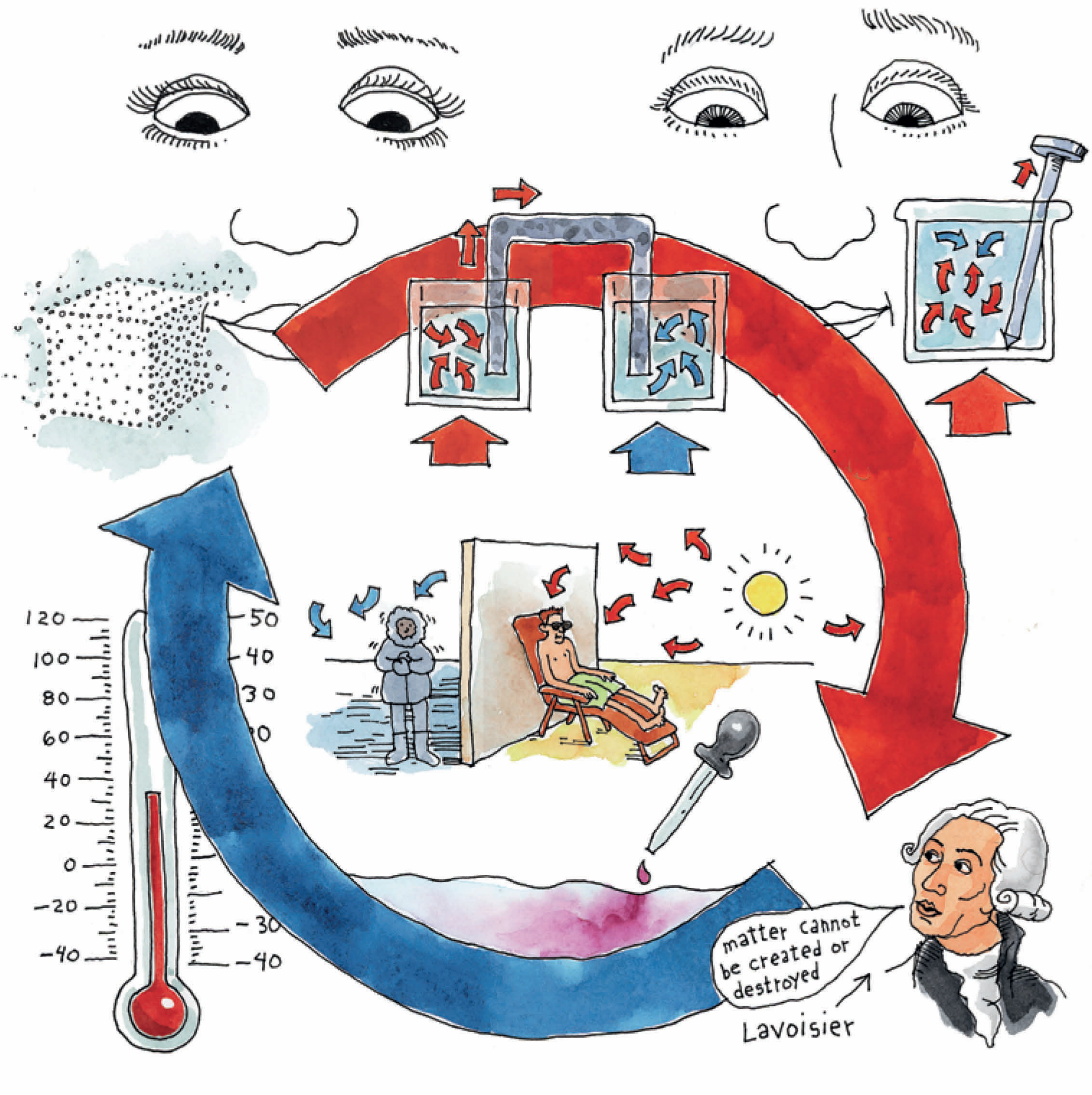
Materials



120
100
80
60
40
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0
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50
40
30
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matter cannot be created or destroyed
Lavoisier

Materials
Grade 5

The activities in this teacher's guide were created by the Center for Inquiry-Based Learning (CIBL) to accompany the Materials Kit for Grade 5. The Materials Kit was specifically designed to meet the North Carolina Essential Science Standards for grade 5 physical science. Activities in this guide require students to think and assume responsibility for investigating the nature of materials and their interactions with heat energy. The kit and teacher's guide are available only with prior professional development. The goal of this unit is to help students deepen their understanding of underlying concepts through concrete experiences with the natural world. CIBL owns all rights for publication and distribution of this guide and the accompanying kit.

This is a pilot version, still under development. CIBL welcomes any feedback you are willing to provide. You can contact us through the CIBL web site on the "contact us" tab at http://ciblearning.org. If you have questions, feel free to call 919 294-9881.

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5.P.2 Understand the interactions of matter and energy and the changes that occur.

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- 5. P.2.3 Summarize properties of original materials, and the new material(s) formed, to demonstrate that a change has occurred.

5.P.3 Explain how the properties of some materials change as a result of heating and cooling

- 5.P.3.1 Explain the effects of the transfer of heat (either by direct contact or at a distance) that occurs between objects at different temperatures. (conduction, convection or radiation).
- 5.P.3.2 Explain how heating and cooling affect some materials and how this relates to their purpose and practical applications.

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Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

In these two 45-minute lessons, students explore conservation of matter in closed and open systems. During the first lesson, students are challenged to predict, record, and explain changes (or not) in the mass of a bottle containing water and sugar cubes as the sugar cubes dissolve and disappear. In the second lesson, they compare the masses of bottles in two different situations in which a reaction is taking place. In one situation, the bottle is open, and it loses mass. In the other situation, the bottle is closed, and the mass remains the same.

Objectives

Students work with the following ideas and content:

- conservation of matter
- Students demonstrate understanding of this idea by explaining their observations of changes in matter and accompanying change (or lack of change) in mass. They give reasons both verbally and in writing for the observed mass relative to changes in characteristics of matter.

Correlations to NC Science Standards

National Standards to be added when adopted in North Carolina.

5.P.2.2 Compare the weight of an object to the sum of the weight of its parts before and after an interaction.

Correlations Common Core State Standards for Mathematics

5.NBT

7. Add, subtract, multiply, and divide decimals to hundredths, using concrete models or drawings and strategies based on place value, properties of operations, and/or the relationship between addition and subtraction; relate the strategy to a written method and explain the reasoning used.

Brief Science Background

When energy and matter interact, things move, change form, heat up, rearrange, or change in some other way. Sometimes matter may seem to disappear altogether, for example, when something burns up. However, when matter changes in a closed system where nothing can enter or leave, nothing is added or subtracted from the total amount of material in the system. For example, if something burns in a closed system, all of the ash and gases resulting from burning remain in the system, and the weight of the system as a whole remains the same.

Part 1 — Where's the Sugar?

Materials

Materials for the whole class

- a scale accurate to .1 gram
- a 12-oz soda bottle with cap
- 2 sugar cubes
- 1 oz. cup with water
- Cartoon to be projected
- Index cards, 3”x 5” ruled

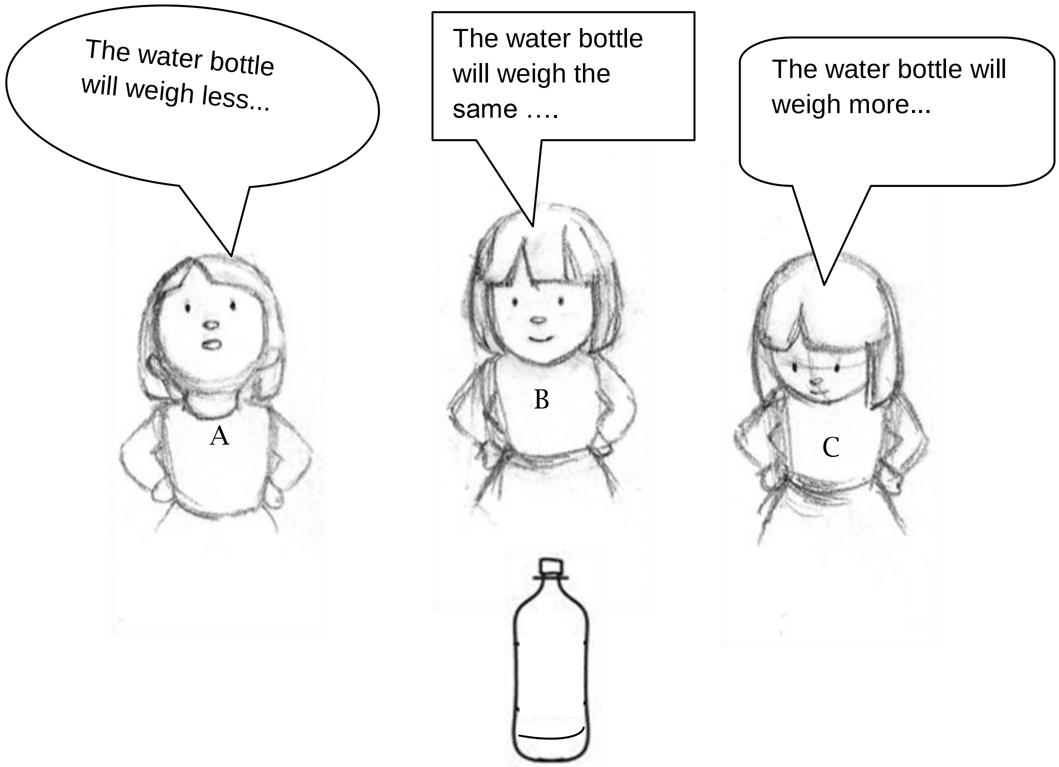
Preparation

1. Pour a few ounces of water in the bottle and weigh the water and bottle on an electronic scale.
2. Have the sugar cubes at hand.
3. If you have a document camera, you can use it to project the scale readout for all to see. Otherwise, select a student to read out the weights.

Procedure

1. Add 1 oz of water to the bottle. Close the bottle with the cap and place it on the scale. Record the mass of the bottle, water, and cap on a SmartBoard™ or whiteboard for the class to see.
2. Leave the water bottle on the scale and add 2 sugar cubes next to the bottle on the scale. Determine the mass and record the mass on the board or SmartBoard™ for all to see.
3. Place the sugar cubes in the water, secure the cap. Do Not Shake.
4. MATH EXTENSION
   When the sugar cubes are sitting in water in the bottle on the scale, tell students, woops! You forgot to determine the mass of the sugar cubes. Ask them to figure out from the information on the board what the mass of the sugar cubes must be. **Don't give hints; just confirm that the information on the board is enough to determine the mass of the cubes. After a minute, accept answers and show how to determine the mass of the cubes. The sugar cubes should still be visible in the bottle.**
5. Take the bottle off the scale and swirl it to completely dissolve the sugar cubes. When they have disappeared, ask students where the sugar went. Accept all answers. Ask students what they think will happen when you weigh the bottle. DO NOT PLACE THE BOTTLE ON THE SCALE. Project BLM 2, the cartoon, and ask students to read the three responses to the situation in the thought balloons.
6. DO NOT PLACE THE BOTTLE ON THE SCALE! Give each student a note card. Ask each student to individually write on the front of their note card which person they agree with: A, B, or C.

Procedure



7. Ask each student to write the quote from the person they chose on the back of the card, and add the word "because…" Then, ask each student to complete the sentence giving a reason for what they think.

6. Have students form groups by like letter. Groups should be 4-5 students. If many students choose the same letter, break them into multiple subgroups advocating for the same letter, but keep group size at 4-5. Give each group 5 minutes to agree on 3 main reasons their statement is correct. Ask them to select a speaker to report their reasons to the class.

9. After 5 minutes, have each group report, but give no indication of the correct answer.

10. Ask students to return to their seats, hold the bottle of water up and place it on he scale. Record the results. The mass should be the same as step 2 above.

11. Briefly discuss with the class which cartoon person is correct (B), but do not discuss conservation of matter yet. Students might think (correctly) that just because the sugar disappeared, that does not mean it is gone. Others might just as reasonably think that A is correct because the sugar is gone. Others might think C is correct because the sugar made the water sticky and sticky things are heavier. For now, it is enough for them to think that the sugar changed what it looked like without changing how much of it is in the bottle.

Notebook Prompt: Write a rule that explains what you just observed.

Part 1 Procedure cont.

12. Project BLM 1, the definition of the Conservation of Matter. Relate it to the exploration that students just completed, especially to their responses to the notebook prompt.

Conservation of Matter:

When matter is enclosed so that none comes in or out, if that matter is rearranged or changed, the amount of matter does not change. The amount is known by how much the enclosed matter weighs.

Part 2 — Bubbles

Materials for the Whole Class or the Teacher

- a digital scale accurate to .1 gram
- 3 effervescent tablets
- A 1-oz cup of water
- A 9-oz cup of water
- document camera
- a 12-oz to 1-liter soda bottle with cap (supplied by teacher – be sure to keep the cap)

Materials for each student

- Science notebook (to be supplied by teacher)

Preparation

1. Wash out the bottle after the previous activity. Pour a few ounces of clean water in the bottle. Turn on and "zero" the electronic scale. If you have a document camera, set it up to project the scale readout for all to see. If this is not possible, choose a student to read the mass to the class during the demonstration.
2. Break one of the tablets in half.
3. Without any water in the 12-oz bottle, practice placing the tablets in the neck of the bottle and sealing the bottle so that the tablets stay in the neck. Steps 5 and 12 of the procedure will go more smoothly with a little experience.

Procedure

This activity is designed to teach the concept of a closed system when dealing with conservation of mass. This can be a difficult idea for children.

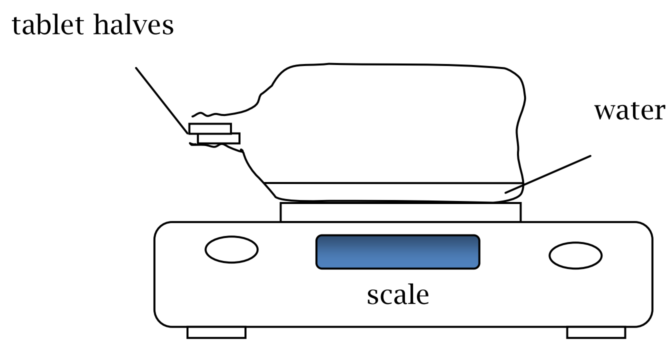
1. Ask students to remind you what the law of conservation of matter says and inform them that we will continue to explore conservation of matter today.
2. Add water to the bottle and place on the scale – no cap. Show (or report) the mass to the class. Record the mass where everyone can see it.
3. Keep the water bottle on the scale and place 1 effervescent tablet (broken in half) next to the bottle on the scale. Read the new mass and record it where everyone can see it.

Part 2 Procedure cont.

4. Say that, in a minute or so, you will put the tablet in the bottle with the water. However, before you do that, you want everyone to see what happens when these tablets get wet. Drop an effervescent tablet in the 9-oz cup of water and either put the cup and fizzing tablet under the document camera or circulate around the room so that students can see it.

   Notebook Prompt: predict what will happen to the total mass of the bottle and its contents when the effervescent tablets are placed in the water. Give a reason to support your prediction. **Most students will predict the mass to remain unchanged like the sugar cube, and as conservation of matter would suggest.**

5. Place the bottle on its side on the scale, and place the two halves of the effervescent tablet in the neck of the bottle. Be careful not to drop either of the tablet halves into the water inside the bottle. Confirm that the mass is still unchanged. Do not use the cap (keep the cap out of sight).



6. Turn the bottle upright and watch the mass for 2 minutes. After two minutes, the effervescent tablet's reaction will be complete. Have a student read the scale out loud as the mass decreases. Lift the bottle from the scale, swirl it a few times, and gently squeeze and release the sides of the bottle. **The gas in the bottle comes from a chemical reaction between the tablet and the water. The gas is heavier than air, so a little squeeze helps push a little more of it out of the bottle.**

7. Place bottle back on scale record the mass. **Over the time of the reaction, and after squeezing, students should see mass decrease by about .5 grams.**

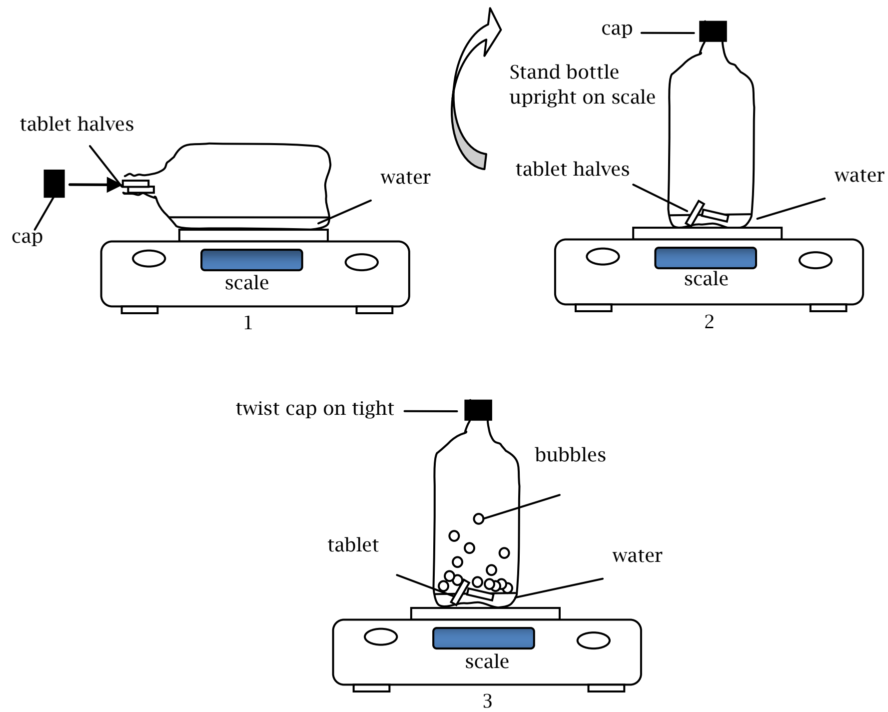
8. Ask students to explain what might account for this loss of mass? **Do Not guide students to understand what has happened.** Share with the class that this example does not seem to follow the Conservation of mass rule. Explain that we will revisit this and provide an explanation after we do one more experiment.

9. Tell the class we will do the experiment again, this time we will add a cap.

10. Add water in the bottle, secure the cap, and place on the scale. Record the mass for the class to see.

11. Keep the water bottle on the scale and add 1 effervescent tablet broken in half next to the bottle on the scale and determine the mass. Record the mass for the class to see.

Part 2 Procedure cont.



12. Place the bottle on its side and place the two halves of the effervescent tablet in the neck of the bottle. Secure (seal) the cap to the bottle. As you do this, avoid dropping the tablets into the bottle and water (keep them in the neck). Stand the bottle up. After bubbling is complete, confirm that mass is unchanged.

13. Turn the bottle upright (give the cap an extra turn to be sure it seals). When you do this, the tablets will fall into the water and fizz. Watch the mass for 2 minutes, or until the tablet halves stop fizzing. The mass should remain unchanged.

14. Ask the students to describe how the second time was different from the first time. Ask how they might account for the mass remaining unchanged this time. **Explain that the effervescent tablet and water react to produce an invisible gas. Emphasize that gases, even though they are invisible and seem to float, actually weigh something.**

15. Tell students you are going to remove the cap, and you wonder what will happen to the mass after you do that.

    Notebook Prompt: predict the mass of the entire system after the cap is removed and then placed back on the bottle.

16. When students finish writing, ask students to listen carefully, then remove the cap. Ask them to describe what they hear. Ask them what they think made that sound. Hold the uncapped bottle up and gently squeeze and release the sides. Place the cap back on the bottle and put the capped bottle back on the scale to weigh it. **Mass should decrease by about .5 grams.**

    Notebook Prompt: Explain what could account for the missing .5 grams?

Part 2 cont.

Wrap-Up

1. Emphasize the difference between open and closed systems with regard to conservation of matter (mass) as follows: **Where no matter can enter or leave a system (closed system), mass remains the same even if matter changes form. If matter can leave or enter (open system), mass can change. Here, a solid became an invisible gas (CO_2) that left the open system (no cap) and stayed in the closed system (cap on).**

2. Ask students what escaped, and why they think the bottle weighed less after you removed the cap (they have already dealt with this in the notebook prompt at step 16). **The open system weighed less because some carbon dioxide escaped. The carbon dioxide gas weighed something. When it left, it took some weight with it.**

3. Ask students how much they think the carbon dioxide gas weighed

Guided Practice

Marla has a soda in an unopened bottle and she weighs it carefully before she opens it. She shakes the bottle vigorously and opens it to hear a whoosh of gas escaping. She says she is going to weigh it again now that she's opened it, but before she does, she asks that she and her friends predict what the mass be. She asks her two friends, Michael and Chris, what they think the mass will be. Here are their predictions:

- Marla – The mass will stay the same because the same amount of soda is still in the bottle.
- Michael – The mass will increase because letting out the air allows the soda to expand which will make it weigh more.
- Chris – The mass will decrease because the gas being released had mass.

Respond to each incorrect person. In your response, explain why you think they are wrong so that it might convince them that you are correct.

Answer Key

Colin missed the fact that the whoosh was gas leaving the bottle, and that everything, even gas, has weight. Therefore, the bottle lost weight.

Michael has mixed up the idea of size (the soda expanding) and weight.

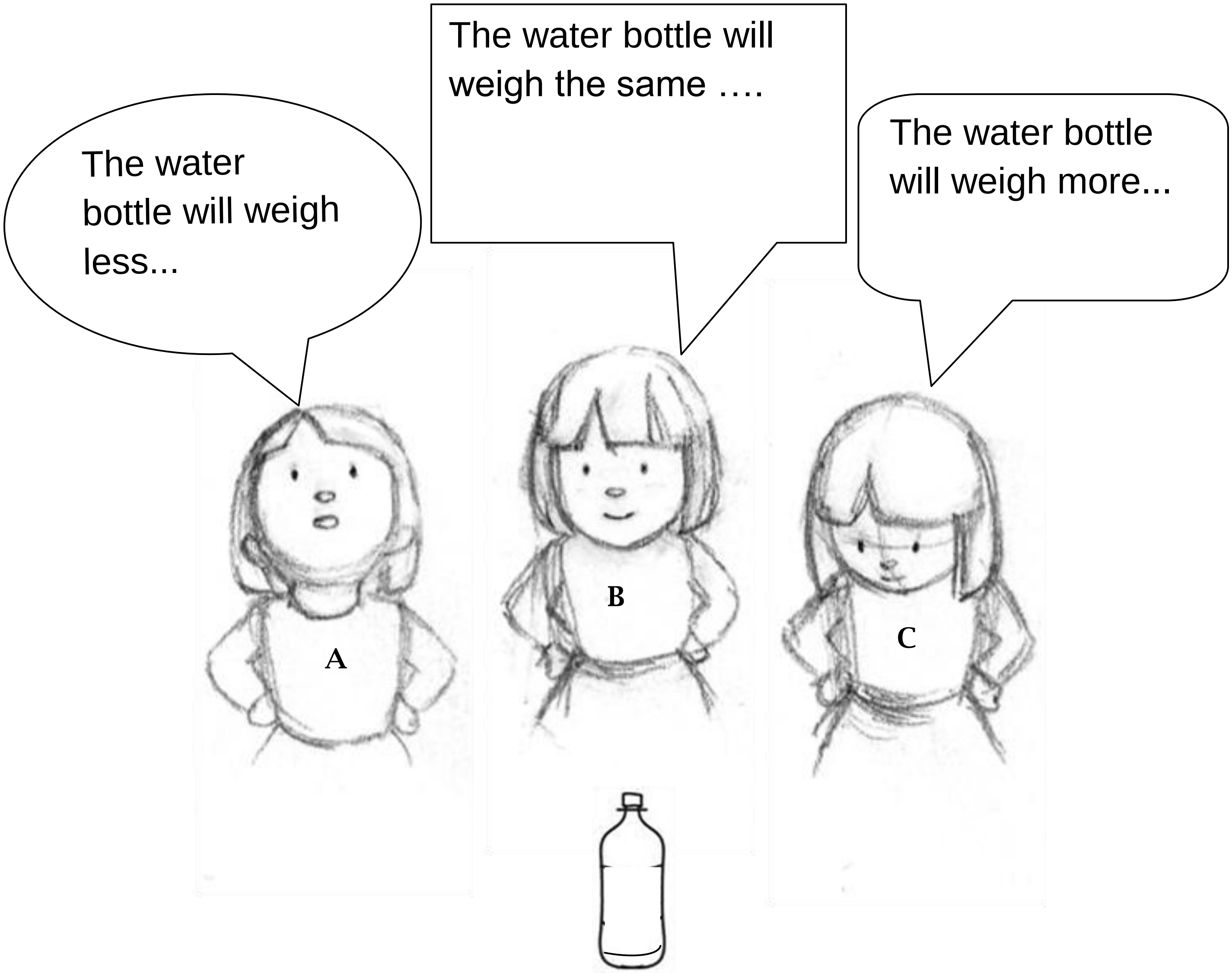
Chris is correct. The gas that came out in the whoosh is matter, and because of that, it has weight.

BLM 1

Conservation of Matter:

When matter is enclosed so that none comes in or out, if that matter is rearranged or changed, the amount of matter does not change. The amount is known by how much the enclosed matter weighs.

BLM 2


The water bottle will weigh less...
The water bottle will weigh the same ….
The water bottle will weigh more...
A
B
C

Appendix

Common Student Preconceptions About This Topic

When students see material disappear, they are likely to assume that it is gone. For example, it is difficult to imagine that all of the matter in a piece of wood still exists after it burns. In particular, students who consider gases to be weightless are unlikely to conserve mass in reactions that involve gases. This idea is related to the fact that children build their idea of mass from noticing how objects differ in the way they press down. Children learn to feel the weight of objects and compare them by felt weight. As a result, students tend to estimate mass from an object's size and appearance. Surprisingly, introducing the particle theory of matter sometimes further confuses the issue. Where a student imagines that a material is composed of very small particles spread out in space, with each particle having a negligible weight, it can seem to be less dense and be interpreted as less heavy. The confusion here is tied to the difficulty in imagining the vast number of molecules or atoms that comprise a small piece of ordinary matter.

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

This 3-day activity has students combine materials that can be completely separated with no change to the original ingredients, and they also combine materials that interact to produce new substances. In these examples, when new substances are produced, student pairs cannot physically separate the initial ingredients. Students list characteristics of materials before they are combined, after they are mixed, and after they try to separate them again. Last year in grade 4, students had experience with properties of matter (Essential Standard 4.P.2.1). This provides a basis for determining whether combining materials creates something with new properties. These activities help students begin to distinguish between physical and chemical change.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- the characteristics of a given material are consistent, and can be described;
- when materials of known characteristics are combined, then physically separated, and no changes in the characteristics of the original ingredients are observed, nothing new has been created;
- when materials of known characteristics are combined and the mixture cannot be physically separated to produce the original ingredients with their original characteristics, the interaction has produced something new;

Students demonstrate this knowledge and understanding by…

- describing characteristics of materials,
- combining those materials and describing the characteristics of the combination,
- trying to completely separate the combined materials,
- describing characteristics of the separated materials, if possible,
- applying a rule for evidence that a combination of materials has created

Correlations to NC Science Standards

5.P.2 Understand the interactions of matter and energy and the changes that occur.

5. P.2.3 Summarize properties of original materials, and the new material(s) formed, to demonstrate that a change has occurred.

Brief Science Background

Some materials can combine as a mixture, which can be separated back into original ingredients. Other materials can chemically combine to make something new, with characteristics different from the original ingredients. This activity combines some materials to produce new characteristics not present in the original materials, and it combines other materials that remain unchanged in the mixture.

Materials

Materials for the whole class for both days

- a supply of 1-oz plastic cups
- a supply of larger plastic (3 ½-oz) cups
- two 9-oz squat plastic cups
- rice
- sand
- 15 paper trays
- 15 sheets paper cut to fit inside trays
- 15 screen squares
- 15 rubber bands
- washing soda powder
- epsom salts crystals
- white beans
- black beans
- a small dropper bottle of universal indicator solution
- a small piece of steel wool
- 45 wooden coffee stirrers
- small funnels
- 30 12.5 cm diameter filter papers
- a permanent marker
- copies, 1 per pair of students, BLM 1 Mixture/Change Record Chart
- to project: BLM 2 “Mixtures and Chemical changes”

Materials for pairs of students for Day 1

- 1 paper tray
- 1 piece of paper cut to cover the flat part inside the tray
- 1 1-oz cup of rice – labeled A
- 1 1-oz cup of sand – labeled B
- 1 1-oz cup of washing soda solution – labeled C
- 1 1-oz cup of epsom salts solution – labeled D
- 3 3.5-oz plastic cups
- 2 wooden coffee stirrers
- 1 piece of screen
- 1 small funnel
- 1 rubber band
- a 12.5 cm diameter filter paper
- 1 copy of BLM 1, the Mixture/Change Record Chart

Preparation for Day 1

1. For all of the following, it is easiest to make setups by assembling the materials listed above for a pair of students on a paper tray. Before putting anything in the tray, place a piece of paper in the tray just large enough to cover the bottom (the paper keeps the tray clean when they separate materials).

2. Make stock epsom salts and washing soda solutions by placing 1 teaspoon of Epsom salts in one 9-oz squat plastic cup (label C), and 1 teaspoon of washing soda in another 9-oz plastic cup (label D). Fill both cups with water to near the top and use a coffee stirrer to mix until dissolved. Label one 1-oz cup per pair C, and one D. Pour the corresponding stock solutions into these. **Fill these 1-oz cups only half full.** Place one cup labeled C and one labeled D on each pair's tray.

3. Label one 1-oz cup per pair of students A, and one B. Pour rice into A and sand into B, half full.

4. Copy BLM 1 mixtures/change chart, one per pair of students and have these ready to give out.

5. In addition to the above cups, place a funnel, a filter paper, 3 3.5-oz plastic cups, 2 coffee stirrers, a piece of screen, a rubber band, and a copy of BLM 1 (Mixture/Change Record Chart) on each pair's tray.

6. Have BLM 2, Mixtures and Chemical Changes, ready to project.

Day 1 Procedure

1. Explain that we will work with different kinds of mixtures for the next few days. Ask the class about mixtures that they know of. If they need help, give examples: salad dressing, soft drinks, dirt, etc. Ask them what ingredients make up these mixtures.

2. Give out the supplies on the paper tray listed in "Materials for Pairs of Students Day 1" and copies of BLM 1 (Mixture/Change Record Charts).

3. Ask pairs to look at their Mixture/Change Record Charts and find the cup A and cup B boxes under "Before Combining." Ask the pairs to write as many characteristics of the stuff in cups A and B as possible in those boxes.

4. When pairs finish writing, ask them to clear the tray (except for the paper) and place a 3.5-oz plastic cup in the middle. Ask them to pour cups A and B into the cup in the middle and stir to mix. Point out the "characteristics of combined substances" column on BLM 1 and ask pairs to list characteristics of the combined materials there. **A typical response might be "like sand, only lumpier."**

5. Ask teams to clear the tray, leaving the piece of paper in it. Ask them to separate the combined ingredients, in the tray, as completely as they can, putting the separated materials back in their original cups. Ask them to record the characteristics of these separated materials on the chart. To record these characteristics, have them use the "characteristics of one separated

Procedure Cont.

substance" and "characteristics of the other separated substance" boxes in the "After Separating" column.

6. Briefly discuss:
   - How were characteristics in the combined sand and rice different from and like just sand and rice by themselves?
   - How did you separate the sand and rice?
   - Describe some evidence that the sand and rice were or were not changed after being combined and separated. Explain how your evidence supports your claim.
7. Give each pair 1-oz cups C and D, half full of liquids. Ask teams to record characteristics of the two liquids in the cup C and cup D boxes under "Before Combining." **Caution everyone not to taste the liquids. Neither liquid is poisonous in small amounts, but don't say so. Student s should never taste chemicals. Both liquids look like water, so pairs will not likely see differences.** When teams have recorded observations, ask them to combine the liquids in the 3.5-oz plastic cup. Challenge them to list characteristics of the combined materials on the chart. When teams finish, ask them to **keep their copy of the chart to use during the next class period.**
8. Ask pairs to use the filter paper and funnel to separate the two liquids. Ask them to place the funnel in a 3.5-oz plastic cup. Guide them to fold the filter paper (project BLM 3 if necessary) and place it in the funnel. When the setup is complete, ask them to pour the milky colored liquid through the filter paper. **Filtering may take as long as 5 minutes. During that time, hold a class discussion about the first two bullets below.**
   - What characteristics did you observe in the two liquids combined that were different from the two liquids by themselves before they were combined?
   - Before you mixed the two liquids, what evidence did you have that they were different or the same? After mixing, what evidence did you have that they were different or the same?

   After filtering, give this notebook prompt.

   Notebook Prompt:
   - Describe how you separated the mixture.
   - Describe your evidence that the two liquids were or were not changed and explain how that evidence supports your claim.

   Ask pairs to set the filter paper aside to dry overnight. Examine it during the next class period and discuss whether it represents "something new." **It is something new because neither of the two liquids that were combined contained white stuff.**
9. Discuss the differences between sand and rice and the two liquids when it comes to combining and separating them. **Comparing these two combinations provides a rich opportunity for students to think, speculate, and explain their thoughts. Try to get as many ideas as possible from them, but do not use this time to teach about mixtures and chemical compounds.**

Procedure for Day 1 cont.

10. Project BLM 2 and ask students to copy it into their notebooks. BLM 2 says:

- *Some ingredients can combine and separate again without changing. These don't make anything new. This kind of combination is called a mixture.*
- *Some ingredients combine but don't easily separate again. These make something new. This kind of combination is called a chemical change.*

Ask

- which kind of combination was the sand and rice, and why?
- which kind of combination was the two clear liquids, and why?

Day 2

Materials

Materials for the whole class for day 2

-
- a steel wool pad
- a 9-oz plastic cup of water

Materials for pairs of students for day 2

- a paper tray with a piece of paper cut to cover the flat part inside
- two 3.5-oz plastic cups
- 1-oz cup half full of white beans – labeled E
- 1-oz cup half full of black beans – labeled F
- 1-oz cup half full of washing soda solution – labeled G
- 1-oz cup half full of indicator – labeled H
- BLM 1 Mixture/Change Record Chart partially filled out on previous day
- a coffee stirrer
- a small funnel
- a 12.5 cm diameter filter paper
- 2 copies BLM 1, Mixtures/Change Record Chart from part 1 of the activity

Preparation for Day 2

1. Per pair, make two 1-oz cups, one labeled E, and one F. Fill the cups labeled E half full of white beans and the cups labeled F half full of black beans.
2. To make washing soda stock solution, label a 9-oz plastic cup G and fill it with water. Stir in 1 teaspoon of washing soda with a coffee stirrer. The solution will be clear with a little foam on top.
3. Per pair, label one 1-oz cup G and fill it half full with solution from cup G.
4. To make indicator stock solution, label a 9-oz plastic cup H and fill it with water. Drip 50 drops of universal indicator from the dropper bottle into the water and stir it with a clean coffee stirrer. The solution should be green.
5. Per pair, label one 1-oz cup per pair H and half fill these cups with solution

Preparation cont.

from cup H.

6. Be sure teams have their copy of BLM 1, Mixtures/Change Record Chart from part 1 of the activity.
7. Per pair, place two 3.5-oz plastic cups, cups E and F, and 2 coffee stirrers on a paper tray. Have these trays ready for teams. Set aside cups G and H to give out later on (in step 6 of the procedure).
8. Set aside a steel wool pad and two 9-oz plastic cups, one empty and one full of water. You will use these in the last step in the activity.

Procedure for Day 2

1. Explain that we will look at more examples of combinations. Project BLM 2 again and say we will decide which kind of combination we make: a mixture or a chemical change.
2. Give out trays of materials. Be sure teams have their copy of BLM 1 partially filled in from the previous day.
3. Ask pairs to record characteristics of the contents of cups E and F in the appropriate places on the chart.
4. When teams finish, ask them to combine cups E and F in a 3.5-oz plastic cup and thoroughly mix. Ask them to describe characteristics of the combined material in the "combined" column of the cup E and F row.
5. Ask pairs to separate the combined beans back into the original cups and describe characteristics of the separated beans in the 2 columns under "After Separating." After everyone does this, share results and discuss. Ask what kind of combination this was, and why. Ask pairs to clean out the small cup and re-use it for the next steps.
6. Give out cups G and H to each pair. Ask them to use cups G and H to repeat what they just did, including recording characteristics of cups G and H in the chart.
7. Ask teams to use the funnel and filter paper as before, pour the combined liquids through it, and record results in the "After Separating" column. **They will not be able to separate it. The liquid will remain blue and look the same as it did before going through the filter.**
8. Ask: "What kind of combination is this, and how do you know?" and discuss differences in combining and separating the two liquids and the bean mixture.
9. Show the steel wool around the class and ask for descriptions of characteristics. Put it in the 9-oz plastic cup and pour the cup of water into it. Ask what kind of combination this is, and ask for reasons. Explain that the cup of water and steel wool will sit until next class period, when we will write down characteristics of the combination. Ask for predictions about what we will see in the cup.

Day 3

Wrap-Up

1. Review:

   - Things that can be combined and separated again, and still have their original characteristics are called mixtures.
   - Things that combine and make something with new characteristics, and can't easily be separated again, are called a chemical change.

2. Ask everyone to go through their Mixture/Change Record Chart and identify each combination as either a mixture or a chemical change.

3. Ask everyone to look at the steel wool and water from the previous class period. Ask them to describe the characteristics of the combined materials. Ask them if they think they can separate the combination back into steel wool and water. Ask if the class thinks this is a mixture or a chemical change. Ask for reasons.

4. Give an example of a mixture such as salad. Explain that the fact that the ingredients are combined doesn't change them, and you can pick through the salad and separate the ingredients unchanged. Ask the class to give examples of mixtures.

5. Explain that an example of chemical change is pancakes. Combining the ingredients in pancake batter and cooking it changes the ingredients into something new, and you can't easily separate the ingredients back into their original form. Ask the class to give other examples of chemical changes.

Guided Practice
Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks.

Choose the response that best completes the sentence.

1. Someone combines a teaspoon of white crystals with a cup of water. It is probably a mixture if:

   A. the water foams, and a gas with a strange smell comes out.

   B. the crystals disappear in the water, but after the combination sits out for a few days, the water evaporates to leave behind the same crystals.

   C. the water changes color and is filtered, but nothing comes out into the filter paper.

   D. the crystals change color.

Day 3

2. Oil and water are poured together in a jar, then shaken up. At first, the jar looks cloudy, but after a few minutes, the oil is all on the top and the water is all on the bottom. This combination is a:

   A. chemical change because the water sinks to the bottom and that is new.

   B. chemical change because the oil turns into small droplets for awhile.

   C. a mixture because the oil and water separate and nothing new is made.

   D. a mixture because the water changes to get cloudy for awhile.

3. A log burns until only smoke and ash are left. This is a:

   A. chemical change because the log changes into things with new characteristics.

   B. a mixture because the smoke is made of tiny pieces of log floating in the air.

   C. a mixture because the ashes can be separated back into log and air.

   D. a chemical change because the smoke can be filtered out of the air.

Answer Key

1. **B**

2. **C**

3. **A**

BLM 1 Mixture/Change Record Chart

NAMES____Date______________________________

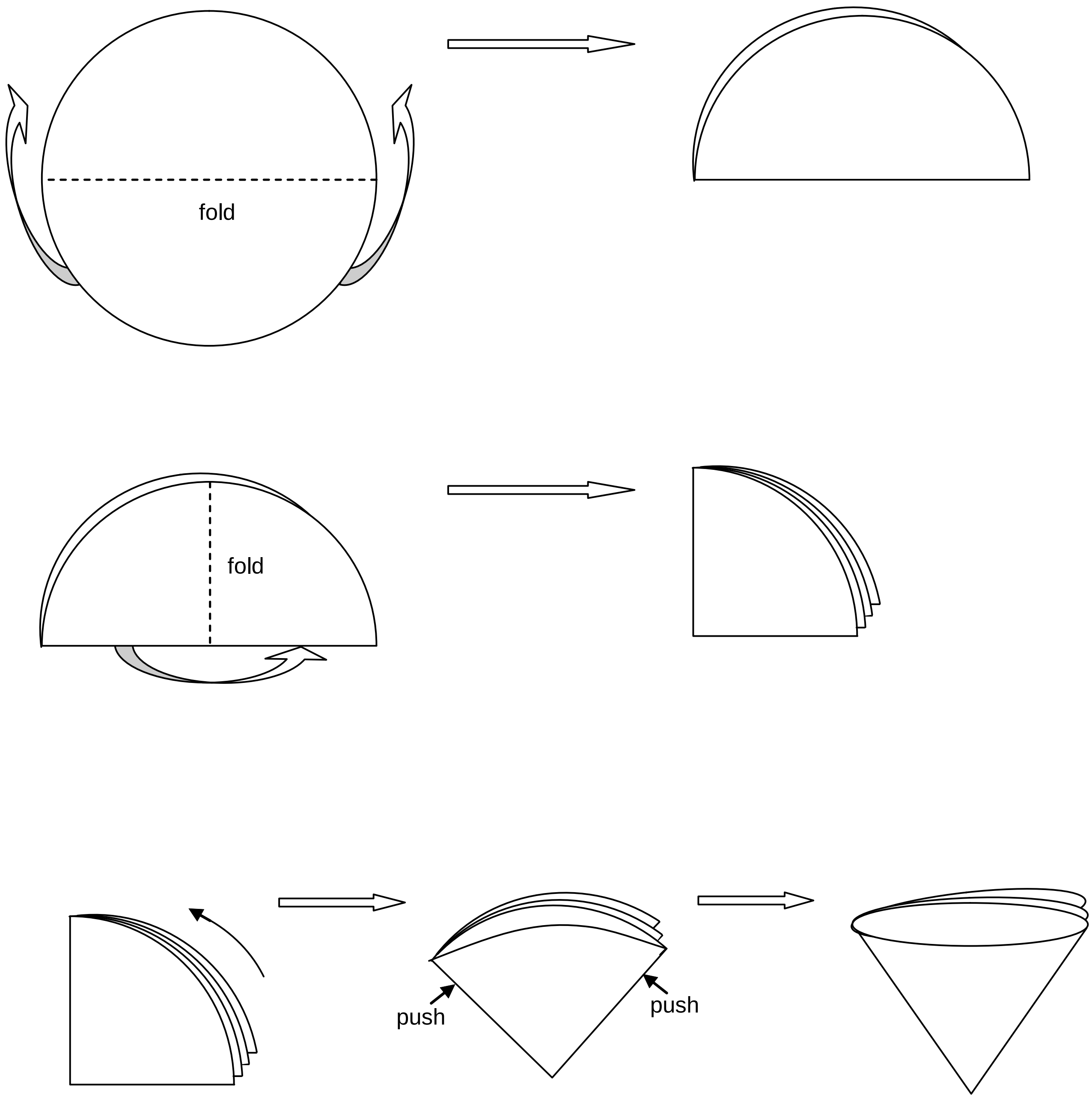
BEFORE COMBINING (enter cup label letter in each box)		COMBINED	AFTER SEPARATING (if it could be separated)	
Characteristics of substance	**Characteristics of substance**	**Characteristics of combined substances**	**Characteristics of one separated substance**	**Characteristics of the other separated substance**
Cup A	**Cup B**			
Cup C	**Cup D**			
Cup E	**Cup F**			
Cup G	**Cup H**			

Mixtures and Chemical Changes

Some ingredients can combine and separate again without changing. These don't make anything new. This kind of combination is called a mixture.

Some ingredients combine but don't easily separate again. These make something new. This kind of combination is called a chemical change.

BLM 3 Folding Filter Paper



Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

This three-day activity consists of two parts. In the first part, *Hot Nail*, students take the temperature of a nail head over a two minute period while the pointed end of the nail is in hot water, then predict the temperature at the four minute mark. Next, they repeat the experience with a nail that does not touch the hot water inside the cup. The class discusses evidence for the source of the heat in the nail head and how it reached the nail head. In the second part, *Bridge Between Hot and Cold*, student teams have a cup of hot water and a cup of cold water. They measure the temperature in both cups then connect the two cups with a piece of metal and continue measuring temperatures for eight minutes. The teacher has a pair of cups hot and cold water, but these are not connected by metal. Students compare and contrast the temperature changes in a system with a heat conductor connecting hot and cold against a system with no connection between hot and cold.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- Materials can conduct heat energy from one place to another.
- Materials in contact with each other can transfer heat from one object to the other.
- Materials that are not in contact with each other do not transfer heat by conduction.

Students demonstrate this knowledge and understanding by...

- arranging materials to conduct heat energy from one place to another, measuring the result, and giving reasons for temperature changes.
- Predicting temperatures along an object that is conducting heat from one place to another.

Correlations to NC Science Standards

5.P.3.1 Explain the effects of the transfer of heat (either by direct contact or at a distance) that occurs between objects at different temperatures. (conduction, convection or radiation).

Brief Science Background

Heat flows from materials at higher temperatures to materials at lower temperatures in some combination of three different ways, by convection, radiation, and conduction. This activity provides students with an experience of heat conduction and opportunities to measure temperature changes it causes. When heat moves by conduction, an area of a material that is hot warms the adjacent area, and that newly-warmed area in turn warms the area next to it. In that way, conduction “passes along” heat energy from place to place within the material. Solids, liquids, and gases all conduct heat. This process also passes heat between separate materials that touch. For example, conduction passes heat from hot tea to a spoon immersed in it. It is enough for grade 5 students to know that conduction is the transfer of heat energy within a material or between materials in direct contact. This lays groundwork for middle school and high school, when students learn about the particle theory of matter. At that time, they can better grasp conduction as mediated by molecules vibrating and colliding. It is not necessary to teach about conduction in these terms in grade 5.

Part 1 — Hot Nail

Materials

Materials for the whole class

- 1 copy per team of 3 of BLM 4, Heat Record Sheet
- 10 paper trays
- 1 hot pot
- 1 large thermos
- 20 4-oz foam cups
- 20 plastic lids for 4-oz foam cups
- 10 1-oz cup lids
- 10 8-oz foam cups (save these for a later activity)
- 20 nails
- 10 digital thermometers
- 2 dish pans

Materials for teams of 3 students

- 1 copy of BLM 4, Heat Record Sheet
- 1 nail to be handed out in Part B
- 1 8-oz foam cup to give out in Part B
- 1 additional cup half full of hot water to give out in Part B

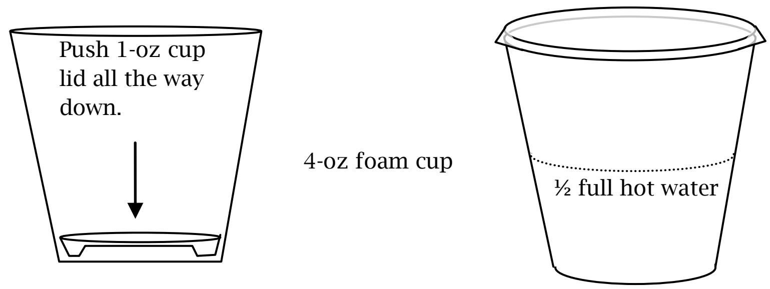
A paper tray containing the following:

- 1 4-oz foam cup with a 1-oz cup lid pressed to the bottom, ½ full of hot water
- 1 lid for a 4-oz foam cup (on the cup half full of hot water)
- one nail
- a digital thermometer

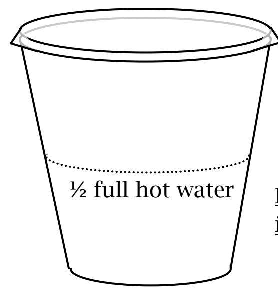
Preparation

1. Heat water 30 minutes before class. Pour 2 hot pots into the thermos (8-10 minutes per pot to heat). Adjust temperature in the thermos to about 130˚F (hotter can burn).
2. One per team, push a 1-oz cup lid to the bottom of a 4-oz foam cup (easier with open side of 1-oz lid up). The lid prevents the nail from puncturing the cup. Just before the activity, pour the cup half full of hot water and seal it with a 4-oz cup lid.

Preparation cont.



3. During Part B of this activity, each team needs another 4-oz cup half full of freshly-poured hot water, sealed with a lid. Do not prepare these additional cups at the beginning of the activity, but be ready to pour and cap them just before Part B of the procedure. Also, for Part B of this activity, have a larger foam cup and another nail available.



4. One per team, place on a paper tray 1 capped 4-oz cup half full of hot water, the nail, thermometer, and empty 8-oz foam cup. Place these where teams can get them.

Procedure Part A

1. Have teams get BLM 4, Heat Record Sheet, and the paper tray of materials. Ask everyone to turn thermometers on. Project BLM 1 to show everyone how to turn on the thermometer and set it to ˚F. Wait to read temperature until after the numbers begin to change very slowly. Project BLM 2 to show how to measure water temperature by sticking the thermometer through the lid. On BLM 2, point out measuring temperature with the edge of the angled thermometer point flat on the nail.

2. Ask teams to measure the temperatures of the nail and the water. The nail is sitting on the tray and has not yet touched the water. Ask them to use BLM 4, the Heat Record Sheet, to record these temperatures.

3. Explain that we will take temperatures of the nail head at set times, so everyone will start together when the teacher says "start."

4. When everyone is ready, start time, ask teams to gently push their nail point down through the hole in the 4-oz cup lid to the bottom of the cup, and call "start." Explain that you will call time after 30 seconds. At that time, everyone will record the temperature of their nail head in the blank on the Heat Record Sheet (BLM 4) marked "30 seconds." Continue to call time at 30 second intervals, asking teams to write the temperature in the appropriate blank. At 120 seconds, keep the timer running and ask teams to predict the nail head temperature and the temperature of the water at the 4 minute mark. Ask them to write these predictions on BLM 4. **While they do this, one per team, pour another**

Procedure Part A Cont.

small foam cup half full of hot water (next part of the activity).

5. At 4 minutes, ask students to record the nail head temperature and water temperature on BLM 4. Measure the nail temperature first, then remove the nail and push the thermometer tip through the cup lid hole to measure the water temperature. Compare these temperatures with predictions.

6. Discuss results with the class. Ask for ideas about how heat gets to the nail head. **Students might incorrectly guess that "heat rises." If they do, ask them how we could test this. The activity can be repeated with a cup upside down. If you do this, the results will be the same or warmer.** Ask teams to discard the water in their cups in a dishpan, and set the (now hot) nail aside.

Procedure Part B

1. Give each team an 8-oz foam cup, a new nail, and a 4-oz foam cup half full of hot water. Ask teams to cap their empty 4-oz foam cups with no water in them and stick the new nail into the lid of that empty cup. Project BLM 3 to show how to put the small cup with nail inside the larger cup. Ask teams to do this and separate the cups again. Explain that using this setup, hot water in the larger cup does not touch the nail in the small cup.

2. Ask teams to measure the temperature of the nail head. Also ask them to measure the temperature of the water in their 4-oz foam cup by sticking the thermometer probe through the lid into the hot water. Ask them to record these temperatures on BLM 4.

3. Draw out ideas from the class about how the temperature of the nail might change when the cup that it is in goes into the larger cup of hot water.

4. Ask teams to do the following all together. Pour the 4-oz foam cup of hot water into the large foam cup. Push the small cup with nail all the way down into the hot water. As soon as they do this call "start."

5. Call time at 30, 60, 90, and 120 seconds, and ask teams to record the temperature of their nail head on BLM 4 at these times. After teams record temperatures at 120 seconds, ask them to predict the nail and water temperatures at 4 minutes (240 seconds) on BLM 4.

6. Discuss differences between setups and results **(nail touching the hot water, and nail not touching it)**. At the 4 minute mark, ask students to record the nail and water temperatures at 4 minutes. **When this activity is over, save the 8-oz foam cups. They will be used in a later activity**.

Wrap-Up

1. Project BLM 5:
   - Where do you think heat at the head of the nail came from? What is your evidence for this?
   - How do you think the heat got to the tip of the nail?
2. Explain that, in Part A, the heat at the head of the nail came from the water by a process called "heat conduction." The heat moved because a place that is hot warms the place next to it. That place that just got warm, in turn,

Part 1 cont.

warms up the place next to it. Conduction "passes along" heat energy from place to place within a material. All materials conduct heat to some extent, but some materials conduct it better than others. This same process works between separate materials that touch. For example, the hot water passed its heat energy to the nail. Conduction is the transfer of heat energy within a material or between materials in direct contact. In Part B, heat was not transferred directly between the water and the nail because the nail did not touch the water.

Part 2 — Bridge Between Hot and Cold

Materials

Materials for the whole class

- 8 paper trays
- 2 ice cube trays
- 1 roll of heavy duty aluminum foil
- 1 hot pot
- 1 large thermos
- 16 4-oz foam cups
- 8 copies of BLM 6, *Bridge Between Hot and Cold*
- 16 digital thermometers
- 16 8oz foam cups to make into cup stands
- utility knife
- 1 half-gallon container (e.g. pitcher, milk bottle, etc.)*

*supplied by the teacher

Materials for groups of 4 students

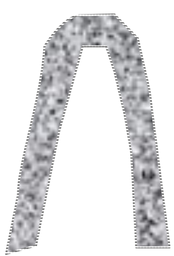
- 1 foot x 2 foot square of heavy duty aluminum foil

On a paper tray:

- 2 4-oz foam cups
- 2 foam cup stands
- 1 copy of BLM 6
- 2 digital thermometers

Preparation

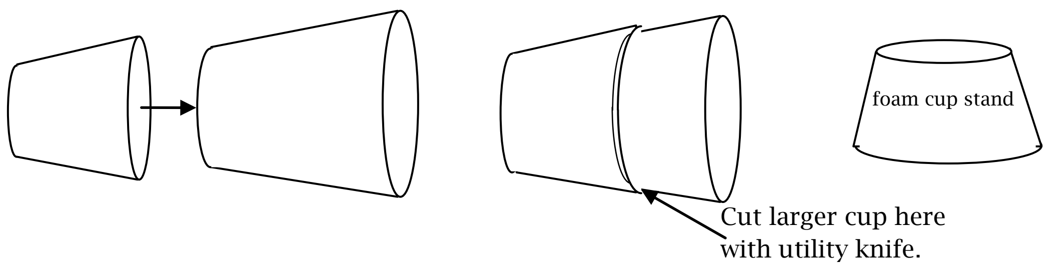
1. Before doing the activity, make a sample heat bridge from a 2' x 1' rectangle of foil folded down to 6" x 6." Fold and roll the 6" x 6" piece tightly into a 6" rod. Bend it to a U shape with legs about 2 ½ inches long. Leave half an inch across the top of the upside-down "U." Show this when students make their heat bridges. It looks like this:



Preparation Cont.

2. Before the activity, make trays of ice, fill a pitcher or jug with it, and top off with water. Remove the ice just before the activity, (ice in cups ruins results).

3. Before the activity, make 16 cup stands. Place a 4-oz foam cup over the bottom of an 8-oz foam cup. Cut around the large cup with a knife where the mouth of the small cup touches it.



4. On the day of the activity, 30 minutes before class, heat water to ≈ 130-140˚F in the hot pot and pour it in the thermos. Water cooler than 130˚F produces small results and water hotter than 140˚F can scald. (5 seconds of exposure at 140˚F can cause a mild burn.) Make 2 pots of hot water and put them in the thermos. A pot takes 8 minutes to heat.

5. On the day of the activity, have two cups (no bridge in these) and two thermometers ready to use for the control cups.

6. On the day of the activity, place the students' heat bridges (made the previous class period), cups, and thermometers on the paper trays. Have one copy of BLM 6 per team.

Procedure

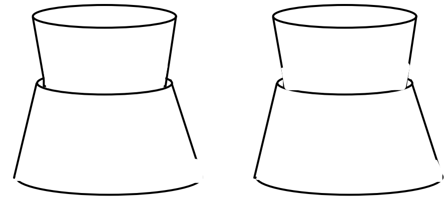
1. The class period before the activity, have students make their "heat bridges." Have your sample and a square of foil ready to demonstrate. Set up teams of 4 and give out 1" x 2" foil sheets. Show the class your U-shaped piece of foil and show them how to fold the square of foil, roll it, flatten it, and shape it. Allow 5 minutes for them to make the foil bridges. Collect these for use in the next class period.

2. On the day of the activity, allow teams to get the paper trays of materials and a copy of BLM 6, *Bridge Between Hot and Cold*. Point out the setup shown on BLM 6.

3. Procedure for Reading and Recording Temperature: Review how to read thermometers by waiting until the reading changes slowly (can take up to 15 seconds). Explain that they will leave the thermometers in the cups, and to get accurate readings, they will swirl the thermometer tip to mix areas of hot and cold in the cups before each reading.

Procedure Cont.

4. Ask teams to put the cups in the foam cup stands to prepare for you to fill them. The cup stands prevent the cups from tipping over when thermometers are placed in them. The 4-oz foam ups in the stands look like this:



5. Circulate to fill the teams' hot and cold cups. To fill cups quickly, ask a helper to pour the cold water. After all cups are full, point out where to enter readings on BLM 6, then ask teams to record the hot and cold cup start temperatures. Ask teams to get their foil bridges and thermometers ready.

6. START When teams have recorded starting temperatures and have foil bridges ready, ask them to connect the two cups with the foil bridge, put the thermometers in, call start, and start the timer. (Teacher Only) Pour the hot and cold control cups (nothing connecting them), swirl with the thermometers, and record their starting temperatures. Leave thermometers in these cups. There is no need to call students' attention to control cups until after teams record final temperatures.

7. At 2 minutes, 4 minutes, 6 minutes, and 8 minutes, call time and ask students to swirl the thermometer tips and record temperatures on BLM 6 when the readings stop rapidly changing.

8. At the 8 minute reading, the teacher records the final temperatures of the water in the control cups, but does not call students' attention to it yet. After the 8 minute reading, ask teams to record the temperature change for both cups over the 8 minute time span (the difference between the start temperature and the 8 minute temperature).

9. Ask teams to report out their start and end temperatures, and write these for all to see. Explain that you have set up two cups with no piece of foil connecting them, and you poured the same hot and cold water in these when everyone began 8 minutes ago. Read out the start temperatures for both cups. Point out the place under "CONTROL CUPS" where they can record these. Ask for predictions of what students think the final temperatures in these cups were, and why. Read out the final temperatures you recorded and ask students to enter them in the appropriate blanks on BLM 6. Also ask them to calculate the temperature changes for both control cups.

10. Ask teams to answer the two questions at the bottom of BLM 6 *as a team*. The whole team must try to agree on answers.

11. Leave the setups undisturbed (they will be used in the wrap-up).

Wrap-Up

1. Ask students to try to explain the movement of heat energy through the whole system. Students who explain it most clearly will explain something like the following: Hot water touching the foil passed heat energy to the foil. The foil passed heat energy from place to place within itself (just like the nail in the previous activity). The hot foil touched the cold water and conducted heat energy to it. Heat energy can transfer between different materials that are touching.

Procedure Cont.

2. Ask students for evidence that heat energy passed between the cups through the foil.
   - Hot water touching the foil passed heat energy to the foil. Our only evidence for this was that the foil did not feel hot when we put it in the water. Evidence from measurement could have been obtained by measuring the temperature of the foil before it went into the hot water, but we did not do this.
   - The foil conducted heat along itself just like the nail. If someone felt the foil after taking it out of the setup, one side was hot and the other side cold. That would be consistent with heat conduction. On the top of the bridge, the foil might show gradual difference in temperature as you move along it, but we did not measure temperatures there.
   - The foil conducted heat to the cold water. We have evidence to support this. The cold water heated up more with foil connecting it to hot water than in the control cups where there was no foil connection. The difference between all the teams' setups and the control is consistent with the foil conducting heat from the hot to cold water.
3. Project BLM 7. Ask students to predict in their notebooks the temperatures at points A, B, and C, then measure the temperatures at those places. Discuss results in terms of heat conduction. Save the cup stands for the next activity.

Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks.

1. I notice that when I use a hot pad to hold a pan cooking pancakes over a stove, the hot pad gets warm after awhile. I wonder how the warmth in the hot pad gets to my hand. Select the best explanation below.

   A. The heat energy comes from the stove under the pan. The pan conducts the heat energy to the pan handle. When I hold the handle with the hot pad, the hot pad conducts some of the heat energy to my hand so that I can feel some warmth.

   B. The heat energy comes from the stove. The heat moves from the stove through the air and into my arm. The heat is conducted down my arm and into the hot pad from my hand. After awhile, heat builds up in the hot pad and I can feel it.

   C. The heat is only from my hand. Heat energy from the stove cannot move through the metal pan into the hot pad. Heat energy can only be conducted inside of a material, not between materials.

2. Jan put her glass of iced tea down on a metal table that had gotten hot in the sun. Her friend, Wilyetta, held her iced tea in a foam drink holder. A few minutes later, Jan's ice was melted, but Wilyetta still had plenty of ice. Select the best explanation below.

   A. Because heat rises, the heat energy from the table rose up into Jan's drink. If the drink had been touching the underside of the table, even if the table was hot, the drink would have stayed cold. Some of the heat

Procedure Cont.

from her drink would have gone up into the table, making the drink a little cooler.

B. The cold from the drink went out into the table, and the drink lost so much coldness that the ice melted. The hot table attracted the coldness. It also attracted the coldness from Wilyetta's drink. Wilyetta's drink also lost some cold even though it did not touch the table, but not enough for the ice to melt.

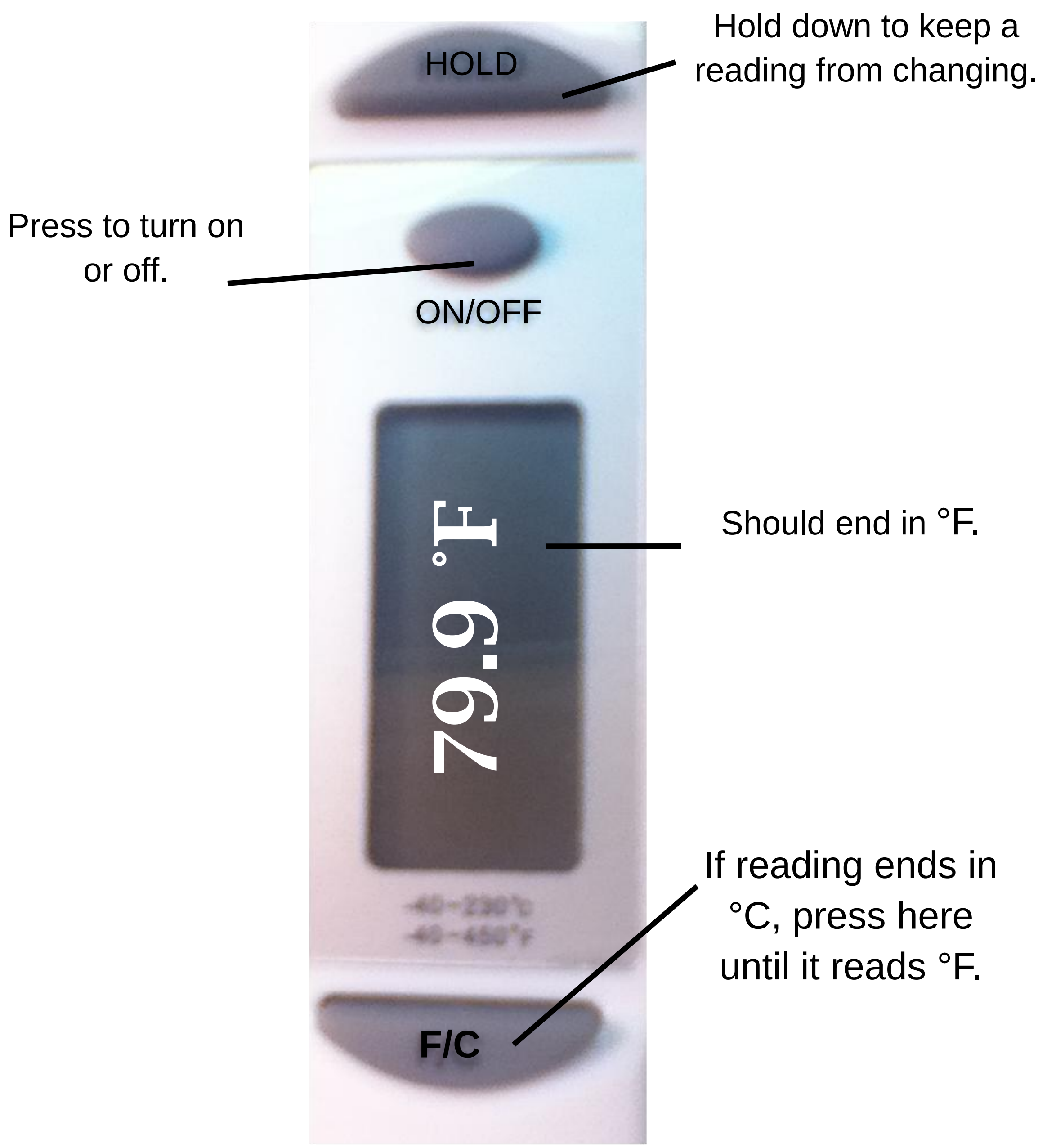
C. Heat energy in the metal table warmed up the outside of the glass where the hot table touched it. After awhile, the heat energy warmed the glass all the way through. The warm glass passed the heat energy to the drink inside it. The drink passed the heat energy to the ice. The heat energy melted the ice.

Answer Key

1. A is correct. B is not entirely wrong because some heat does move from the stove into the air, and some of that could move into someone's arm. If you hold a piece of cloth for a long time, it's possible to feel body heat build up in it. However, all of that would be very small in comparison with heat being conducted from the pan handle. C is not correct because heat energy can move from the stove through the metal pan, and it can be conducted between different materials.

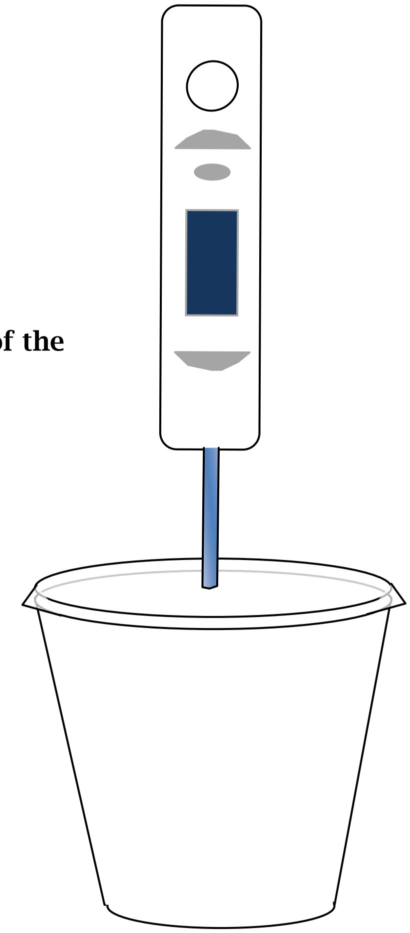
2. A is incorrect. Heat rising is a result of convection in gases or liquids. It does not happen in solids, such as a glass. The heat from the glass would not rise up into the table. B is incorrect because "coldness" is not a substance that moves around or is attracted. For Wilyetta's drink to warm by conduction, her glass must contact something warm. C is correct.

BLM 1 the Digital Thermometer

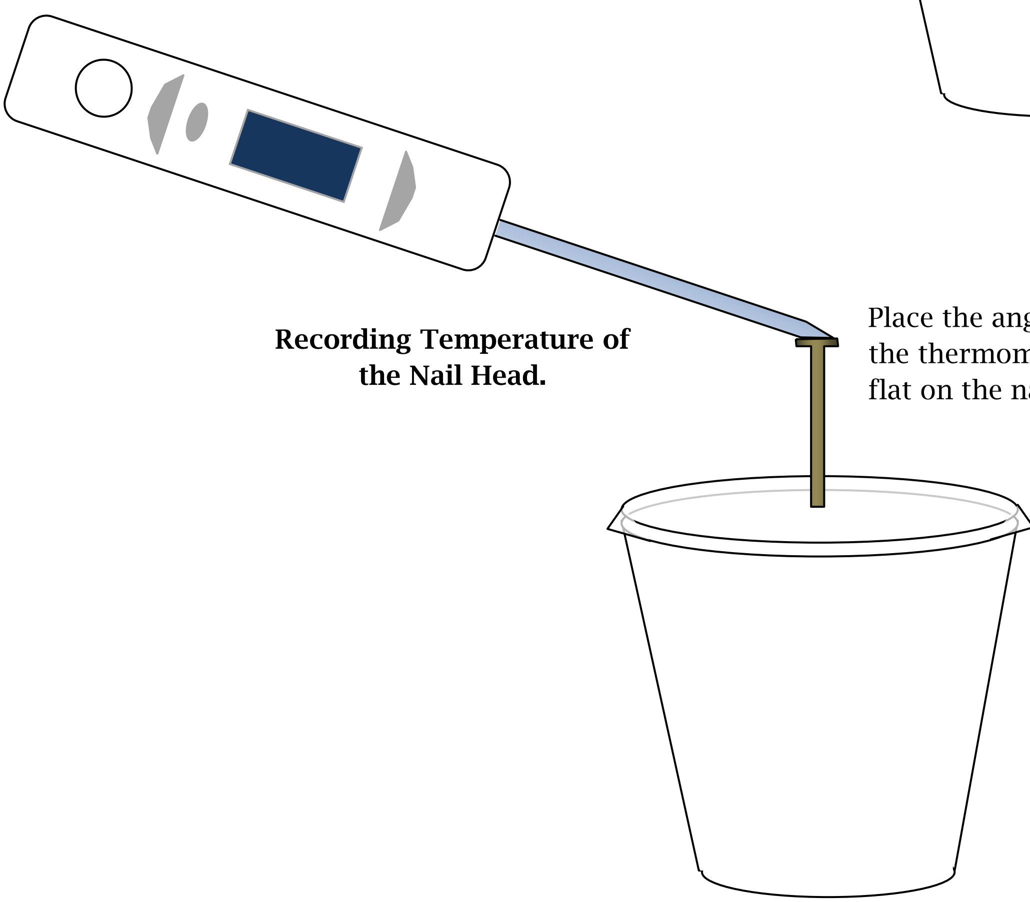


BLM 2

Recording Temperature of the Hot Water.

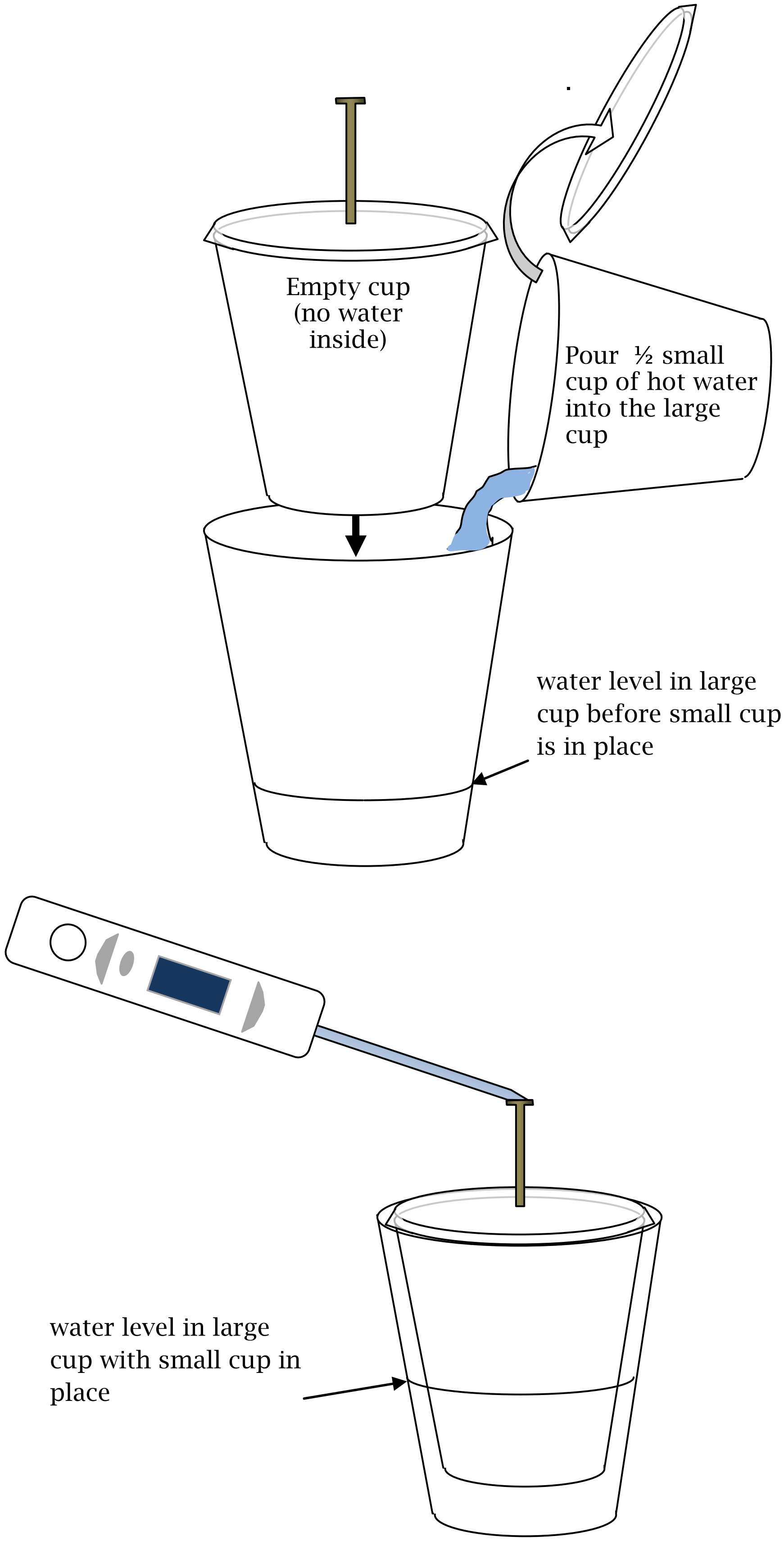


Recording Temperature of the Nail Head.



Place the angled side of the thermometer point flat on the nail head.

BLM 3 Setup for Hot Water that Does Not Touch the Nail



BLM 4 Heat Record Sheet

CUP WITH THE NAIL IN HOT WATER

Temperature of the nail head before it went into the cup ________˚F

Starting temperature of water in the cup________˚F

nail head temperature at 30 seconds______˚F

nail head temperature at 60 seconds______˚F

nail head temperature at 90 seconds______˚F

nail head temperature at 120 seconds__________˚F

nail head temperature at 240 seconds **predicted**______˚F **actual**________˚F

water temperature at 240 seconds **predicted**________˚F **actual**________˚F

CUPS WITH HOT WATER THAT THE NAIL DOES NOT TOUCH

Starting temperature of water in the cup________˚F

Temperature of the nail head before it went into the cup ________˚F

nail head temperature at 30 seconds______˚F

nail head temperature at 60 seconds______˚F

nail head temperature at 90 seconds______˚F

nail head temperature at 120 seconds__________˚F

water temperature after 120 seconds______˚F

nail head temperature at 240 seconds **predicted**______˚F **actual**________˚F

water temperature at 240 seconds **predicted**________˚F **actual**________˚F

Questions:

Where do you think the heat that warmed up the nail head came from?

____

____

How do you think the heat got to the head of the nail?

____

____

____

____

____

____

BLM 5

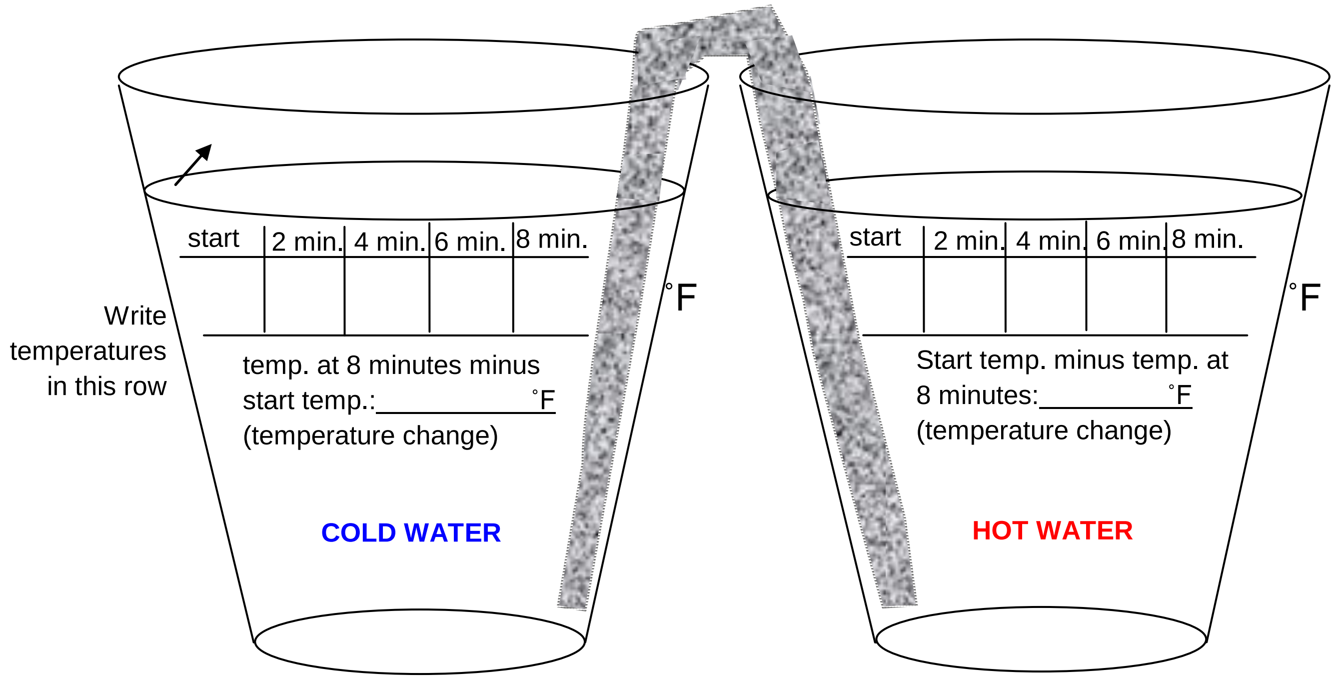
Each Team must agree on answers to these questions

- Where do you think the heat on the tip of the nail came from? What is your evidence for this?

- How do you think the heat got to the tip of the nail?

BLM 6 Bridge Between Hot and Cold

YOUR CUPS



CONTROL CUPS

Starting Temperature of the **cold** Control Cup__________________________

Starting Temperature of the **hot** Control Cup___________________________

Temperature of the **cold** Control Cup **after 8 minutes**___________________

Temperature of the **hot** Control Cup **after 8 minutes**____________________

Temperature change of the **cold** Control Cup **after 8 minutes**___________

Temperature change of the **hot** Control Cup **after 8 minutes**____________

Give reasons that you think might explain changes in temperature in the cups connected by the foil:

____

____

____

____

After 8 minutes, temperatures in the cups that were connected by foil changed differently from the cups that were not connected. Calculate the differences and give reasons that you think might explain them:____

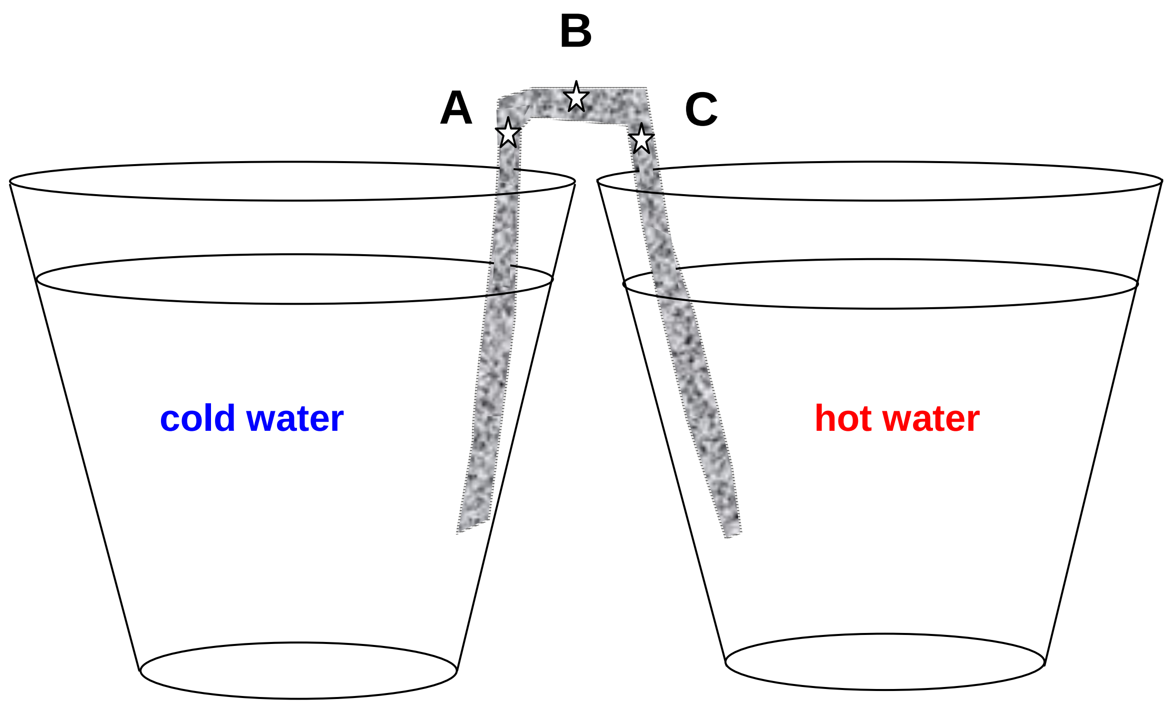
____

____

____

____

BLM 7



Predict the temperatures at points A, B, and C in the diagram above. Give reasons for each prediction.

After you predict, measure and record actual temperatures at these places.

Point	Predicted Temperature	Actual Temperature	Reason for Prediction
A	˚F	˚F	
B	˚F	˚F	
C	˚F	˚F	

Appendix

Common Student Preconceptions About This Topic

Many students imagine heat as a substance that can flow into and out of objects, rather than as energy that is transferred. Many also think that cold is a substance that flows in the same way, like a fluid, but is the opposite of heat. This is also a common and natural conception among adults. When someone opens a door on a cold winter day, people very reasonably say, "Don't let the cold in!" 5th grade students might understand the examples in this activity as a "hotness material" or "coldness material" flowing through things. This is much the way early scientists understood heat, as fire-like elements contained in matter called "phlogiston" or "caloric." Even after students grasp the particle theory of matter later on in middle grades and high school, there is little in the way of concrete experience to shift the concept of heat as a substance. Explanations of heat transfer as invisible abstractions such as molecules, atoms, electrons, vibration, collisions, and kinetic energy are unlikely to clarify understanding. At grade 5, it is enough for students to understand that energy in the form of heat can transfer through materials in different ways, depending on the material. They can also understand that some materials transfer heat more efficiently than others.

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

In this 1-2 day activity, students use drops of dye to explore currents in two trays of water. One tray is subjected to heat and cold at opposite ends, and the other is of uniform temperature throughout. Students first compare the behavior of dye drops in the hot end of the unevenly-heated tray with the behavior of dye at one end of the uniform temperature tray. Afterward, they predict the behavior of dye at the cold end and try it, and make detailed observations. Finally, they predict how different colored dyes at the hot and cold ends will move in relation to one another, try it, and make more observations. The teacher wraps up the activity by introducing the terms "convection" and "current." At this point, the idea that the dye is tracing currents in the water is reinforced. Students then conduct a culminating activity that relates these terms to uneven heating, mixing, and the movement of heat through water.

Objectives

Students work with the following ideas and content:

- Heat and cold (different temperatures) in a fluid cause the fluid to move and mix.
- Heat makes some of the fluid rise.
- Cold makes some of the fluid sink.

Students demonstrate understanding of these ideas by:

- Predicting the motion of fluids subjected to heating and cooling,
- Explaining that for fluids to move in response to heat, different areas of the fluid must be at different temperatures.

Correlations to NC Science Standards

5.P.3.1 Explain the effects of the transfer of heat (either by direct contact or at a distance) that occurs between objects at different temperatures. (conduction, convection or radiation).

Brief Science Background

Convection is all around us. It is the evening breeze, ocean currents, and steam rising over a stove. Any time a liquid or gas is heated more in one place than in another, convection causes currents that move the heat around in it. The reason for convection is not appropriate to teach to fifth graders. However, (for teacher background only) it happens because a liquid or gas takes up more space when it is warmed, and it takes up less space when cooled. Whether warm or cool, the liquid or gas still weighs the same, but heating or cooling makes it expand or contract. The not-so-obvious result is that the stuff that takes up more space rises and the stuff that takes up less space sinks, even though its weight is unchanged. It's like what happens when you shake up a jar containing large and small beans. Even if all the beans weigh the same, the large ones move toward the top and the small ones move toward the bottom. As things rise and sink, they produce currents. We experience those currents in the air as a breeze, or as smoke rising above a fire. In the Atlantic Ocean, we experience convection currents as the Gulf Stream flowing past the Eastern Seaboard.

Materials

Materials for the whole class or the teacher

- 24 deli trays (4” x 6”)
- 16 small foam cups
- a permanent marker
- 2 dishpans
- 8 32-oz plastic containers
- a hotpot
- a thermos
- two ice cube trays
- two dye dropper bottles, one red and one blue
- 8 digital thermometers
- (optional) white paper

Materials for groups of 4 students

- three 4 x 6 deli trays containing room temperature water
- one small foam cup labeled “C” containing ice water
- one empty small foam cup labeled “H”
- a digital thermometer

Preparation

1. A day before the activity, set out the eight 32-oz containers filled with water to come to room temperature. Have these available on the day of the activity for students to replenish water in their trays. Also, fill the ice trays and freeze them.
2. On the day of the activity, fill two trays for each team with room temperature water to the shoulder of the tray (about ¼ inch from the top).
3. On the day of the activity, heat water in the hotpot, pour it into the thermos, and adjust the temperature to about 130° F. Three full hotpots fill the thermos. During the activity, you will pour hot water from the thermos into the small foam cups at each team’s station.
4. Place the two dishpans where teams have access and a little spillage will do no harm. Teams dispose of used water in these between parts of the activity.
5. Use the permanent marker to label small foam cups “C” and “H,” one each per team. Just before the activity, fill the “C” cups with ice and add water to the brim so that ice protrudes above the lip. Place these full ice water cups and the empty “H” cups in the empty trays as shown in BLM 1.
6. Set up the student workspaces (see materials for groups of 4 above and the diagram under procedure below) with both trays of room temperature water on the table top. Students see results more easily when the setup is over a white background. If your tables are dark, put white paper under the setup.

Preparation cont.

7. Set up the student workspaces (see materials for groups of 4 above and the diagram under procedure below) with both trays of room temperature water on the table top. **Results are clearer over a white background. Place white paper under setups if tables are dark.**

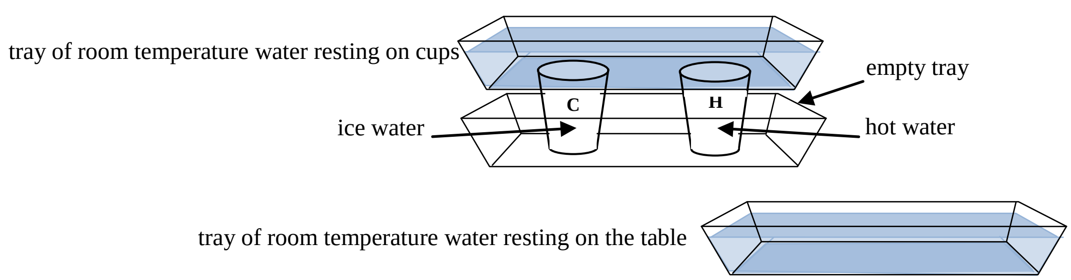
Procedure

1. Explain that each team will explore what happens to drops of dye placed in two different trays of water. Ask them to carefully observe both trays and to especially note what is different about the two trays.

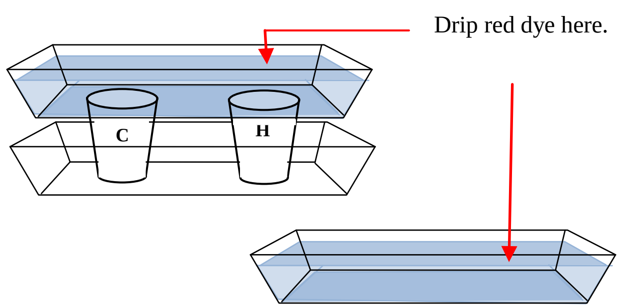
2. Show how to turn on thermometers and set them to ˚F (˚F provides a finer measure). Explain that if thermometers automatically turn off, to just turn them back on. Ask students to measure and record water temperature in both trays.

3. Circulate around the room to pour hot water into the cups labeled H. **Pour to near the top but not to the brim. In contrast, the cold cup labeled C should be full to the brim with water containing ice so that some ice protrudes above the top of the cup. You might need to add a little water to the cold cup.** Ask students to record water temperatures in both cups (H and C) and record these in their notebooks as "beginning temperature H" and "beginning temperature C."

4. Project BLM 1 and ask students to set up their stations as in the diagram. **When teams place the tray of room temperature water on the cups, a little water should spill from the cold cup into the empty tray below. Ice in the cup should touch the tray resting above it.** After this, ask teams to let the setup rest undisturbed for 2 minutes. Ask them not to touch the table or the setup throughout the activity. While setups rest, ask students to predict (as class discussion) what they think will happen when you drip dye in over the cup labeled H.



5. After setups settle, circulate among teams with the red dye dropper to add 3 drops of dye to the tray of water resting on the cups. Drip near the surface but not touching, <u>directly over the center of the "H" cup</u>. In the tray on the table top, drip the dye <u>at the same relative location</u>.



Procedure Cont.

Allow about 3-4 minutes to observe the movement of the dye. When teams finish observing, ask them to respond to the following notebook prompt.

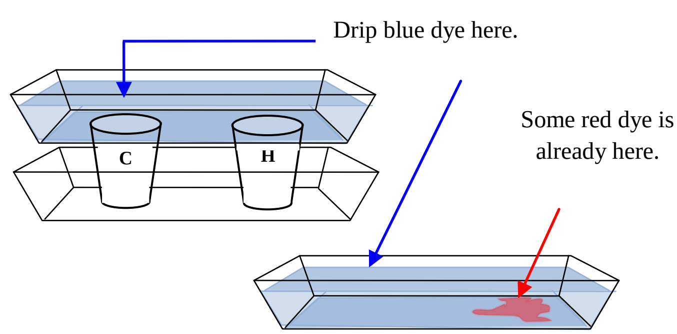
Notebook Prompt: Describe how the dye moves in both trays and compare them. Include a sketch of the pattern of dye in both trays.

6. Conduct a whole-class discussion to bring out observations about differences in the pattern of dye in the two trays. Ask students to speculate about reasons for the differences. **Accept all ideas. Do not correct misconceptions or teach about convection now.**

7. Explain that the class will repeat what we have just done, only this time, add dye over the middle of the "C" (ice water) cup and on the other side of the tray on the table top. Hold a class discussion about what students think they will see both trays. Get as many predictions as possible.

8. Ask students to leave the tray on the table top in place, and carefully take the tray that is resting on the cups, empty it in one of the dishpans, and refill it from one of the 32-oz room temperature water containers. Ask them to measure the temperature of the refilled tray, then place it on the cups as before. Ask them to let the tray rest for 2 minutes.

9. As teams are ready, circulate with the blue dye dropper to drip 3 drops into trays resting on the cups directly over the center of the "C" ice water cup. Also drip 3 drops at the same relative location in the tray on the table top. Ask students to observe for 3 minutes.



10. Hold a class discussion and ask the following:

- Describe how the blue dye moved in both trays.
- How do results compare to our predictions?
- How might you explain the movement of the blue dye?

11. Ask students to leave the tray on the table top untouched (now with blue and red blobs at opposite ends). Ask teams to empty the tray that was sitting on the cups, and replace the water with clean room temperature water as before. Ask them to put the refilled tray back in place on the cups again.

12. Explain that we saw how dye moved from the hot and cold cups separately. Ask the class what they expect to see if we put dye over both cups at the same time? Bring out ideas. Some students might need to draw on the board, or have you draw for them.

Procedure Cont.

13. Circulate among the teams with both dye dropper bottles and drip 3 drops of red over the "H" cups and 3 drops of blue over the "C" cups. Since there is already dye at both ends of the tray on the table top, no more dye needs to be added to that tray. Ask students to observe. After they have observed for 3-4 minutes, give out BLM 2, project the notebook prompt, and ask students to respond to it.

    Notebook Prompt: Describe the movement of the red and blue dye. Give possible reasons for what you saw. Use the handout to draw how the dye moved.

14. When students finish describing and drawing, ask where the most mixing occurred, and why they think this might be.
15. Ask teams to measure temperature of the bottom of the tray directly over the center of the C cup, the H cup, and midway between them, and record all three temperatures in their notebooks.
16. Ask teams to remove the tray from the cups, set it aside, measure water temperature inside the C and H cups, and record these labeled as "final temperature H" and "final temperature C."

Content Wrap-Up

1. Ask students to explain their ideas about the function of the dye. Ask students for temperatures they measured in the tray over the cups. The two colors followed the movement of different temperatures of water. Explain that we call water or air that is moving in the same direction a "current." The dye traced currents. Ask students for places they have come across currents (e.g. a stream, the beach, or air currents in a house from HVAC). Write "current" for all to see, and ask students to write it, and define it in their own words in their notebooks.
2. Remind everyone of class discussions about the currents in the trays. Recall discussion points about heat and cold making currents. Explain that currents in water or air caused by one place being warmer than another are called "convection" currents. Write this term for all to see, and ask students to define it in their own words in their notebooks. Ask what direction the currents moved (both vertically and horizontally).
3. Ask students to calculate the change in water temperature in the H and C cups from beginning to final (with a plus for increase and minus for decrease). You might need to tell them to subtract the final from the beginning temperatures that they have recorded. Put results up for all to see. In general, all of the H cups lost temperature, and all of the C cups gained. Explain that convection currents move heat from hot places to cool ones. The current moved heat from the hot cup to the cold one.

Notebook Prompts:

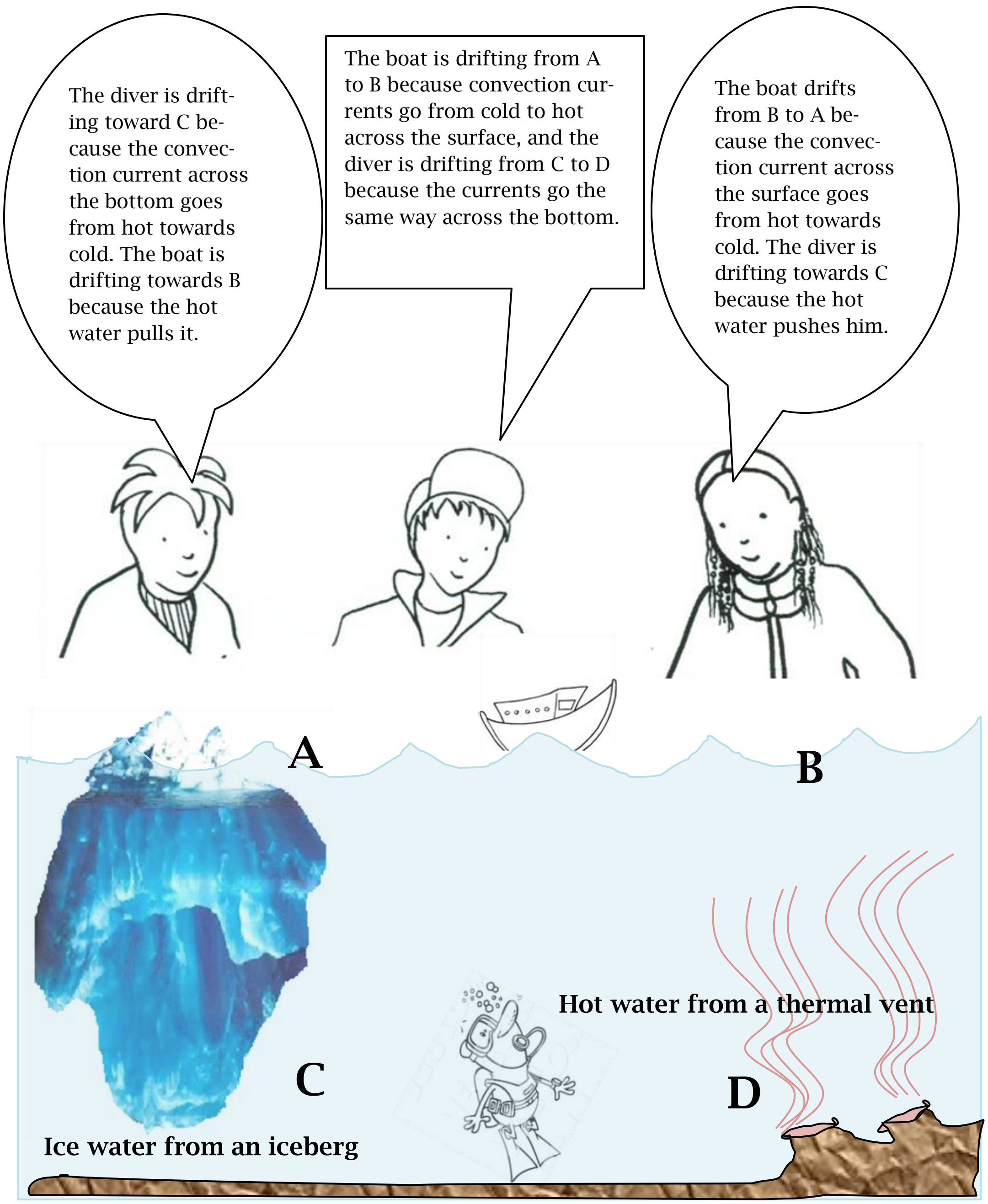
- A new student has come into the class, and you are trying to catch that person up on what's been going on. Explain what we have done and use the terms "current" and "convection" to describe what you saw. Also describe how heat moved.

- Describe any changes that you think would occur if the blue dye was placed in the tray of room temperature water above the hot H cup and the red dye was placed above the cold C cup (opposite the way we did it).

Guided Practice

Project BLM3, the concept cartoon, for all to see. Ask students to choose a character they disagree with (or partially disagree with) and explain what is wrong with that character's reasoning.

In the scene below, the scuba diver is too tired to swim, and the boat is out of gas. Only the currents in the ocean are moving them. Hot water from the sea floor and ice water from the iceberg are making the currents in this part of the ocean. Which directions are the boat and diver drifting, and why?

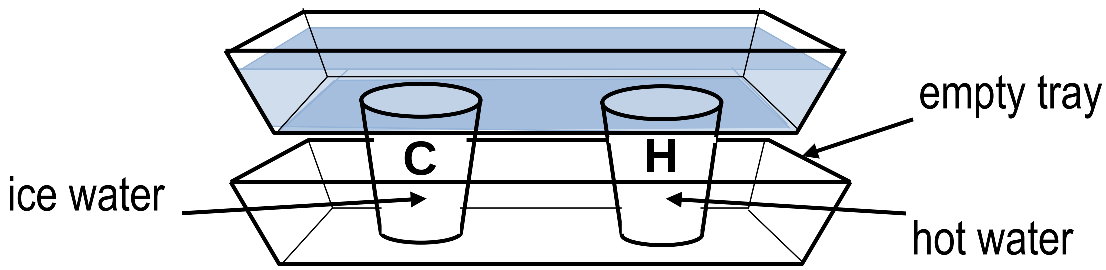


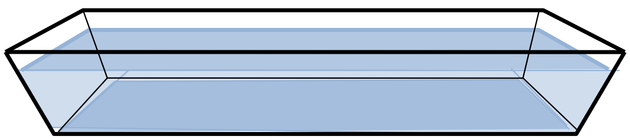
Answer Key

- The boy with no hat says the diver is drifting toward the iceberg. The convection current moves from the thermal vents across the surface of the water toward the iceberg, and then from the iceberg toward the thermal vents across the bottom. The diver would be drifting toward the thermal vents, not away from them.
- The boy in the baseball cap is correct about the direction the diver drifts. The convection current moves across the bottom from the iceberg toward the thermal vents, making the diver drift toward the thermal vents. However, the currents do not move the same way across the bottom and the surface. Contrary to what he says about the current on the surface, it would move toward the iceberg, pushing the boat from B to A.
- The girl correctly says the boat would drift from B to A because convection currents would move from the thermal vents toward the iceberg. However, she says that the diver would drift toward C. Contrary to what she says, the diver would drift toward D because the convection current moves across the bottom from the iceberg toward the thermal vents.

BLM 1

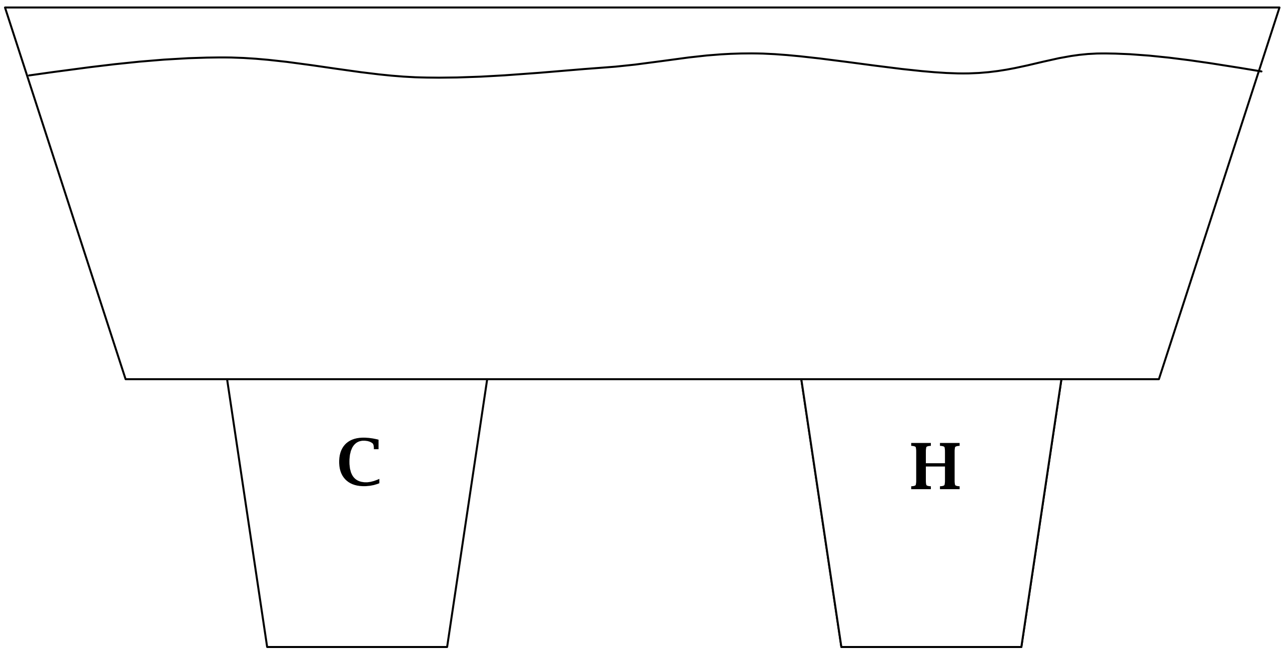
tray of room temperature water resting on the cups

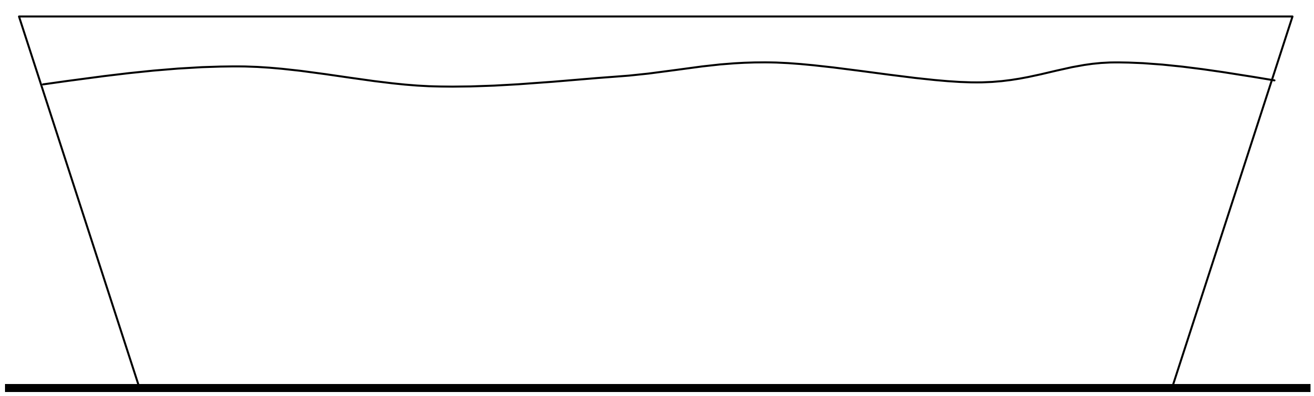




tray of room temperature water resting on the table

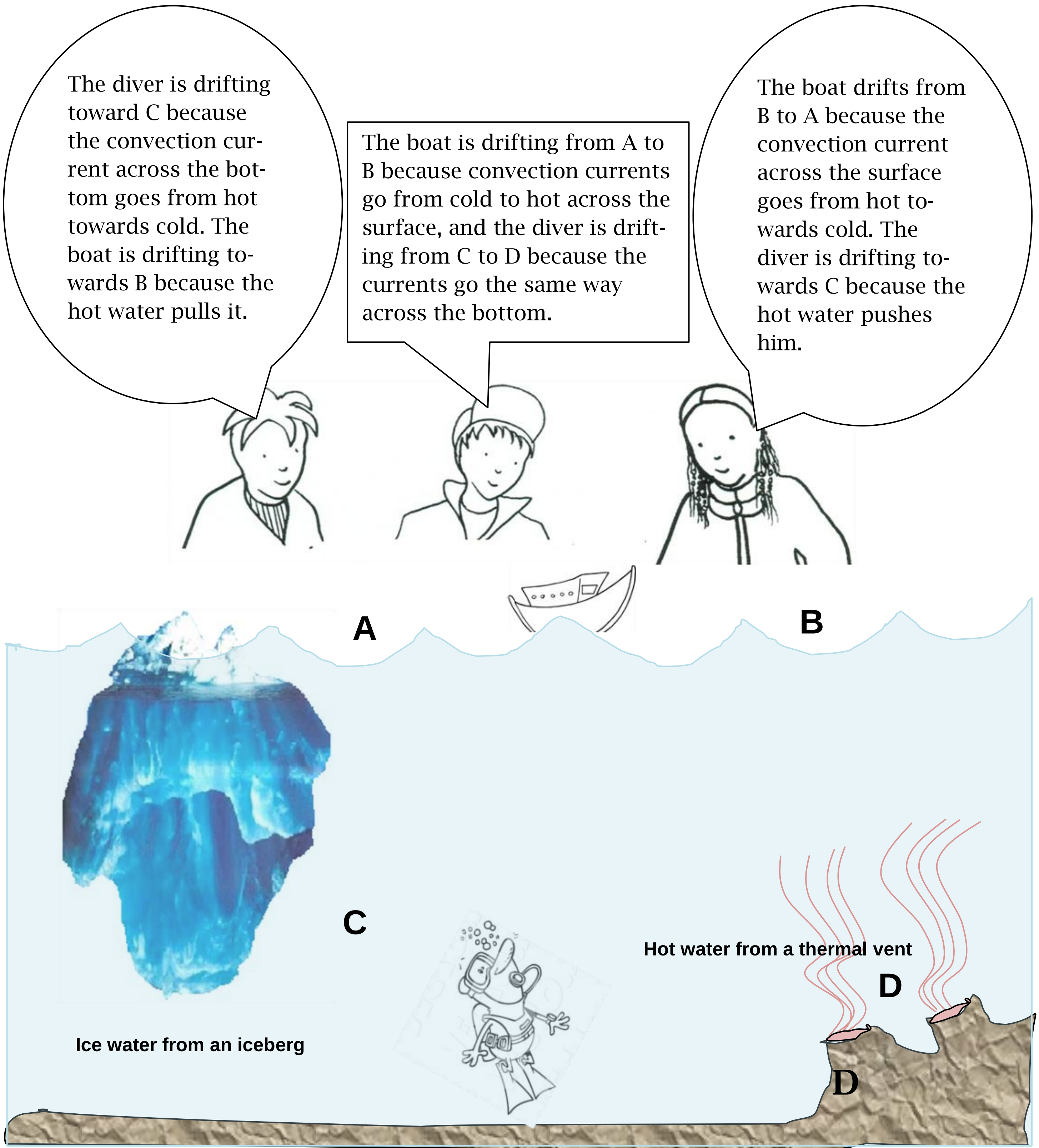
BLM 2





BLM 3 Concept Cartoon

In the scene below, the scuba diver is too tired to swim and the boat is out of gas. They are drifting in the currents. Hot water from the sea floor and ice water from the iceberg are making the currents in this part of the ocean. Which directions are the boat and diver drifting, and why?



Appendix

Common Student Preconceptions About This Topic

Children are familiar with the idea that “heat rises,” but they think of heat as a material that rises, not of a heated gas or fluid becoming buoyant in its surroundings. As a result, they tend to reduce the idea of convection to “heat rises.” Fewer students are familiar with the idea that cooler areas tend to sink. If they are aware of this, they are likely to think of cold as a material that is the opposite of heat. At fifth grade, without a grasp of the particle theory of matter, students are not well equipped to understand how heating and cooling materials decreases and increases density (mass stays the same while volume changes). Even if students know this as a fact, it is difficult to explain the forces that cause floating and sinking to drive convection. It is more appropriate for 5^{th} grade students to understand that different amounts of heat at different places in a fluid or gas generate specific, predictable currents in that material. They might also understand that convection currents distribute heat around the gas or fluid.

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

In this 1-day activity, students compare temperature changes in direct sunlight with temperature changes in shade. In general, students record a difference of about 10 degrees as a result of radiant heat from the sun. Next, students receive a porous material that blocks some sunlight and lets some sunlight through. Their challenge is to use measurements of temperature change to determine how much of the direct sunlight this material blocks.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- Heat energy can move from one place to another through space.
- The amount of radiation affects the amount of heat transferred.

Students demonstrate this knowledge and understanding by...

- comparing temperatures at the same time and location in the sun and in the shade,

Correlations to NC Science Standards

5.P.3.1 Explain the effects of the transfer of heat (either by direct contact or at a distance) that occurs between objects at different temperatures (conduction, convection or radiation).

Correlations to Common Core Mathematics Standards

The second part of the Grade 5 section of the Common Core Mathematics Standards explains: (2) Students develop understanding of why division procedures work based on the meaning of base-ten numerals and properties of operations. They finalize fluency with multi-digit addition, subtraction, multiplication, and division. They apply their understandings of models for decimals, decimal notation, and properties of operations to add and subtract decimals to hundredths. They develop fluency in these computations, and make reasonable estimates of their results. Students use the relationship between decimals and fractions, as well as the relationship between finite decimals and whole numbers (i.e., a finite decimal multiplied by an appropriate power of 10 is a whole number), to understand and explain why the procedures for multiplying and dividing finite decimals make sense. They compute products and quotients of decimals to hundredths efficiently and accurately.

Brief Science Background

Heat can move away from hot objects through space, by radiation. Heat comes to earth from the sun in this way. Radiant heat travels in a straight line, just as light does, and is said to “radiate.” Where heat radiation strikes, it raises the temperature of the material that absorbs it. A solid opaque object can block radiant heat in the same way that it blocks light. This is why it is cooler in the shade. Radiant heat warms the areas in sunlight and temperatures are cooler in the shade because radiant heat is blocked. We feel radiant heat at a distance, without touching its source and without warm air moving it. For example, we feel warmth on our skin when standing at a distance from a stove or a fire. We feel this without a breeze blowing warm air toward us and without making

Part 1 — Restless Heat –50 minutes

contact with the stove or fire. This heat travels by means of radiation. It is also possible to partially block radiant heat. For example, gardeners can buy 50% shade cloth, or 70% shade cloth to put over plants that need less sun .

Materials

Materials for the whole class

- 16 digital thermometers
- BLM 1 to project (to explain how to use the thermometer)
- copies of BLM 2, Heat Shadow Record sheet, one per pair
- coffee filters
- black construction paper

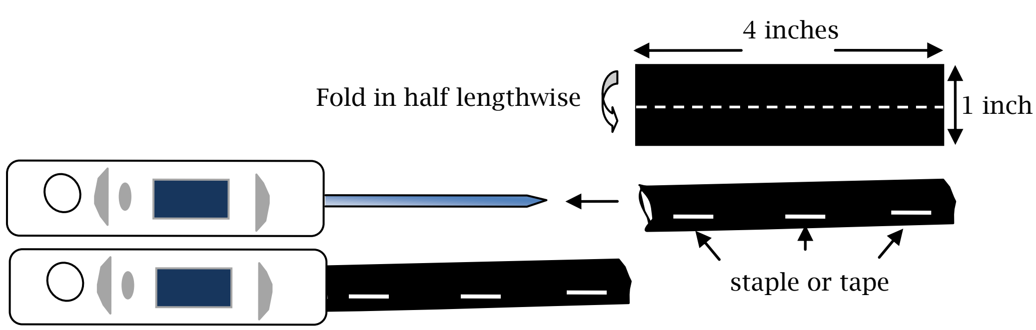
Materials for pairs of students

- BLM 2, Heat Shadow Record Sheet
- 1 coffee filter
- a digital thermometer
- a black paper sleeve
- a notebook or folder to use as shade *

* supplied by students or teacher

Preparation

1. This activity is done outdoors. Choose a clear cool day to do this if possible. Clouds skew readings if they cross the sun while students are measuring temperature. Cooler days produce slightly better results, but the activity also works on a hot day.
2. The activity can work outdoors over any surface, but it works best over grass away from buildings and cars. Hot air from sun-heated pavement, concrete, walls, or vehicles raises shade temperatures.
3. Copy a BLM 2 for every 2 teams and cut copies in half (2 sheets per copy).
4. Students need black paper sleeves to cover the thermometer probes. The sleeves reduce variations in temperature caused by breezes, and they increase the temperature range between sun and shade. Either the teacher or students can cut 1" x 4" pieces of black paper, one per team. Fold the paper in half lengthwise, and staple or tape it. There is no need to close the end.



CIBL

Procedure

1. Before going outdoors, ask teams to put the sleeve over the thermometer probe and keep them there. Ask teams to turn on thermometers and set them to ˚F. BLM 1 helps to explain how to operate thermometers. Be sure every team has BLM 2 for recording and that everyone has a notebook to shade the thermometer (a sheet of paper is not enough).

2. Before teams move into the sun, say that they need to keep thermometers in direct sun the whole time. Try to move move into the sun at the same time. When they are in the sun, immediately start timing. After 2 minutes, call time. Ask everyone to record the temperature on BLM 2.

3. After teams record the temperature in the sun, ask them to shade their thermometers with a notebook on your mark. Call start and after 2 minutes call time. Ask teams to record the shade temperature on BLM 2.

4. Bring the class inside and ask teams to calculate the difference between shade and sun temperatures. Put everyone's results up for all to see. The difference will be between 6-12 degrees depending on the day.

5. Ask these questions. **Accept all answers. Avoid teaching about radiant heat at this time.**
   - Where does the heat come from that warms the thermometer in the sun?
   - Speculate how heat gets from where it originates to the thermometer.
   - Without sun shining on the shaded thermometer, where does the heat come from to warm it?

6. Ask teams to get coffee filters, look at light through them, and describe what they notice. Ask how much light they think the paper blocks. Hold a brief discussion about possible relationships between amount of light blocked and amount of cooling shade provided. **Accept all ideas.** Ask teams to record on BLM 2 a prediction of temperature in the shade of a coffee filter after 2 minutes. Ask teams to agree on and be able to explain their reasons.

7. Take the class back out and use the same procedure as before to measure the temperature in the shade of the coffee filter after 2 minutes. When teams shade with the coffee filter, ask them to keep the thermometer in the shade under the filter and not touch the filter with the black paper on the probe.

9. Bring the class back in and post temperatures in the sun, the shade of the coffee filter, and complete shade. Ask everyone to calculate the % of heat from the sun that they think the coffee filter blocked. **Let the teams struggle with how to do this. This activity is less about getting the right answer than about how to think through this type of problem. Do not give them a formula. In the end, many will arrive at something like this:**

$$\frac{\text{(full sun temp)} - \text{(coffee filter shade temp)}}{\text{(full sun temp)} - \text{(full shade temp)}} \times 100 = \text{\% of heat from the sun blocked by the filter}$$

Wrap Up

1. Ask all teams for their calculation of % of heat from the sun that they think the filter blocked.

2. Ask the class:

   - What evidence do we have that the coffee filter blocks <u>all</u> the heat from the sun?
   - What evidence do we have that the coffee filter blocks <u>no</u> heat from the sun?
   - What evidence do we have that the coffee filter blocks <u>some</u> heat from the sun?
   - How did your team figure the % of solar heating that the coffee filter blocked. **The problem is to represent the fraction of solar heating that the coffee filter blocked. The temperature difference between full sun and complete shade represents how much direct sun heats more than shade. This "whole" (some part of which was blocked) is the denominator of the fraction. The temperature difference between full sun and *partial* shade under the coffee filter represents the amount of heating that the coffee filter blocks. It is the "part," or numerator. To represent this fraction as %, divide the numerator by the denominator and multiply by 100.**

3. Explain radiant heat in terms of what we have seen. The sun gives off heat to things that do not touch it. There is not even a breeze to carry the heat from the sun to the earth (no air in space). Radiant heat travels the same way as light, in a straight line. Where the beam of heat radiation strikes, it raises the temperature of whatever absorbs it. A solid object can block some or all radiant heat in the same way that it would block light. Temperatures are cooler in the shade of a tree because leaves absorb and block the sun's radiant heat. We feel warmth near a stove or a fire because the heat reaches us by radiating through space.

Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions before an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks.

1. A girl is sitting outside on a sunny day. She sits in the sun for awhile, and then moves to shade under a tree. Choose the statement below that describes what she would say about the temperature and gives the best reason for what she feels.

   A. The girl says she feels cooler in the sun. Under the tree, the leaves block the breeze. Direct sunlight makes no difference in temperature because the sun is very far away, and it cannot touch the girl.

   B. The girl says she feel warmer in the sun. In the sunlight, radiant heat comes from the sun to warm her skin. In the shade of the tree, the direct

Part 1 cont.

rays of the sun can't reach her, so she feels cooler.

C. The girl says the temperature feels the same in both places. If there were thermometers in both the sun and the shade, both would read the same. The only thing that warms the girl is the air around her, which is the same in both places.

2. Heat from a fireplace has warmed up a glass of water sitting on a nearby table. Another glass of water sitting on the table the same distance from the fire has a book between it and the fireplace. Which choice below is the best comparison between the temperatures of the two glasses and the way that the heat traveled to them?

A. The glass with the book between it and the fireplace is cooler because radiant heat from the fireplace cannot reach it. The other glass receives more radiant heat and is warmer for that reason.

B. Both glasses are the same temperature. They are both the same distance from the fireplace, so the temperature is the same for both of them. The book between the glass and the fire makes no difference.

C. The glass behind the book is warmer. The book blocks the breeze and lets that glass warm up more by convection from the air and conduction from the table. The other glass is more exposed to the air, which cools it off.

3. A gardener has covered her vegetables with 50% shade cloth so that they get some sun but not too much. On a day when the temperature in full sun is 100 ˚F and 90 ˚F in the shade, which is the best estimate of the temperature where the vegetables are?

A. 50 ˚F because 50˚F is 50% of 100˚F (the full sun temperature), and below the shade temperature

B. 95 ˚F because 5˚F is 50% of the difference between the sun and shade temperatures

C. 45 ˚F because 50˚F is 50% of 90˚F (the shade temperature), and below the

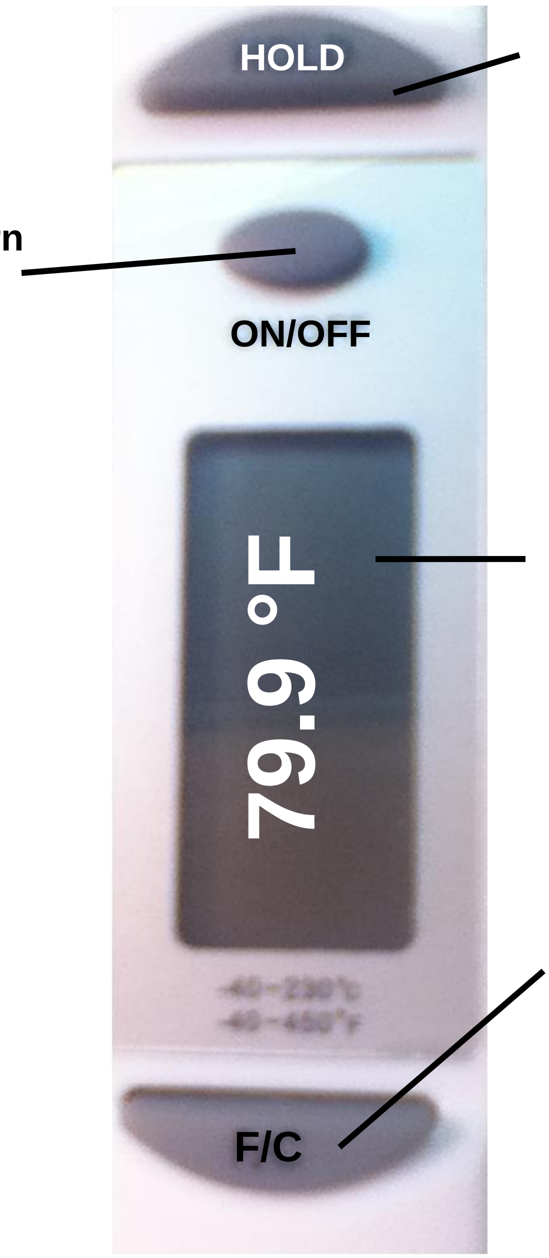
Answer Key

1. A. is incorrect because direct sunlight does make a difference in temperature even though the sun does not touch the girl. The girl is being warmed by radiant heat, which does not require contact. **B. is correct.** C is incorrect because the girl, and thermometers, would be warmer in the radiant heat from the sun.

2. A. is correct for the reason given. B. is incorrect because the book blocks radiant heat from the fire and leaves the glass behind it cooler. C. is incorrect because convection and conduction would warm or cool both glasses equally. The radiant heat from the fire would heat up the glass that is exposed to the fire.

3. A. is incorrect because the 50% shade cloth would block 50% of the temperature change between full sun and full shade, not 50% of the 100 ˚F in full sun. **B is correct for the reason given**. C. is incorrect because is incorrect because 50% shade cloth would block half of the temperature change between full sun and full shade, not 50% of the 90 ˚F in full shade.

BLM 1


Hold down to keep a reading from changing.
HOLD
Press to turn on or off.
ON/OFF
79.9 °F
Should end in °F.
If reading ends in °C, press here until it reads °F.
F/C

BLM 2 Sun and Shade Record Sheet

Names____Date________

What's the Difference Between Sun and Shade?

Temperature after 2 minutes in shade:___________________________˚F

Temperature after 2 minutes in sun:_____________________________˚F

Temperature difference between sun and shade__________________˚F

Partial Shade

Prediction of % of heating that the coffee filter blocks_____________%

Temperature after 2 minutes shaded by coffee filter______________˚F

Actual % of heating that the coffee filter blocks___________________ %

- -

Names____Date________

What's the Difference Between Sun and Shade?

Temperature after 2 minutes in shade:___________________________˚F

Temperature after 2 minutes in sun:_____________________________˚F

Temperature difference between sun and shade__________________˚F

Partial Shade

Prediction of % of heating that the coffee filter blocks_____________%

Temperature after 2 minutes shaded by coffee filter______________˚F

Actual % of heating that the coffee filter blocks___________________ %

Common Student Preconceptions About This Topic

Appendix

Most children's ideas of energy are associated with living things, or linked with a force, a movement, or some kind of fuel. Children often view energy as a fluid that is an ingredient in things. Very few children view heat as a form of energy that can radiate through empty space like light. Because of this, although researchers have studied children's ideas of heat transfer through conduction, there are few studies of children's conception of radiant heat. In general, children's ideas of radiant heat do not develop much differently from their ideas of the nature of light. For Grade 5 students, it is enought to know that light and heat can interact with materials to warm them up, that this can happen without an object touching the source of heat, and that the amount of heating depends upon the amount of light reaching the object.

Hot Cans

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

In this 3-day activity, teams of 3 students design a system for keeping a can hot. All cans get hot water at once, and teams are challenged to keep their can as hot as they can. Students have learned about conductors and insulators in grade 4 and explored conduction, convection and radiation in earlier activities. On the first day, teams decide on materials and draw a few designs to try during the next class period. During the next class, they try out and analyze designs. On the third day, they choose their best design, run it, look at other designs around the class, and predict which ones they think will work best. In the process, they explore data from the whole class to draw conclusions about practical applications of materials with regard to heating and cooling.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- How heating and cooling affect different materials,
- How materials can be used as thermal conductors and insulators.

Students demonstrate this knowledge and understanding by:

- Designing and building a device to keep a can warm,
- Evaluating the usefulness and characteristics of materials used as thermal insulators.

Correlations to NC Science Standards

5.P.3.2 Explain how heating and cooling affect some materials and how this relates to their purpose and practical applications.

Brief Science Background

A hot teapot sitting on a table in a cool room eventually cools to room temperature, even with a tea cozy on it. Things that are hotter than their surroundings and have no source of energy eventually cool down. However, a tea cozy does slow the rate of cooling. Common devices for keeping things warm include thermos bottles, foam cups, and insulated lunch boxes. Insulators are often nonmetallic and lightweight for their size. To stop heat loss, they are fashioned to surround the thing they are meant to keep warm. Similarly, a metal handle on a pot on the stove conducts heat from the pot to your hand, and can burn a person. To prevent this, pot handles are often made of insulators, which conduct heat slowly.

Materials

Materials for the whole class all 3 days

- Newspaper*
- 1 box sandwich bags
- 2 rolls masking tape
- 1 roll box tape
- 1 thermos
- 1 Hot Pot
- 1 Funnel
- wash cloths to use as hot pads
- 2 cans per team
- 1 can lid per team
- 1 digital thermometer per team
- 1 roll aluminum foil

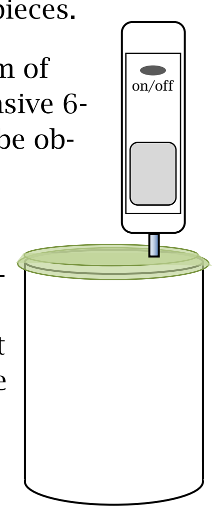
Materials for groups of 3 students all 3 days

- 1 empty 6-oz aluminum can
- 1 can topper
- 1 digital thermometer
- wash cloth to use as a hot pad
- access to insulating and building materials such as newspaper, fabric, foam, sandwich bags, tape, etc.
- science notebooks (1 per student)

Part 1 — Hot Can Warmer Designs

Preparation

1. About a week before the activity, send home a note requesting clean scrap fabric, such as T-shirts, socks, sheets, flannel, wool, etc. for students to use as insulating material.
2. A few days before this activity, collect newsprint (5-6 old newspapers from the library) and cardboard for students to use as structural pieces.
3. You will need a rinsed 6-oz aluminum soda can for each team of three. All teams must use this same small-sized can. Inexpensive 6-oz 6-packs of soda are available from WalMart, or these can be obtained from home.



Procedure

1. Explain that teams of three will work on an engineering challenge to keep a can hot. Teams will get a sealed can of hot water with a thermometer in it. **Show an example.** Teams must design a system to keep the can hot using materials from the classroom and from home. The best designs will show the least temperature change after 10 minutes.

Procedure

2. Show tape, sandwich bags, foam, newsprint, cardboard, and all other items available for designs. Explain that teams can bring teacher-approved items from home if they follow these rules:
   - Raw materials only, no commercial products designed to keep things warm such as soda koozies, insulated lunchboxes, etc.
   - Things that can be destroyed as part of the activity (nothing of value).

3. Set up teams of three and give each a copy of BLM 1. Ask them to use the rest of the class period to draw designs and list materials on BLM 1 in the "Draw and Describe Design" column. Remind them that designs must be simple and assembled quickly. At the end of class, each team will show the teacher BLM 1 with their designs and lists of items to bring from home (also listed on BLM 1). Students can only bring in things that the teacher approves.

Part 2 — Hot Can Warmer Trials

Preparation

1. Have cans, tape, wash cloths to use as hot pads, and all other materials available.

2. Starting about 20 minutes before class, heat pots of water twice, one after the next. Store these in the thermos for the first trial and adjust to 130-140 ˚ F. Before class, pour the hot cans, snap on plastic covers, and insert the thermometer probes. To keep them warm, bunch them and cover with a small blanket or coat. Give them out with rags to use as hot pads.

3. Have a hot can for your "control" for both trials (a new one for each trial). This can sits out on a table with no insulation. The teacher records its temperature when each trial starts and again when the trial ends. After each trial, calculate its temperature drop and give this number as the example of what happens when nothing is done to keep it warm.

4. <u>Second Trial Hot Cans</u> The second trial requires another full thermos of 130-140 ˚F water. Heat more water right after filling the thermos with the first two pots for the first trial. When you have emptied the thermos into the first trial cans, this third pot will be hot and can be poured into the thermos. Heat a fourth pot while students work on the first trial, add it to the thermos, and adjust temperature. Treat the second trial hot cans just as in step 2 above.

Procedure

1. Explain that teams will try out two ideas today in two 10-minute trials. The goal for each trial is for the temperature of the can to drop as little as possible. Give out BLM 1 and ask teams to enter first trial data in the "Trial 1" section. Show teams how to turn thermometers on and read 140 ˚F (if a thermometer times out, they can turn it on again).

2. Ask everyone to get their materials and say that they will get a hot can in 3 minutes. After 3 minutes, with materials gathered, give out the hot cans with a rag to use as a hot pad. Set out the control can and record it's starting temperature. Ask teams to record their starting temperatures on BLM 1. Say that

Procedure Cont.

everyone now has 10 minutes to build a design they made during the last class, with the hot can.

3. After 10 minutes, ask everyone to record the final temperature of their can and temperature loss (subtract final temperature from starting temperature) on BLM 1 under Trial 1.
4. Let everyone know the temperature loss of the control can. Designate a "refill depot" in the room. Ask teams to return their cans there then fill in the analysis section of BLM 1. While teams do this, empty the trial 1 cans and refill them with hot water for trial 2.
5. Conduct trial 2 by repeating steps 1-4.
6. Ask teams to use the back of their record sheet to sketch and describe a plan for the final challenge. Remind them to have these plans ready for the next class period. If a team wants to bring in more materials, ask them to list them. As before, they can bring in only things that you approve.

Part 3 — Hot Can Warmer Challenge

Preparation

Preparation is the same as for the previous class period except that you will need to make copies of BLM 2, 1 per team.

Procedure

1. Be sure that everyone has their design drawings and descriptions and a science notebook. Explain that teams will try designs made using lessons learned from the two trials. Ask them to be prepared to record the starting and final temperatures of their can and the control can. Assign each team a number and ask them to write that number next to their Hot Can Warmer.
2. Say that this time, teams have 3-5 minutes to get ready. After that, nearly everything will go as with the previous 2 trials. The best design is the hottest after 10 minutes.
3. Give each team a copy of BLM 2. Give access to building materials and allow 3-5 minutes to build the Hot Can Warmers.
4. After 3-5 minutes, give out hot cans and set aside a control as before. Call "start." Take the temperature of the control. Remind teams to record their starting temperature. The teacher takes the starting temperature of the control can, <u>then turn their thermometers OFF</u>.
5. When all thermometers are off, tell students that they have nearly 7 minutes to circulate around the room and find the three set-ups that they think will be most successful. Ask them to write those 3 numbers in their notebooks, and beside each number, include a reason why they think that particular Hot Can Warmer will be one of the top 3.
6. After nearly 10 minutes, tell teams to turn their thermometers back on. At 10 minutes, call "stop" and ask everyone to record their final temperature. At this time, the teacher records the final temperature of the control can.

Procedure

7. Ask each team to call out their team number, their final temperature and the temperature loss. When they finish doing this, the teacher calls out and records the starting and final temperatures of the control can. Ask students to write these numbers by each team number on BLM 2, and the control can numbers in the appropriate blank. These will be used in the wrap-up in the next class period.
8. If possible, maintain all of the setups with the cans in them, or if this is not possible, take pictures of them. The setups are useful in the wrap-up during the next class period.

Wrap-Up

1. Take a poll of predictions: "Which team numbers did you predict would be in the top 3?" and record the results on the board as a frequency table.
2. Show the results taken on the previous day by team number. Ask: "Which Designs Worked Best?"
3. Ask: "If you could do yours over, what would you try?"
4. Discuss the materials that people used and how they worked.
5. Discuss characteristics of materials that worked well and those that did not work well.
6. Introduce the terms "heat conductor" and "heat insulator" and relate these to students' designs and other elements of the activity (e.g. the aluminum in the can is a heat conductor).

Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions before an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks.

1. Four cups made of different materials were filled with a hot drink 30 minutes ago. One cup is glass, one is metal, one is Styrofoam™, and one is plastic. Circle the following choice that places the cups in the correct order of how hot they would keep the drink.

	Cool	**Lukewarm**	**Warm**	**Hot**
A.	Glass	Metal	Styrofoam	Plastic
B.	Metal	Glass	Hard plastic	Styrofoam
C.	Styrofoam	Metal	Glass	Hard Plastic
D.	Styrofoam	Plastic	Glass	Metal

2. Race car engines get very hot during races. An engineer wants to put a material between the engine and the driver to protect the driver from the heat. The engineer is choosing based characteristics of the material. Circle the choice below that you think would work best. The thing that would work best:

   A. is very heavy and thin

   B. allows air to pass through it

   C. is flexible and heavy

   D. is lightweight and thick

3. Circle the choice below that best completes the following sentence. A cup of hot liquid that you can hold your hand is made of a material that has the property of being a good...

   A. ...heat conductor.

   B. ...heat trap.

   C. ...heat insulator.

   D. ...heat filter.

Answer Key

1. **B**
2. **D**
3. **C**

Extensions

1. Try the reverse of this activity with cans of cold water (not ice water). The object is to keep the water warmest.

2. Pose the question: What would happen to the temperature of two cans if we put no water into a control can, and no water in another can placed inside a really good Hot Can Warmer setup? Try it. Wait 10 minutes, and read the thermometers. **The thermometers will read the same.**

3. Ask: What is the Hot Can Warmer doing to the can? Discuss this with students. **A good hot can warmer slows heat from leaving the can, but it does not make heat. Insulation does not warm things. If the two cans start out at the same temperature, and no source of energy heats either one, insulation will make no difference in temperature.**

BLM 1 Design Record Sheet

Trial 1

temperatures	labeled drawing and description of the design	analysis of results
YOUR CAN Starting temperature________˚F Final temperature__________˚F Temperature loss__________˚F **CONTROL CAN** Starting temperature________˚F Final temperature__________˚F Temperature loss__________˚F	Items needed from home: ______________________ ______________________ ______________________	

Trial 2

temperatures	labeled drawing and description of the design	analysis of results
YOUR CAN Starting temperature________˚F Final temperature__________˚F Temperature loss__________˚F **CONTROL CAN** Starting temperature________˚F Final temperature__________˚F Temperature loss__________˚F	Items needed from home: ______________________ ______________________ ______________________	

On the back of this page, draw your final design and list all materials needed.

BLM 2 Hot Can Warmer Predicted Results

In the left column, circle the 3 Hot Can Challenge Teams that you predict will have the best results. In the right column, describe features of these designs that you think make it work well. Record actual results for the Control Can *and* your 3 choices in the columns labeled "Final Temperature" and "Temperature Loss."

Team #	Final Temperature	Temperature Loss	Features of the circled team's Hot Can Warmer that you think will give good results.
CONTROL CAN			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Appendix

Common Student Preconceptions About This Topic

Many 5th graders think of heat as a substance that can flow into and out of objects, rather than as energy that can be transferred. They also think that cold is the opposite of heat, a substance that flows in the same way, like a fluid. With regard to the effects of heat insulators, many children predict that a thermometer placed in a mitten will give a higher reading than one placed outside the mitten. It seems only natural to them that the mitten makes warmth.