Science Unit: ***Matter***

Lesson 14: ***Conduction, Insulation and Convection***

Summary:	In this lesson, students explore the concept of **heat** by: (1) Comparing the **rate of melting** for an ice cube covered in cloth to an uncovered ice cube (2) Studying **insulating materials** in their lunch kits (3) Feeling the distribution of heat in a metal rod after it is heated at one end only (4) Using food colouring to observe **convection currents** in water
Science skills:	Close observation, accurately drawing observations, accurate measuring, collecting data, recording results, classifying data, inferring, concluding.
School Year:	2013/2014
Developed for:	Champlain Heights Annex Elementary School, Vancouver School District
Developed by:	Ingrid Sulston (scientist); Mona Francis and Ramona Smith (teachers)
Grade level:	Presented to grades 2/3; appropriate for grades 1 – 7 with age appropriate modifications
Duration of lesson:	1 hour and 20 minutes
Notes:	Another ice-melting activity is in Lesson 3 (Physical Changes to Matter) in the "Matter" unit of the Scientist in Residence Program: www.scientistinresidence.ca/pdf/physical-science/Matter/SRP_Matter_Lesson%203%20F.pdf Matter and Heat are also explored in Lesson 5 (Heat and Matter) in the Matter unit of the Scientist in Residence Program: www.scientistinresidence.ca/pdf/physical-science/Matter/SRP_Matter_Lesson%205%20WF.pdf

Objectives

Students will be able to:

1. Understand heat in molecular terms.
2. Experience and observe heat conduction and convection.
3. Observe and understand the effects of insulating material on the movement of heat.

Background Information

Heat is the transfer of energy through matter via an increased motion of the molecules/atoms that the matter is made up of. Heat energy can give molecules so much motion that they change state from a solid to a liquid, or from a liquid to a gas. Heat can move in three ways; Two of these, conduction and convection, are introduced in this lesson. (Radiation is the third.)

Conduction

Conduction is the transfer of energy by molecules/atoms as they collide and transfer energy to each other: molecules with more (heat) energy bump their neighbors, so giving them more energy, which bump their neighbors in turn. The increased energy of molecules moves through the object and is called “heat transfer by conduction”.

Convection

Convection only occurs in liquids and gases, and is the transfer of energy via a group of molecules/atoms that have more motion than their neighbors. The group of more active molecules flow through the matter, taking their energy with them. This form of heat movement is called “heat transfer by convection”.

Vocabulary

Matter:	A substance that occupies space. The three states of matter are solid, liquid and gas.
Molecules and atoms:	Tiny particles that make up everything around us. Molecules and atoms are too small to see individually, but with enough of them together they make objects we can see.
Heat:	A form of energy that moves through matter. Molecules move faster as they gain heat energy. Heat can move in different ways e.g. conduction and convection.
Conduction:	The transfer of heat through the collisions of molecules or atoms. As the particles collide with each other they transfer their (heat) energy to each other, so the heat moves.
Convection:	The transfer of heat by the movement of a group of molecules in a liquid or a gas. A faster moving group of molecules have more heat energy and move the heat to a new place.
Solid:	A state of matter. The molecules in a solid are packed tightly together. Solids keep their shape (even in a granular solid, the individual grains keep their shape).
Liquid:	A state of matter. The molecules in liquids are free to move but remain close to each other. Liquids can change shape, but always take up the same amount of space.

Materials for Ice melting, conduction and insulation activities

- Two ice cubes, kept frozen until the lesson starts, for each group of two or three students
- Two pieces of saran wrap, about 20 x 20cm, for each group of two or three students
- A piece of thick cloth, about 20 x 20cm, for each group of two or three students
- Ice melting worksheet for each student (follows this lesson)
- About six copper rods, approx. 30cm long, or other metal that conducts heat well
- A kettle of hot water
- Students’ lunch bags, ideally containing various insulating food containers
- Lunch bag insulation worksheet for each student (follows this lesson)

Materials for convection demonstration

- Large tub with clear sides, 30-40cm wide and 20-30cm deep
- Four sturdy cans, or supports, a touch taller than the styrofoam cup
- A styrofoam cup
- Cold water, to fill the tub
- Food dye
- A kettle to produce boiling water
- Optional: a few ice cubes
- Pipette

In the Classroom

Introductory Discussion

1. Remind students of the states of matter, and what the molecules are doing in each state:
    a. In a solid: molecules are packed tightly together.
    b. In a liquid: molecules are free to move but are still bonded to each other so move as a group.
    c. In a gas: molecules are completely free to move and fill the space they are in.
2. Tell students that in this lesson they will investigate heat.
3. Show them a video (e.g. ref. 1) illustrating what happens as heat is added to a liquid (The molecules gain more energy and move faster).
4. The following activities will investigate different kinds of heat. After each activity, the class will discuss what is happening at the molecular level.

Processes of science that the students will focus on: close observation, accurately drawing observations, accurate measuring, collecting data, recording results, classifying data, inferring, concluding.

Safety guidelines: Caution is required when dealing with boiling water.

Science Activities

(1) Experiment: Ice Melting

Purpose of Experiment:

To observe how fast ice melts in different conditions and to understand melting in terms of heat transfer.

Experimental Treatments: Ice cube with and without a wrapping, exposed to the warmth of the classroom.

Control treatment	Ice cube with no wrapping
Test treatment	Ice cube wrapped in cloth

Methods and Instructions:
Set-up prior to experiment: none
Students work in pairs or groups of three.

1. Give each group two ice cubes. (Place the ice cubes on a piece of saran wrap to reduce mess). Students immediately wrap one ice cube in the saran wrap, then in the cloth. Leave the other ice cube exposed to the air - this is the *control* (the standard to compare to).
2. Leave the activity to run until at least half of the control ice cube has melted (between 15 and 30 minutes, depending on the temperature of the classroom).
3. During the wait, students draw the experiment in the top panel of the "Ice melting" worksheet (included). Activity (2), and maybe also activity (4), can be run during the wait.
4. After the wait period, ask students to open up the ice cube packages, compare the wrapped ice cube to the control (no wrapping), and record the relative sizes of the remaining ice cubes on their worksheet.
5. Students report to the class which of their ice cubes had melted more. The results are recorded on the board as they are reported. It is expected that in most cases the cloth-wrapped ice has melted less than the control. If individual groups of students get different results, they are still real results, and should also be recorded. This is real science, and heat is complex so often does not give clean results. With multiples of each experimental condition, the class can find out what happens *most of the time*.
6. Discuss the results (this happens after activity (2) so the concept of heat in terms of molecules has already been introduced):
    - The air in the classroom is warm and is made up of rapidly moving gas molecules. When these air molecules bump into the solid ice, they pass their energy to the ice molecules, by *conduction*.
    - As the air molecules transfer heat energy to the ice molecules, the ice turns from a solid into a liquid (the ice melts).
    - When the ice cube is wrapped in cloth, the air in the classroom does not come in contact with the ice (it is blocked by the cloth), so they heat energy is not transferred to the ice. The cloth molecules do not transfer heat well, so they "insulate" the ice from the classroom's warm air.
7. If any data does not fit the common trend, ask students to brainstorm ideas about why these experiments were different (e.g. a warm spot in the classroom, the experiment was opened while running).

(2) Activity: Heat Conduction in a Metal Rod

Purpose of Activity: To experience conduction of heat, and to understand conduction in terms of molecules.

Methods and Instructions:
Set-up prior to experiment: none
Students sit in one group, in a circle on the carpet/floor space.

1. Space the metal rods out around the circle. Ask students to touch a metal rod and feel how warm it is. (You may need to ask them not to *hold* the rods or the warmth from their hand will heat up the rod.)
2. Gather up the rods, briefly dip them in the kettle of just-boiled hot water, and lay them out again. Ask the students to briefly (copper metal heats up very fast) touch the end that was in the water.

3. Students may also explore and feel the end of the rod that was not in the water, and the centre of the rod, and notice differences along the rod. They may also notice that after a short while, the whole rod will cool down again.
4. Discuss what is happening in terms of heat:
    - The hot water gives energy to the metal rod (where the rod touched the water).
    - The energy from the hot water makes the molecules of the metal rod move faster, which we can feel as warmth (heat).
    - The heat spreads up the rod as the faster molecules at the end of the rod bump into adjacent molecules. As a result, the middle of the rod (even though it was not touching the water) feels warmer as well.
    - Eventually the molecules in the rod will transfer their heat energy to the molecules in the air and the rod will cool down again.
    - The movement of heat when molecules transfer energy between each other by colliding with each other is called “conduction”.

(3) Activity: Lunch Bag Insulation Investigation

Purpose of Activity: To recognize and understand the purpose of insulation in everyday items.

Methods and Instructions:
Set-up prior to experiment: none
Students work alone for this activity, but are encouraged to discuss what they find with neighbors.

1. Students get out their lunch bags and open them up. They look at the containers and the bag itself, to find insulating materials, which block heat movement.
    - Sometimes insulators are there to prevent heat from *escaping the food*, e.g., soup containers keep warm soup warm.
    - Sometimes insulators are there to prevent heat from *getting to the food*, e.g., the padded lunch bag keeps a cool sandwich cool.
2. Students draw their lunch bag and the *insulators* they found on the “Lunch Bag Insulation” worksheet (follows this lesson). Examples:
    - Anything padded or thick plastic (lunch bag itself, plastic containers, thick wrapping) does not transfer heat well, so it will block heat from getting into food that needs to stay cold.
    - Metal soup containers have a layer of air between two walls. Still air in a vacuum does not conduct heat well, heat is prevented from rapidly leaving the soup container.
    - Silver-lined bags reflect heat (by another heat transfer process called “radiation”).

(4) Activity: Convection demonstration

(This demonstration was adapted from ref. 2.)

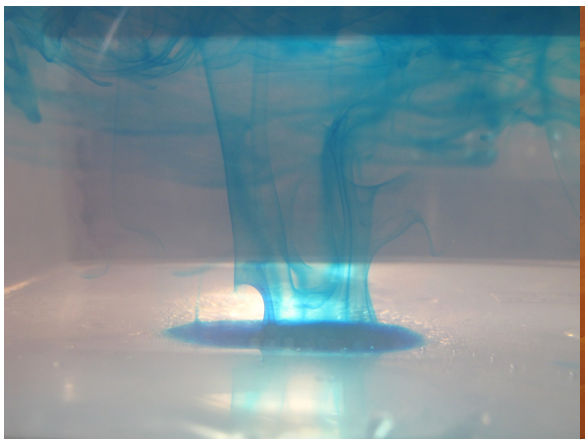
Purpose of Activity: To show *convection* with a powerful visual.

Methods and Instructions:
This demonstration is ideally done at the end of the lesson, though if a longer wait time is needed for activity (1), it may be done after activity (2).

Set-up prior to experiment:

- Stand a desk or table in an open area of the classroom.
- Boil the kettle of water, so that it is quick to boil again when needed.
- Arrange the four cans on the desk so that they can support the tub at each corner.
- Fill the large tub with cold water and stand it on the four cans so that it is stable.
- (Optional: add a few ice cubes to cool the water for 5 minutes or so, then remove them again.)

1. Ask all the students to sit in a circle around the tub, so that they can see through the sides of the tub.
2. Wait for the water to become completely still before proceeding.
3. Suck up a little food dye into the pipette, then very slowly and carefully lower the pipette into the water and deposit a pool of food dye on the base of the tub. Slowly remove the pipette from the tub, so as to disturb the water as little as possible.
4. Boil the kettle, then immediately fill the styrofoam cup with boiled water. Slide the cup under the tub, and leave it directly below the pool of food dye.
5. After a minute, streams of food dye should start to flow upwards from the pool of dye (see photos below and ref. 2).
6. Make sure all the students are able to see the food dye streaming upwards before continuing discussion. (You may need to carefully wipe condensation from the outside of the tub for a clearer view.)



7. Explanation:
    - The hot water in the styrofoam cup heats up the water and food dye directly above it, making the molecules move faster as they gain heat energy.
    - This group of fast moving molecules flow upwards in the water (because they are less dense than the surrounding cooler water). They take heat energy with them, and are moving by convection.
    - The visualized convection currents are beautiful as they trace out curving patterns.

Closure Discussion

1. Summarize what heat is: energy that moves through matter by making a group of molecules move faster.
2. Summarize how heat can move: the faster moving molecules can either, bump into their neighbors and pass their energy to them (conduction), or they can move as a group through a liquid or gas (convection).

References

- <www.middleschoolchemistry.com/multimedia/chapter1/lesson2> Middle School Chemistry lesson plans and resources. American Chemical Society. Accessed May 13, 2014.
- <www.youtube.com/watch?v=IpnHAj4R-Z8> Lou Knebel. Convection current demonstrations. Activity (4) is adapted from the first experiment shown. Accessed May 13, 2014.