radiation sheet*
- *Test Yourself: Conduction, Convection, and Radiation answer key*
- Science journals

Additional Resources

Media

The Convection of Heat, by Eureka! (Films for the Humanities and Sciences, PO Box 2053,

Princeton, NJ 08543, www.films.com)
Bill Nye the Science Guy: Heat (Disney Educational Products, (800) 295-5010, http://dep.disney.go.com/; ISBN 1-932644-98-9

Background for Teachers

Heat is the transfer of thermal energy between substances that are at different temperatures. Energy is always transferred from the warmer object (which has a higher temperature) to the cooler one (which has a lower temperature). Similarly, molecules with a lot of energy move faster than molecules with a smaller amount of energy, thus causing the former to have more heat. Heat transfer will continue until both objects have reached the same temperature or the same speed.

For example, an ice cube in a glass of water eventually melts. This is because the heat from the water, which is warmer, flows to the ice cube until both are at the same temperature, and therefore no ice cube is left.

There are three methods of heat transfer: conduction, convection, and radiation. Conduction occurs through direct contact. When two substances come into contact, their particles collide. The energy from the faster-moving substance is transferred to the slower-moving substance until they are moving at the same speed. At this point, their temperatures will be the same. An example of conduction is a spoon warming up when it is placed into a cup of hot cocoa.

Convection is the transfer of heat in air or a fluid through currents. An example is a pot of water warming up on a hot stove. As it heats up, the particles spread out and become less dense. The warm water on the bottom of the pot rises and displaces the cold water. As this occurs, the cold water sinks. So hot air rises, cools, and falls.

Radiation is the transfer of energy as electromagnetic waves. It does not need to directly touch anything or move particles as in conduction and convection. Radiation occurs through empty space, as in the sun heating the earth or feeling warm in front of a fire.

Many demonstrations are needed for this experiment. Prior to beginning the lesson, prepare several cups of beans and BBs. Lay cloth and a piece of glass on the snow or colored paper and glass on the pavement at least an hour before the lesson. Plug in the hot plate. Heat a cup of water to almost boiling. Set up the candle spinner or create the paper spinner. Make a transparency of Hogle Zoo Heat! Make sure the radiation portion of this lesson is done on a sunny day.

This lesson is divided into heat concepts and could be done over a two or three day period if desired.

Intended Learning Outcomes

2. Manifest science attitudes and interests
3. Understand science concepts and principles.

Instructional Procedures

Invitation to Learn

Turn a hot plate to high temperature. Obtain the metal ball and ring set and instruct students to obtain their science journals. Show how the ball easily passes through the ring. Now place the ball on top of the hot plate. Allow it to warm, then try to place the ball through the ring again. It will not work. Ask the students to write the following in their journals: What happened when the ball was heated? Why do you think it won't it go through the ring now? What do you think will happen when both the ball and ring are heated? Set the ball and ring on the hot plate as the students write. When finished, again place the ball through the ring. This time, it will work. Were their predictions correct?

Instructional Procedures

Heat is made up of molecules

After completing the invitation to learn, leave the hot plate on and begin heating up a cup of water.

Ask if anyone has an idea of how or why heat affected the metal of the ball and ring. After listening to a few students, explain that metal expands when heated and contracts when cooled. Metal is a high conductor of heat. In other words, metal will quickly become hot when it is touched by heat. The handle of the ball and ring is made of wood because wood is not a high conductor of heat. Heat flows more quickly through metals than it does through woods.

Write this definition of heat on the board: Heat is the transfer of energy between two objects at different temperatures. Instruct students to write the definition in their journals.

Explain that everything is made up of small particles called atoms, which have energy and are constantly in motion. Heat is directly associated with groups of atoms, called molecules. The hotter something is, the faster its molecules are moving. This means that molecules in cold objects move slower than the molecules in hot objects. For heat to transfer, one molecule has to bump into another molecule.

Obtain the three clear glass cups (do not use plastic), the food coloring, and the measuring cup. Fill one glass with a cup of very cold water, one with a cup warm water, and one with the cup of almost boiling water. Ask the students to make a prediction in their journals: what will happen when I put one drop of food coloring in each glass?

Allow time for writing then drop the food coloring in each. Watch the food coloring spread out, paying special attention to the streaks and whether it spreads out evenly within the water. Watch the clock and have the students write down observations after 0 seconds, 30 seconds, and 60 seconds. They will notice how quickly the coloring in the glass of boiling water spreads compared to the others.

Ask what this proves about molecules and allow time to share. Then explain that water and food coloring are both made up of molecules. The food coloring molecules in a glass of water are pushed around by the water molecules and eventually spread throughout the glass, even if you don't shake or stir the water. Since molecules in hotter objects move faster than molecules in slower objects, the food coloring spreads more quickly in the hottest water.

Conduction

Ask what situations the students can think of that involve heat. List the ideas on the board. These may include heating a home in the winter, sitting by a campfire, cooking or baking, getting into a hot tub, blowing on your hands on a cold day, hot car seats in the summer, sitting on a beach, touching a hot curling iron, etc. Think of as many ideas as possible. Leave the list on the board.

Tell the students that there are three types of heat transfer which will be demonstrated today. To introduce the concept of conduction, bring out several cups of beans and BBs. Allow each student to put a finger into one cup, then the other. Which is colder? Ask students to write their observations in their journals.

If you measure the temperature of the beans and BBs, you'll find they are about the same. The students probably though the BBs were colder. Explain that this was caused by conduction. Explain that conduction occurs when objects touch. The heat from the warmer object is transferred to the cooler object, eventually evening out the temperatures. In other words, the faster molecules from the warmer object bump into the slower molecules of the cooler object until they are all traveling at the same speed. Think of "can touch" when you think of conduction. Have students write down their own definition of conduction in their journals.

Remind the students about the invitation to learn. What was the ball and ring made of? (metal) What did we learn about metal? (conductor of heat) Brainstorm types of metals: steel, iron, gold, silver, copper, etc. Tell the students that BBs are also made of metal. Since metal is a conductor of heat, the BBs only feel colder than the beans because the metal is conducting heat away from your hand. You perceive the heat that is leaving your hand as cold.

Remind your students about heating up the water for the food coloring on the hot plate. Since

the saucepan touched the hot plate, heat was transferred from the hot plate to the pan via conduction.

Next, obtain the compound bar. Tell the students that this bar is made of two different metals. Allow the students to share their ideas about what they think will happen when you touch the bar to the hot plate.

Turn the hot plate to high and place the bar on top. Watch it bend. Explain that the curving results from the two metals expanding unequally. Run the bar under cold water or place in a container of water. It will immediately resume its straight shape.

Look at the list of ideas on the board and ask the students which of these have to do with conduction. If a student response is correct, have him/her explain why. Put a star next to the correct responses.

Convection

Looking at the list, ideas will remain that do not have to do with conduction. Introduce the second form of heat transfer.

Tell the students that convection is the transfer of heat through air or fluid through currents. Ask if they have ever noticed the difference in temperature on the top floor of their house verses the basement. That is convection. Heat goes higher; cold creeps lower. This is why heating vents in homes are located along the floor, while air-conditioning outlets are located near the ceiling (although in Utah the heating vents are sometimes located near the ceiling in basements so the builders do not have to put in another set of HVAC ducts).

Again remind the students about heating the water for the food coloring demonstration. The hot plate caused the saucepan to get hot via conduction. But the water got hot due to convection. The hot water at the bottom of the pan expanded and became lighter than the colder water above it. So the heavier water sank to the bottom and the warmer, lighter water rose to the top. Eventually, after changing places several times, the water became hot enough to boil.

Obtain a candle spinner or the pre-cut paper spiral attached to a string. Light the candles of the spinner and watch the vanes spin. If using the paper spinner, hold it above a hot plate. Be careful to hold it high enough that the paper will not burn. Watch it spin.

Ask the students why they think this is happening. After listening to ideas, remind the students that hot air rises. The hot plate produces a current of hot air. As the air rises, the convection produced causes the vanes or spinner to turn.

Set up another example of convection by folding a piece of tissue paper in half widthwise, then in half widthwise again. Create a prism out of the paper. Stand it on top of the aluminum pie tin. Using safety precautions, use a lighter or match to light the top of each edge of the triangle formed. The flames will quickly travel down the prism and get trapped inside, then gently raise the tissue paper in the air. Eventually the tissue paper will float down. Catch it with the aluminum tin, let it cool, and then discard.

Ask the students what is happening this time. Heat is again rising. When the heat escapes from the flames, it falls.

Look at the remaining list of ideas on the board and ask the students which of these have to do with convection. Also ask the students if any of the starred ideas also have to do with convection. If a student response is correct, have him/her explain why. Put a smiley face next to the correct responses.

Radiation

Introduce radiation, the transfer of energy as electromagnetic waves. It does not need to directly touch anything or move particles as in conduction and convection. Radiation occurs through empty space, as in the sun heating the earth or feeling warm in front of a fire.

For the last time, remind the students about boiling water on the hot plate. Tell them that before the sauce pan was even placed on the hot plate, the heat could be felt without touching the

burner. That is radiation.

Tell the class that Ben Franklin, one of our founding fathers, experimented with radiation in the 1700s. One sunny winter day, he and a friend laid colored cloth patches and a pane of glass out on the snow and noted how deeply each eventually sank into the melting snow below it. Ask the students what they think the results might have been.

After listening to the ideas, bring a pad of paper, a pencil, and a heat gun outside to the pre-set cloth patches (if it is a snowy day) or the paper (if there is no show) set out prior to beginning the lesson. Using the infrared temperature gun, test the temperature of each and record the data. The students will see that the black cloth/paper and the glass pane will be significantly warmer than the white cloth/paper. Dark colors will also be warmer compared to the lighter colors. If you did use cloth, lift up each piece and note the indentation in the snow. The white will make little to no indentation; the black will be the deepest. Likewise, if using a light pane of glass, it too will sink as deep as the black paper.

Return to the classroom and have the students note their observations in their journals. Explain that it took a long time for the results of Franklin's experiment to make sense. We now know that black absorbs light and heat, while white reflects them. Similarly, since glass is clear, light travels right through it, but absorbs the heat radiated by the sun -- the infrared -- and therefore gets just as hot as the black cloth. Infrared radiation is reflected by the cloth patches because they are opaque.

Look at the list of ideas on the board and ask the students if any of these have to do with radiation. Again, items involving conduction and convection may involve radiation, as well. If a student response is correct, have him/her explain why. Circle the correct responses.

To wrap it up, tell the students that heat is usually transferred in all three ways, as in the boiling water discussed throughout the lesson. As another example, place the *Hogle Zoo Heat!* transparency on an overhead projector. Cover the pictures. Take students through the situation presented, uncovering each picture as the time comes. You may also cover all of the words of the transparency and allow students to explain the type of heat transfer at each step to check for understanding.

Pass out a copy of *Test Yourself: Conduction, Convection, and Radiation* to each student to assess their understanding of heat transfer. Have them write down any questions they have about these concepts in their journals.

Extensions

Curriculum Extensions/Adaptations/ Integration

Invite a health care professional to discuss how your body maintains temperature and why you might have a fever when you are sick.

Show either or both of the DVDs The *Convection of Heat* or Bill Nye's *Heat* to reinforce the concepts of energy, conduction, convection, and radiation.

Show the seven-minute video from NASA entitled *Infrared: More Than Your Eyes Can See* to learn more about infrared radiation.

Invite a firefighter to discuss fire prevention, how knowledge of heat transfer is important to get out alive, why a fire must be vented, and the difference in temperature between the top of a room and the floor.

Learn about the importance of heat when blowing glass. If possible, attend a glass blowing demonstration. The Bill Nye video contains a small section about glass blowing.

Family Connections

Cook a meal using a Dutch or solar oven. Discuss how conduction, convection, and radiation help in the cooking process.

Carefully place a paper cup full of water in a fire and watch it boil. Make sure the cup is

surrounded by glowing embers. Discuss how conduction, convection, and radiation prevent the cup from burning.

Assessment Plan

Ask students to try any or all of the questions on the *Test Yourself: Conduction, Convection, and Radiation* sheet.

Over a three-day period, have students write down three encounters with heat per day in their journals. How did these experiences have to do with conduction, convection, and radiation? After the three days, collect the journals to check and assess.

Bibliography

Research Basis

Loucks-Horsley, S., & Olson, S. (Eds.). *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*. Washington, D.C: National Academies Press, 2000.

Word Smith as you Choose discusses engaging students in exploring and communicating their thinking through writing, which has shown tremendous benefits in science and mathematics. Writing explorations help students in understanding concepts more deeply, improving problem solving strategies, assessing their personal thinking skills, learning to consider themselves as deep thinkers, and overall becoming better learners in and out of the classroom. Journals are concrete and visible evidence of student thinking, effort, and progress. They should show if students have or have not achieved the desired learning, if they have misconceptions, their reflections, their journey towards understanding a concept, and/or if more instruction is needed.

Kruger, A., & Sutton, J. (Eds.). (2001). *EdThoughts: What we know about science teaching and learning*. Colorado: Mid-continent Research for Education and Learning.

This book supports standards-based reform of science education. Research and best practices are provided, as well as ways to improve classroom instruction. A list of additional resources is also available for those desiring deeper understanding of certain concepts. All articles rely on the national standards for best practices. A common theme is the importance of quality science education for all students.

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