Objective

Students will experiment to determine that when different amounts of water are mixed, the volumes are additive but temperatures are not. Activities are for grade levels K-4.

National Science Education Standard

<u>Science As Inquiry: Content Standard A</u>

As a result of activities in grades K-4, all students should develop:

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Missouri Grade Level Expectations

<u>Strand 1: Matter and Energy – Mixtures and Solutions</u>

Concept 1B: Properties of mixtures depend upon the concentrations, properties, and interactions of particles.

Concept 1C: Properties of matter can be explained in terms of moving particles too small to be seen without tremendous magnification.

<u>Strand 7: Inquiry</u>

Concept 1: Science understanding is developed through the use of science process skills, scientific knowledge, scientific investigation, reasoning, and critical thinking.

Materials

3 clear plastic (100 mL capacity) cups per group
Thermometers
Cold water
Hot water
Insulated containers (hot and cold water storage)
Data sheet

Background

Animals possess various adaptations that enable them to deal with changing environmental temperatures. Mammals are able to generate heat within the body to maintain a stable body temperature. This heat is lost to the environment when the surrounding temperature is lower than the mammal's body temperature. All mammals have a form of insulation to preserve their body heat in cold environments. Ocean mammals like whales and seals have thick layers of fat called blubber to protect them from the frigid temperatures of the oceans. Land mammals rely on body fur to keep them warm in the coldest winter air.

Humans are mammals and thus require an external body covering. Like all mammals, humans have some body hair but their hair is no longer thick enough to provide the needed insulation. Using their brains, humans have discovered various substitute body coverings to insulate their bodies. The history of clothing is the history of people attempting to devise body coverings to maintain a constant body temperature. The spacesuit serves the same purpose as did the cave dweller's animal skins centuries ago.

Engage

Have students hold hands with someone else. What do you notice about the person's hand? What happens to the temperature of each person's hands? Is there a change? Why?

Explore

Procedure#1 (in pairs):

1. Measure the temperature of water in a Styrofoam cup with a lid (this should be room temperature).
2. What will happen if we add crushed ice? Add crushed ice and measure temperature again. What happens? Why?

Procedure#2 (in pairs):

1. Each group should have the "What's the Temperature" Data Sheets. Each group will record predictions and observations on the data sheet.
2. Pour 30mL of hot water (either hot tap water or water heated in a coffee maker) into the cup labeled "hot".
3. Pour 30mL of cold or ice water into the cup labeled "cold". Be certain no ice is transferred.
4. Measure and record the temperature of each water sample on the data sheet.
5. Predict and record both the volume and the temperature that will result when the cold water is added to the hot water.
6. Pour the cold water and hot water into the cup labeled "mixed", mix, read and record the temperature and volume of the mixture.
7. Have each group of students record their data on the classroom data chart and discuss the results of the experiment.
8. Have the students repeat steps 2-7 using 20mL hot water and 40mL cold water. Be sure to have students predict the temperature and volumes before beginning.
9. Have the students repeat steps 2-7 using 40mL hot water and 20mL cold water. Be sure to have students predict the temperature and volumes before beginning.

Explain

In this activity, students observe that when mixing samples of water, the volumes are additive, but temperatures are not. To say that volumes are additive means that the final volume of water can be accurately predicted by adding the two volumes that are mixed together. (For example, 30mL water + 30 mL water = 60 mL water). However, students observed that in this mixing, the temperature of the final mixture was not the addition of the two starting temperatures. (For example, equal volumes of 10°C water + 40°C water result in about 25°C water, not 50° C). To address this issue, let's first discuss the term "temperature".

While temperature is a difficult term to precisely define, we all have an intuitive idea of what it means. It is a relative measure of the "hotness". A hot object has a higher temperature than a cold object. If these two objects were placed next to each other, the hot object would become cooler and cold object would become warmer. These temperature changes result from a loss or gain of heat energy.

Heat flows from things that are warmer to things that are cooler. When two samples of water at different temperatures are mixed, the final water sample will have a temperature somewhere between the original temperatures and the relative amounts of water in the original samples.

For example, if equal volumes of hot and cold water are used, the resulting temperature should be halfway between the two original temperatures; however, if a greater amount of hot water than cold water is used the final temperature should be closer to the original temperature of the hot water. Similarly, when more cold water is used, the final temperature should be closer to the original temperature of the colder water.

While the mathematical relationship to determine the final temperature may not be appropriate for class discussion, you might find it useful to know that one exists. The temperature can be estimated by the following relationship:

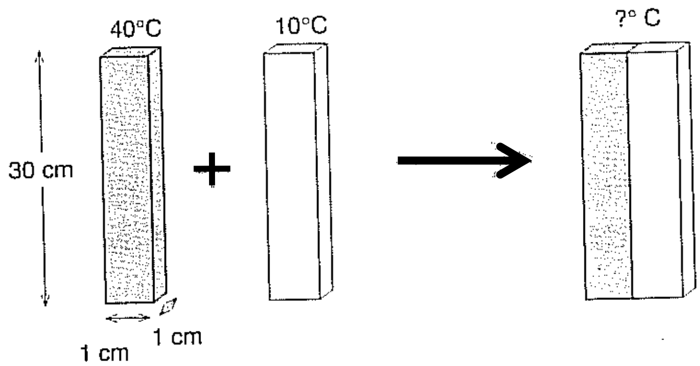
$$(T_{cold})\left(\frac{V_{cold}}{V_{total}}\right) + (T_{hot})\left(\frac{V_{hot}}{V_{total}}\right) = T_{final}$$

where T_{cold} is the temperature of cold water, V_{cold} is the volume of cold water, T_{hot} is the temperature of hot water, V_{hot} is the volume of hot water, V_{total} is the total volume after mixing, and T_{final} is the temperature of the final mixture. For example, assume you have 20 mL 10℃ water which you mix with 40 mL 50℃ water. The final temperature would be

$$(10^\circ C)\left(\frac{20mL}{60mL}\right) + (50^\circ C)\left(\frac{40mL}{60mL}\right) = 37^\circ C$$

The relationship above is derived from the more general relationship for heat transfer that uses the temperature, mass, and specific heat of the substances mixed. (Specific heat is a measure of the ability of a substance to absorb heat). Note that the actual final temperature will be less than calculated as some heat is lost to the cup and air. Don't worry about getting exactly the temperature predicted by the formula; in general, it will be a little lower than predicted due to loss of energy to the container and surroundings.

When discussing the results, you may find it helpful to use blocks to reinforce the concepts. A 1-cm x 1-cm x 30-cm block has a volume of 30 cm^3 (volume=l x w x h). If the block was hollow it could hold 30 mL water (1 cm^3 = 1 mL). Laying two such blocks each containing 30 mL water next to each other would show the final volume is double that of the initial. The issue of temperature could be addressed by pointing out the temperature can't get any hotter than the hotter block nor colder than the colder block.



Elaborate/Extend

- Challenge students with summarizing questions such as, "why do you think that you go the measurements that you did from mixing the different volumes of water at the different temperatures? Why didn't all the hot and cold mixtures result in the same temperature? Were your predictions closer to the actual temperature with your first, second, or third trial? Why or why not?
- Have students design an experiment to determine if the order of mixing affects the outcome of the experiment.
- **Cross-Curricular Integration (Math):** the students add the volumes of water mixed in the experiment.

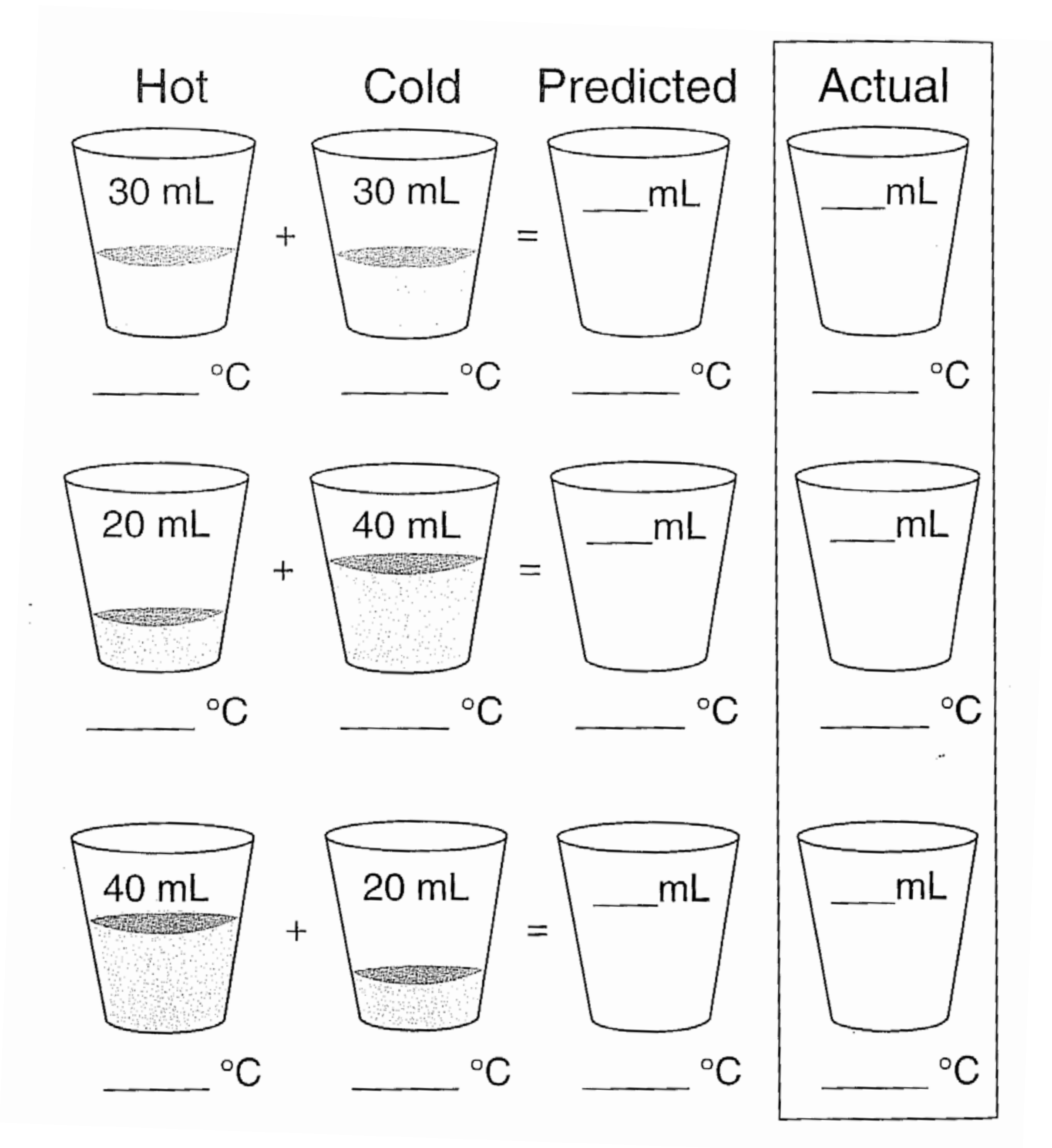
Evaluate

- Use the completed Data Sheet as a group assessment.
- Adapt the Data Sheet to challenge students to predict what would happen if they mixed water at different temperatures than in the 'procedures'.
- Individually question students on such topics as: What happens to the temperature of the water when you mix hot and cold water? What happens to the volume of the water when you mix hot and cold water? An individual written assessment, including completion of the "What Happens to the Water?" Assessment Sheet is an option for older students.

Name ______________________________ ____________________________________

______________________________ ____________________________________

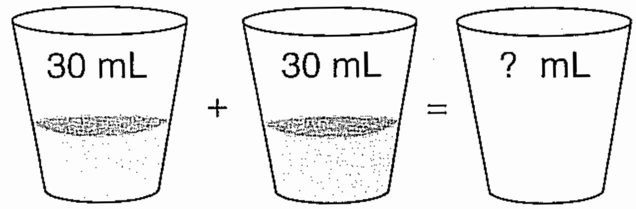
Temperature Mixing
What's the Temperature? – Data Sheet



Temperature Mixing

Temperatures and Volumes – Class Data Chart

This is a smaller version of a large chart that would be used to record the results of each group. Whole class discussion on the results would follow. Were predictions the same? Were results the same? If there were differences, can you explain the differences?



Group Number	Predicted Temperature	Predicted Volume	Actual Temperature	Actual Volume
Group 1				
Group 2				
Group 3				
Group 4				
Group 5				

Temperature Mixing

What Happens to the Water? – Assessment Sheet

You have 20 mL water at 40℃ and 20 mL water at 60℃. You mix them together.

What will the final temperature be? ___________________________

What will the final volume be? _______________________________________

Draw a diagram to show what you think would happen.

Explain your answer. ____

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Activity adapted from “Teaching Chemistry with Toys”

http://www.nbtc.cornell.edu/mainstreetscience