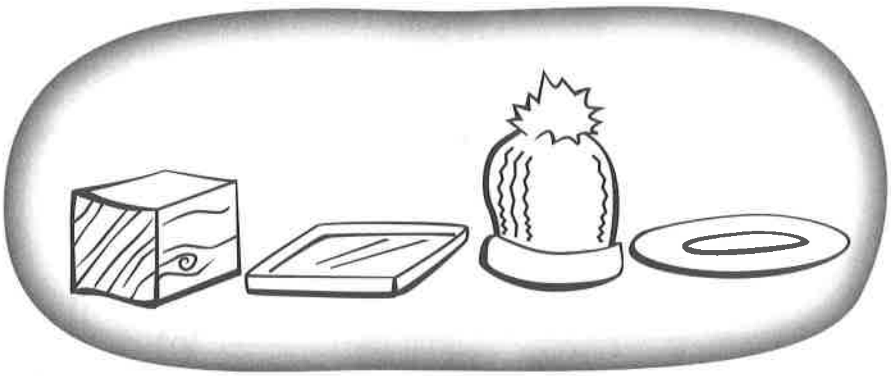
Objects and Temperature

Taz and Kyle are comparing the temperature readings of four different objects:

- block of wood
- metal tray
- wool hat
- glass plate



They place the objects on a table in their science classroom and leave them overnight. A thermometer is attached to each object. The next day they record the temperature of each object at the same time.

Put an X next to the statement that best describes your prediction about the objects' temperature.

____ None of the objects will have the same temperature.

____ Two of the objects will have the same temperature.

____ Three of the objects will have the same temperature.

____ All of the objects will have the same temperature.

Describe your thinking. Provide an explanation for your answer.

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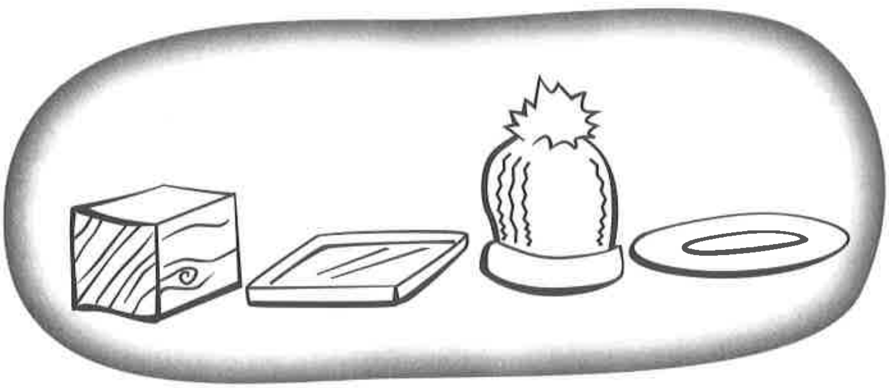
Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about temperature. The task specifically probes to find out whether students recognize that non-heat-producing objects exposed to the same ambient conditions will have the same temperature, regardless of the material they are made of.

Related Concepts

heat, energy, temperature

Explanation

The best response is that all of the objects will be at the same temperature. Heat is generally a measure of the total kinetic energy of the molecules in a system. Temperature is generally a measure of the average kinetic energy of the molecules. In this example all the objects are exposed to the same ambient conditions. There is no detectable transfer of energy resulting in additional energy being absorbed or lost by the material that would change the average motion of their atoms or molecules and thus change the temperature. Therefore, since the average motion of the atoms or molecules does not change, the temperature remains the same. What is confusing is that when these objects are touched, some may appear to be "colder" or "warmer" than others. For example, the metal tray feels colder than the wool hat. Energy flows from warmer objects to cooler ones. Your hand at body temperature, which is warmer than room temperature, will transfer heat to the object touched. An object like metal is a better heat conductor than an object like the wool hat. Therefore, it will conduct heat from your hand faster. As a result, the metal feels cooler to you than the hat. They are at the same temperature, however, because the average kinetic energy of their particles is the same.

Curricular and Instructional Considerations

Elementary Students

Students' experiences with materials in their environment may intuitively affect their idea that the temperatures will be different. Any young student who has touched metal on a cold day and touched wood exposed to the same conditions would infer that the metal has a colder temperature. Younger students will also believe some materials appear to be inherently cold, such as metals, or warm, such as hats. Students at this level do not conceptually distinguish between heat and temperature. However, it is a grade-level expectation in the national standards that students will understand that heat moves by conduction. Yet, linking this idea to what happens when you touch different objects and they feel warmer or colder is a more sophisticated idea that develops later in middle school. This probe is useful in determining the intuitive ideas students have about the temperature of everyday objects.

Middle School Students

Students at this level will continue to confuse heat and temperature and fail to recognize the heat transfer involved when heat-conducting objects are touched. The idea that heat results from the motion of molecules and that a transfer of energy is involved when there is a change in heat is a grade-level expectation in the middle and high school standards. However, this is still an abstract notion. The probe is useful in determining if students still persist in their intuitive notions about heat and temperature.

High School Students

Heat and temperature ideas become more complex at this age. Yet, students may still hold onto similar ideas they had in elementary grades. High school students build on their experiences with energy transfer in the middle grades to investigate heat quantitatively by measuring variables such as temperature change and kinetic energy (NRC 1996). However, misconceptions about energy transfer and the distinction between heat and temperature may still persist and be uncovered through use of this probe.

Administering the Probe

Be sure students understand that the objects on the table are all experiencing the same conditions, including the same room temperature. You may wish to model the probe scenario and have students touch the objects before answering the probe or show them the objects to remind them what the materials are. This probe can be combined with "The Mitten Problem" (p. 103) to assess ideas about heat energy and temperature in a different context.

Related Ideas in *National Science Education Standards* (NRC 1996)

K–4 Light, Heat, Electricity, and Magnetism

- Heat can be produced in many ways, such as burning, rubbing, or mixing one substance with another. Heat can move from one object to another by conduction.

5–8 Transfer of Energy

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
- ★ Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

9–12 Conservation of Energy and the Increase in Disorder

- ★ Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993)

3–5 Energy Transformation

- Heat is produced by mechanical and electrical machines and any time one thing rubs up against another.
- ★ When warmer things are put with cooler ones, the warm ones lose heat and the cool ones gain it until they are all at the same temperature.
- Poor conductors can reduce heat loss.

6–8 Energy Transformation

- Energy cannot be created or destroyed, but only changed from one form into another.
- Energy appears in different forms. Heat energy is in the disorderly motion of molecules.

9–12 Energy Transformation

- Heat energy in a material consists of the disordered motions of its atoms or molecules.
- Transformations of energy usually produce some energy in the form of heat, which spreads around by radiation or conduction into cooler places.

Related Research

- Students in the age range of 8–12 are able to use and read a thermometer to take temperature readings. They tend to make judgments about the temperature of an object based more on the nature of the material than the temperature of the surrounding medium (Erickson 1985).
- Students are likely to think that objects of different materials in the same room will be at different temperatures even if they are told that the objects are kept at room temperature (Erickson 1985).
- One place students would be expected

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

to understand the distinction between heat and temperature is in chemistry classes. However, most of the chemistry problems assigned to students in introductory chemistry classes do not require students to make the distinction, so students have little opportunity to acquire the distinction. Chemistry teachers may be unaware that students lack this skill and may have the expectation that they do understand the difference (Gabel and Bunce 1994).

- The concept of thermal equilibrium when several objects are in prolonged contact with the same air in the same room is often missing. Students have difficulty recognizing the equality of temperatures at thermal equilibrium (Tiberghien 1985).

Suggestions for Instruction and Assessment

- This probe can be followed up as an inquiry-based investigation. Ask the question, encourage students to commit to a prediction, and then test it. The dissonance involved in discovering that the temperatures are the same should be followed with opportunities for students to discuss their ideas and resolve the dissonance.
- Provide opportunities for students to investigate the temperature of different materials in the same warm and cold surroundings.
- Help students understand what is happening when you touch metal versus when you touch a wool hat or block of wood. Help them use ideas about conduction and transfer of energy in this context to explain why it feels as if they are at different temperatures.
- Use everyday examples such as why you would rather stand on a rug in your bathroom on a cold morning if you are in your bare feet than stand on the bathroom tiles. Use multiple examples like this to relate the idea that objects may feel warmer or colder even though the temperature is the same.
- Be careful how you use terms such as *heat* and *temperature* and alert students to examples.
- Instruction about heat, temperature, and heat exchange should be carried out over a long period and not in one single instructional unit. These are difficult ideas that take time and multiple experiences to develop.

Related NSTA Science Store Publications and NSTA Journal Articles

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* London and New York: RoutledgeFalmer.

Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice.* Thousand Oaks, CA: Corwin Press.

Robertson, W. 2002. *Energy: Stop faking it! Finally understanding science so you can teach it.* Arlington, VA: NSTA Press.

Related Curriculum Topic Study Guide

(Keeley 2005)

"Heat and Temperature"

References

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

Erickson, G. 1985. Heat and temperature: An overview of children's ideas. In *Children's ideas in science,* eds. R. Driver, E. Guesne, and A. Tiberghien. Milton Keynes, UK: Open University Press.

Gabel, D., and D. Bunce. 1994. Research on problem solving in chemistry. In *Handbook of research on science teaching and learning,* ed. D. Gabel. New York: Simon and Schuster.

Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice.* Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.

Tiberghien, A. 1985. Heat and temperature: The development of ideas with teaching. In *Children's ideas in science,* eds. R. Driver, E. Guesne, and A. Tiberghien. Milton Keynes, UK: Open University Press.