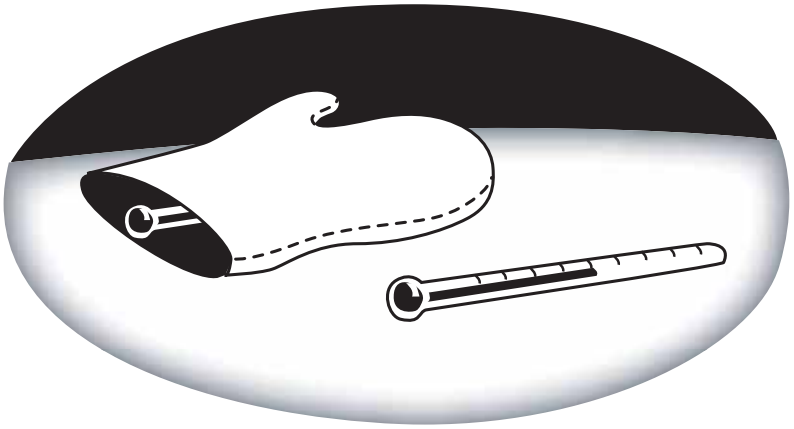
The Mitten Problem

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about sources of heat energy. The probe is designed to find out whether students believe an insulating object, like a mitten, produces its own heat. Their explanations reveal whether they can differentiate between a heat source and an object affected by a heat source.

Related Concepts

heat, energy, temperature

Explanation

The best response is C. The temperature readings inside the mitten and outside the mitten will be the same. Heat describes the energy that is transferred between two interacting systems at different temperatures. A heat source can produce its own heat energy or it may simply be an object that is at a higher temperature than the surroundings. The mitten in this case does not produce its own heat energy, and it did not have a higher starting temperature to begin with when the thermometer was inserted. The mitten is an insulator that keeps heat, generated by the human body and transferred to the surrounding air, from leaving the mitten as quickly as it leaves a bare hand. The mitten, which is an insulator, slows down the transfer of heat energy to the surrounding environment outside the mitten. If there is no source of additional heat energy inside the mitten, the mitten will have the same temperature as its ambient surroundings. Temperature is closely related to the measure of the average kinetic energy of

molecules and atoms. During this experiment there is nothing to significantly cause the average motion of the atoms and molecules of the mitten or the air inside it to increase. The temperature in the room remained the same throughout the experiment. Therefore the temperature will most likely remain the same inside the mitten as outside the mitten.

Curricular and Instructional Considerations

Elementary Students

Students experiment with heat in the elementary grades and begin to understand that heat-related phenomena can be observed, measured, and controlled in various ways. The concept of energy is complex, yet students develop intuitive notions about energy, including heat. Basic ideas at this level are observational. Grade-level expectations in the national standards include development of the idea of various ways heat is produced, that heat moves from warmer objects to cooler ones, and that there are ways to reduce heat loss. Students at this level do not distinguish between the words *heat* and *temperature,* and this may confound their understanding of what heat is and how it travels. This probe is useful in determining early ideas about heat transfer and whether students think insulating objects, such as mittens, coats, and blankets, generate their own heat.

Middle School Students

Students' understandings about heat will build on their K–4 experiences. They become familiar with the ideas that energy is an important property of substances and that many changes involve energy transfer in the form of heat. However, students still have many misconceptions about heat and where it comes from. Confusion between concepts of temperature, heat, energy transfer, and a heat source is common at this level and focusing on transformations may help them address their naive ideas. The idea that heat results from the motion of molecules 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 preconceptions about temperature, energy, and non-heat-generating objects.

High School Students

Heat and temperature ideas become more complex at this age. Yet, students may still hold onto ideas they had in elementary grades as well as fail to distinguish between the use of the words *heat* and *temperature*. 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). Students can experience and analyze a wide variety of actions that give off heat and understand that the mitten prevents some heat given off by the body from dissipating into the environment outside the mitten. However, misconceptions about heat sources may still persist and be uncovered through use of this probe.

Administering the Probe

You may wish to use props to model the idea that the mitten with the thermometer inside and the thermometer on the table are exposed to the same ambient conditions. This probe may be combined with "Objects and Temperature" (p. 109) to further probe for students' ideas about heat transfer and temperature.

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

- Although the operational distinction between temperature and heat can be fairly well understood after careful instruction, research with high school students indicates that the idea that heat is the energy of random motion and vibrating molecules is difficult for students to understand (NRC 1996).

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

- Heat energy is an unexpectedly difficult concept for students to grasp, as temperature is often mistaken as heat. Most children can't distinguish between heat and temperature in grades K–4. They may think that some materials are intrinsically warm (blankets or mittens) or cold (metals) (Driver et al. 1994).
- Studies have discovered a vast store of ideas about thermal phenomena in children ages 10–12—for example: heat makes things rise, heat and cold are material substances that can be transferred from one thing to another, and heat accumulates in some areas and flows to others (Erickson 1979, 1980).
- Studies in England found that even though many 14- and 16-year-old students have been exposed to formal instruction about heat, most students still seem to associate the term *heat* with the meanings they have constructed for it during their everyday encounters with hot and cold objects rather than from those encountered in the classroom (Erickson 1985).
- Students gave various responses to researchers to describe the difference between heat and temperature, including (1) there is no difference between them (the most common response), (2) temperature is a measurement of heat, and (3) temperature is the effect of heat (Ericks 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 temperature remains the same should be followed with opportunities for students to discuss their ideas and resolve the dissonance. Be aware that in a similar study conducted with elementary students investigating a similar problem by placing thermometers inside a coat, the initial results were not enough to change their thinking. Students believed the thermometer needed to stay inside the coat for a longer period of time. It took successive trials with varying lengths of time before some students (but not all) would accept the idea that the temperature remains the same. Some students will also challenge the results by saying the thermometer is defective.

Topic: Heat/Temperature
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- Provide a variety of experiences with heat and energy transfer so students can understand the different forms and how they are measured.
- Instruction about heat, temperature, and heat exchange should be carried out over longer periods of time and revisited rather than being taught in just one unit.
- Students may hear and use words like *heat conductor* and *insulator* but may not understand them in the context of a problem such as this probe.
- During elementary years students should have multiple opportunities to identify things that give off heat and things that

do not seem to give off heat in order to develop the idea of a heat source. At this level students can identify obvious heat sources, such as a lightbulb.

- At the middle level, the more abstract idea of "cold" objects as sources of heat can be addressed. For example, challenge students to consider how an ice cube can be considered a source of heat.
- Explicitly address the idea that the heat needed to warm something, such as your hands inside a mitten, must come from somewhere. This leads to discussions that trace where the energy comes from and where it will go and leads students to see how body heat is trapped inside the mitten.

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 Guides

(Keeley 2005)
"Energy"
"Heat and Temperature"

References

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

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.

Erickson, G. 1979. Children's conception of heat and temperature. *Science Education* 63: 231–230.

Erickson, G. 1980. Children's viewpoints of heat: A second look. *Science Education* 64: 323–336.

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.

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