TEACHING LEARNING COLLABORATIVE (TLC) **PHYSICAL SCIENCE**

Different Metals Conduct Heat Differently Grade 5

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Science Content Standards: Grade 5, 1c — *Students know* that metals have properties in common, such as high electrical and thermal conductivity.

Lesson Concept: Different metals conduct heat differently.

Conceptual Flow:

Most elements (75%) in our world are metals.

- Metals have common properties.
  - Magnets will stick to metals with steel or iron in them.
  - Some metals conduct heat and electricity better than other metals.
  - Metals are malleable (capable of being shaped) and ductile (capable of being hammered thin or fashioned into a new form).
- Metals have specific uses depending on their properties.
  - Metals that are good conductors are used for electrical wiring.
  - Metals that are less ductile are used in building bridges and buildings.
  - Metals that are malleable are used in jewelry.

Teacher Background:

In general, metals are shiny, reflecting most of the light that strikes them. They are malleable and ductile (that is, they will bend under pressure and are not brittle). They have a broad range of melting temperatures (e.g., mercury is a liquid at room temperature, gallium will melt in one's hand, and tungsten has a melting temperature around 3,400 degrees Celsius). The thermal and electrical conductivity of all metals is high compared to nonmetallic substances, such as plastics and ceramics, rocks, and solid salts.

(Adapted and excerpted from the *Science Framework for California Public Schools: Kindergarten Through Grade Twelve*.)

Metals generally conduct heat better than other solids. In metals, some of the electrons are not stuck to individual atoms but flow freely among the atoms. This makes metals such good

conductors of electricity. If one end of a metal bar is hot, and the other is cold, the electrons on the hot end have a little more thermal energy (random jiggling) than the ones on the cold end. So as the electrons wander around, they carry energy from the hot end to the cold end, which is another way of saying they conduct heat.

How fast metals conduct heat depends on things like how many free electrons they have, how fast they are moving, and how far they go before they bump into something and change direction. Those are the same factors that determine how well the metal conducts electricity. There's a "rule" indicating that the thermal conductivity (at some temperature) is proportional to the electrical conductivity. That's convenient because it's much easier to measure electrical conductivity than thermal conductivity.

Most ordinary metals have about the same density of electrons (number per volume), so the main reason for the differences in how well they conduct electricity is the difference in how easily the electrons move around. In some metals (copper, gold, silver, aluminum) the electrons can travel past hundreds of atoms before bumping into something that makes them change directions. In others (especially alloys with more than one type of metal atom) the electrons travel only past a few atoms before bouncing off some irregularity in the material. Although this is not the only factor giving the different thermal conductivities, it is probably the biggest one.

(Adapted from: http://van.physics.illinois.edu/)

This site may be helpful in further explaining conductivity of metals (http://van.physics.illinois.edu/qa/listing.php?id=1818). For more information, go to http://van.physics.illinois.edu, then click the button on the left "Ask the Van," and do a custom search on specific science questions.

Materials Needed for the Lesson

For Explore #1:

Teacher Materials

- Three (3) large cooking spoons (one completely plastic, one wood, one completely metal)
- Hot plate
- Matches
- 1 quart pan of water. (If possible, obtain a cooking pan with a copper bottom which can also be used in Explore #2)

Student Hands-on Materials

For each table group:

- 6 cups (5 inch-tall; Styrofoam)
- Three 12 inch-bridges (one wooden, one plastic, one metal) – see "Advanced Preparation" below

- 3 candles (one-inch tall)
- 15 chocolate chips (light colored small chips work best)
- Tweezers to pick up chips
- Stopwatch or a wrist watch with a second hand

Student Handouts

- "Heat Conduction Data Table" (one for each group)
- "Analyzing the Data" (for each student)

Advanced Preparation

- Make a poster for a wooden, a metal, and a plastic spoon, and place the posters around the room.
- Obtain a cooking pan with a copper bottom (use one from Explore #1 if one was used). If a pan with a copper bottom is not available, cut out a picture of a copper bottom pan from a magazine or catalog.
- For the bridges, purchase one of each for each group: 12-inch metal rulers (without the cork on the bottom), 12-inch wood rulers (remove metal edge if there is one), and 12-inch plastic rulers (not acrylic as these may melt over the candle). (Each ruler could be cut into two 6-inch bridges, if desired.)
- Place bridges, cups, chocolate chips, and candles into large zip-lock bags for easy distribution to table groups.

For Explore #2:

Teacher Materials

- "Conductometer" (available for about $10.00 each from Nasco Science, PO Box 3837, Modesto, CA 95352; 209-545-1600; 800-558-9595; www.eNASCO.com; other science equipment/materials stores may also sell these)
- Votive candle (or use the 1 inch tall candles from Explore #1) and matches
- Overhead of "The Conductometer Test"

Student Hands-on Materials

For each table group:

- One Conductometer
- 1 candle
- 1 cube of butter
- Plastic knife

Student Handout

- "The Conductometer Test"

Advanced Preparation

- Purchase a Conductometer for each group
- Cut a cube of butter into ½-inch cubes and keep very cold (Provide five ½-inch cubes for each Conductometer); or allow students to cut their own cubes from a larger piece of butter.

5E Lesson: Different Metals Conduct Heat Differently

Teacher Does	Student Does	Concept
ENGAGE: Have a poster for each of the three spoons around the room. In the front of the room, have a pan of boiling water. Put spoons (wooden, metal, plastic) in the pan of boiling water. Ask students: ▸ *Which spoon do you think would feel the warmest at the end of the handle first? Choose the spoon that you think will heat the quickest and go stand by that poster.* ▸ *Discuss in your group why you think this spoon will conduct heat to the handle the fastest. Select one explanation to share.* Have each group share an explanation. ▸ *Explain your thinking. I think this … because …* . Have several students touch the spoons to determine which one is the hottest. Record their claims on the board. Explain that they will work in groups to do an	Choose a spoon poster and go stand by it. Discuss with group why this particular spoon will heat the quickest. Decide on which answer to share with the class. **Expected Student Response (ESR):** From cooking at home, the metal spoon gets hot fast. I think this because _____. I think the plastic got hot the fastest, because plastic melts. The wooden spoon will get hot first because the wood soaks up the hot water.	Different materials conduct heat differently.

Teacher Does	Student Does	Concept
investigation about how heat moves and if it moves differently in different materials.		
EXPLORE #1: Describe that they will be testing three materials: metal, wood, and plastic. Model in the front of the room how to set up the bridges and chocolate chips. The cups are the structure to support the bridge. Place 5 chocolate chips on each bridge: one in the center, then two on each side each one inch apart (1 set one inch from the center then the next one set two inches from the center). Set the candle under the center chocolate chip. To each table group, distribute 6 cups, 3 candles, 15 chocolate chips (5 for each bridge), 3 bridges (one plastic, one wood, one metal), and the "Heat Conduction Data Table". Ask students to set up their experiment as modeled. Explain that once the candle is lit with the bridge placed over it, they must record observations every minute detailing what is happening to each of the chocolate chips on each bridge. ▸ *To identify which chip is melting, label in your mind each of the 5 chips as 1, 2, 3, 4, and 5 (#3 chip has the candle under it; #1 is farthest to the left and #5 is farthest to the right).* Ask groups to assign a timekeeper. Light the candles for each group and have students observe the chocolate chips on each bridge. Every minute, they should record their observations concerning which chips are melting. Go to "**Explain #1**".	Set up the bridges, chocolate chips, and candles. Observe the chocolate chips. Record observations every minute.	Heat moves away from the heat source to areas of lesser heat. Metals conduct heat better than other materials.

EXPLORE #2: ▸ *We learned that metals conduct heat better than other materials. Do you think that different metals conduct heat differently?*	**ESR:** All metals conduct heat the same because they are metal.	
Show and describe the "Conductometer". Tell students that each rod or spoke is a different type of metal and that the abbreviation for each metal is engraved or stamped with one or two letters where the spokes meet the circle in the middle (i.e., S=Steel; B=Brass; A=Aluminum; C=Copper; NS=Nickel Silver). ▸ *You will write the abbreviation for each metal on "The Conductometer Test" sheet. You will use a piece of butter of the same size and place one piece at the end of each spoke. Then you will put this over a heat source and record on your sheet the order that each butter piece melted off.*		
Provide a "Conductometer" to each group and a copy of "The Conductometer Test" to each student. ▸ *Look at your conductometer and write the location for each of the five types of metals (S, B, A, NS, C) that correspond to each spoke on the drawing. Start with the one to the right of the handle and go to the left and around.*	On the diagram of the "Conductometer" students label the different metals.	
Use an overhead of "The Conductometer Test" to show students where to write the abbreviation for each metal. ▸ *Check that everyone's diagram in your group is labeled correctly. Then raise your hand and I will light your candle and provide you with cubes of butter.*	Students check each other's papers and raise hands to get the materials.	
As groups raise their hands, check that the students have labeled the different types of metals in the same order as on the actual "Conductometer." (Conductometers made by different companies may have different locations for various metals.)		
Remind students to make certain that all their butter pieces are fairly equal in size (they may need to use a plastic knife to trim some pieces). They should place one piece of butter	Students follow directions and record observations.	

on the outer tip of each metal. Then they can place the middle of the "Conductometer" over the candle. They should observe and record (on their "Conductometer Test" sheets) the order that the pieces melted off each metal rod. (You may need to model this one the overhead. Go to "**Explain #2**".		
EXPLAIN #1: Distribute "Analyzing the Data" sheet to each student. ▸ *Using the data gathered, answer the questions on your data sheet.* ▸ *Which type of bridge conducted the heat the quickest? What is your evidence?* Go to "**Explore #2**".	**ESR:** The metal bridge conducted heat the fastest. I know this because (or my evidence is that) the chocolate chips melted on the metal bridge first.	Different metals conduct heat differently.
EXPLAIN #2: ▸ *Which metal conducted heat the best or the quickest? Use your data to explain.* ▸ *I claim _____ conducts heat the best; my evidence is _____.* If available, show a cooking pan with a copper bottom. (A picture from a magazine of a pan with a copper bottom can also be used.) ▸ *Why do you think the manufacturer put copper on the bottom of the cooking pan?* ▸ *Using the word "conductor" what can you say about copper and heat?*	Copper conducts heat the quickest. I claim copper conducts heat the best; my evidence is that the butter melted and fell off the copper rod (or spoke) first. **ESR:** Because copper heats up quicker than other metals used for cooking pans. **ESR:** Copper is a good conductor of heat.	Some metals conduct heat better than other metals.
EXTEND: Do the "Pencil Activity" (see pg. 272, right column, "a", in the *Everyday Science Sourcebook* by Lawrence F. Lowery; ISBN: 0-86651-260-8). A description of this activity is described below: Obtain a pencil with a metal cap on one end (or with a metal band around an eraser). Tightly wrap a white piece of white paper around the end of the pencil so that it covers the wood and the metal. Heat the pencil in a	Make prediction of what will happen to the paper and record observations.	Metal can conduct heat away from paper. Wood does not conduct the heat away from the paper.

flame at the metal tip end. When the paper starts to char, remove the pencil from the flame. Ask: ▸ *Where do you think the paper is charred? Why do you think that?* Open the paper and show to the class. ▸ *Where is the paper charred?* ▸ *In our activity with the bridges, was it wood or metal that was a better conductor of heat?* Evaluation: ▸ *In this demonstration, why is the paper charred by the wood and not by the metal?*	**ESR:** The paper will be charred where it was covering the metal. **ESR:** The paper is charred where it was covering the wood, but not where it was covering the metal. **ESR:** Metal **ESR:** The heat was conducted away from the paper by the metal, but not by the wood, so the paper by the wood got charred.	

Input Question: What was the location of the chocolate chips that were melting first? (Explore #1)

Process Question: Which type of bridge conducts the heat faster? (Explain #1)

Output Question: Why do you think the manufacturer put copper on the bottom of a cooking pan? (Explain #2)

Names: _____

STUDENT HANDOUT

Heat Conduction Data Table

Record what is happening to the chocolate chips at each location on each bridge.

Which chip is melting? Chip # 1, 2, 3, 4, or 5? (#3 chip has the candle under it; #1 is farthest to the left and #5 is farthest to the right.)

Minutes	Metal	Wood	Plastic
1			
2			
3			
4			

 Name: _____

STUDENT HANDOUT

Analyzing the Data

1. At the end of 1 minute, on which bridge(s) did a chocolate chip begin to melt? (plastic, metal, or wood)

   What was the location of the chocolate chips that were melting?

2. At the end of 3 minutes, describe the location of the chocolate chips that were melting on each bridge.

Plastic	Metal	Wood

3. **Based on your data**, which bridge conducted the heat the best (the quickest)?

   Explain your thinking (what is your evidence?):

Name: _____

STUDENT HANDOUT

The Conductometer Test

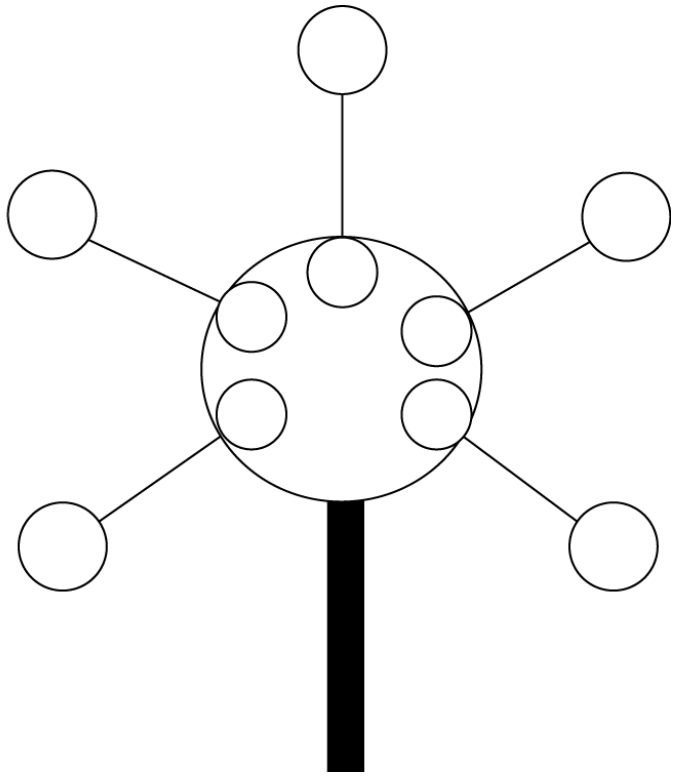
Part 1

1. Look at your "Conductometer" and copy the letter (or letters) for each of the five metals that correspond to each rod (or spoke).

2. Place a number on each of the end pieces of metal as the butter melts off: 1st=**1**, 2nd=**2**, 3rd=**3**, 4th=**4**, 5th=**5**

The 5 Metals

S = Steel
B = Brass
A = Aluminum
NS = Nickel Silver
C = Copper



Part 2

My claim is that _____ conducts heat better than (list all other metals in your experiment)

_____

My evidence is _____

_____

_____