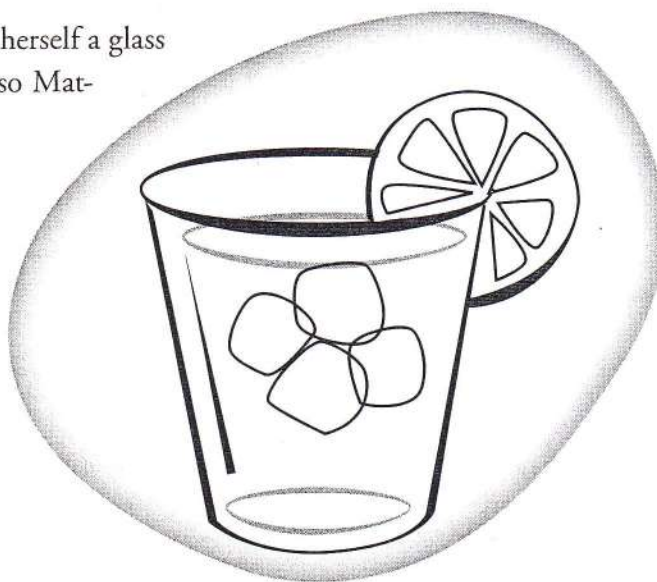


Ice-Cold Lemonade

It was a hot summer day. Mattie poured herself a glass of lemonade. The lemonade was warm, so Mattie put some ice in the glass. After 10 minutes, Mattie noticed that the ice was melting and the lemonade was cold. Mattie wondered what made the lemonade get cold. She had three different ideas. Which idea do you think best explains why the lemonade got cold? Circle your answer.

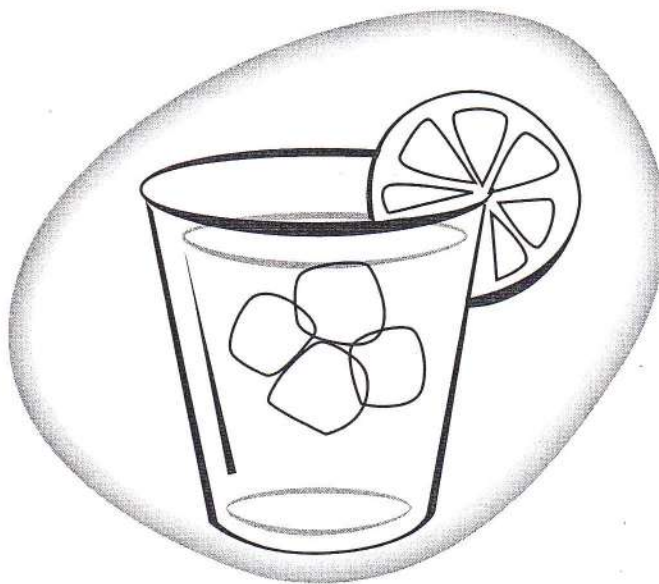


- A** The coldness from the ice moved into the lemonade.
- B** The heat from the lemonade moved into the ice.
- C** The coldness and the heat moved back and forth until the lemonade cooled off.

Explain your thinking. Describe the “rule” or reasoning you used for your answer.

Ice-Cold Lemonade

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about the transfer of energy. The probe is designed to determine whether students recognize that heat flows from warmer objects or areas to cooler ones.

Related Concepts

conduction, energy, energy transfer, heat

Explanation

The best response is B: The heat from the lemonade moved into the ice. Heat (thermal energy) is associated with the motion of molecules in a substance. This energy is transferred from one place to another through the processes of

heat flow. This thermal energy will only move from a warmer object to a cooler object, never the other way around. In the case of the lemonade and ice, as the molecules in the warmer lemonade came in contact with the molecules in the cooler ice, heat flowed into the ice from the lemonade. This process cooled the lemonade and melted the ice.

Common language contains many references to the idea of "cold" moving from place to place. Children are advised to close a refrigerator door, so as not to "let the cold out," and we complain about winter chills that "get into your bones." Such phrases reinforce the common notion that something known as cold can move from place to place. Because what we

sense as warm or cold simply refers to the average kinetic energy (thermal energy) of an object's molecules, these references to cold moving are generally misnomers for the transfer of heat energy from warmer to cooler objects.

Curricular and Instructional Considerations

Elementary Students

In the early grades students use the terms *heat*, *hot*, and *cold* to describe encounters with objects and their surroundings. They have experiences mixing same and different amounts of hot and cold water together and finding the resulting temperature. As they reach the age of eight or nine they can talk about heat as a type of continuum from cold to hot, but they commonly associate heat with objects such as the stove, the Sun, or a fire. Developing the formal idea of heat transfer is difficult for younger elementary students and can wait until middle school. At this grade level it is sufficient for students to know that heat moves from one place to another, which can be observed with their senses. This probe is useful in determining students' early conceptions of the flow of heat.

Middle School Students

Students at this level have a general concept of heat but still associate it more with the nature of objects rather than energy transfer. Students' experiences with the movement of heat expand to include conduction, convection, and radiation. By the end of middle school, students should be able to connect their understand-

ing of the motion of molecules to the transfer of heat in examples involving conduction and convection. Even with formal instruction, middle school students will still have difficulty understanding the direction of heat flow. This probe is useful in determining whether students hold on to their preconceived notions, particularly the idea that cold moves out of an object or substance.

High School Students

The concepts of heat, thermal energy, and energy transfer can now be extended into new contexts, including nuclear reactions and biological energy transfers. However, it is still likely that students will hold onto their preconceptions about the movement of cold, possibly until the laws of thermodynamics are introduced in physics. This probe is useful in determining whether these ideas persist.

Administering the Probe

You may wish to use visual props for this probe. For example, pour a glass of warm lemonade. Place a thermometer in the glass of lemonade and tell the class what the temperature of the lemonade is. Add ice to the glass of lemonade. After 10 minutes, tell the class what the temperature of the iced lemonade is and pose the question in the probe. Be aware that the language in the probe is intentional. The word *moved* was used instead of *transferred* to avoid memorized definitions of energy transfer. You may want to ask students to draw their ideas, noting whether they perceive heat as a substance that moves, similar to the historical

“caloric” model, or use ideas about the motion of particulate matter.

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.

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.
- In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers.

9-12 Conservation of Energy and the Increase of 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.
- ★ Everything tends to become less organized and less orderly over time. Thus in all energy

transfers the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction and convection and the warming of our surroundings when we burn fuel.

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

3-5 Energy Transformation

- ★ When warmer things are put with cooler ones, the warm ones lose heat and the cool ones gain it until they are all the same temperature. A warmer object can warm a cooler one by contact or at a distance.

6-8 Energy Transformation

- Thermal energy is transferred through a material by the collisions of atoms within the material. Thermal energy can also be transferred by means of currents in air, water, or other fluids.
- Energy appears in different forms and can be transformed within a system. Thermal energy is associated with the temperature of an object.

9-12 Transformations of Energy

- Thermal energy in a system is associated with the disordered motions of its atoms or molecules.

Related Research

- Middle school students often do not explain the process of heating and cooling in terms

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

of heat being transferred. When transfer ideas are involved, some students will think that cold is being transferred from a colder to warmer object. Other students think that both heat and cold are transferred at the same time (AAAS 1993).

- Middle and high school students do not always explain heat-exchange phenomena as interactions. For example, students may say that objects tend to cool down or release heat spontaneously without acknowledging that the object has come in contact with a cooler object or area (AAAS 1993).
- Numerous studies have shown that few middle and high school students understand the molecular basis of heat transfer after instruction. Difficulties in understanding remain even with instruction that is specially designed to explicitly address the difficulty of understanding heat transfer (AAAS 1993).
- Many researchers have found that children have difficulty understanding heat-related ideas. Harris (1981) and other researchers suggested that much of the confusion about heat comes from the words we use and that children tend to think of heat as a substance that flows from one place to another. Cold is also thought of as an entity like heat, with many children thinking that cold is the opposite of heat rather than being part of the same continuum (Driver, Guesne, and Tiberghien 1985; Driver et al. 1994).

Suggestions for Instruction and Assessment

- The *Benchmarks* (AAAS 1993, p. 81) state

that energy is a major exception to the principle that students should understand an idea before giving them a label for it. Because energy is such a mysterious concept, children can actually benefit from hearing the term and talking about it before being able to define it. Developing a formal conception of energy and energy-related concepts should wait until students are ready.

- Elementary students should have multiple experiences putting warmer and cooler things together, measuring the temperature, and describing the result. It is not until middle school that students begin to describe and draw a particulate model to explain what happens.
- In upper elementary grades, students can investigate warm and cold objects, observing how heat seems to spread from one area to another. Starting with objects that are warmer than their immediate environment to investigate heat transfer may make more sense than starting with objects that are colder than their surrounding environment.
- Computer probeware may be more effective than ordinary thermometers in helping students observe small changes in temperature during heat transfer.
- Be aware that many students think that cold moves. When developing the idea of heat moving from warmer to cooler areas, have students generate examples of everyday phrases that describe the movement of cold, such as “shut the door or you will let all the cold in.” Engage students in critiquing these phrases in terms of how energy moves.

- Explicitly address the idea of interactions when teaching about energy transfer so that students do not develop the notion of it being one-sided. Have students identify the materials or objects involved in the interactions.
- Instruction on heat and heat transfer should be carried out over the long term and not done in one short unit. These are difficult and abstract ideas, and it takes time and multiple experiences for students to use these ideas scientifically.
- High school students should have multiple opportunities to use heat energy transfer ideas in multiple contexts, including chemical, nuclear, geologic, and biological contexts. Revisiting heat transfer ideas reinforces the concept and helps students see how powerful the “big idea” of energy transfer is in explaining a wide range of phenomena.

Related NSTA Science Store Publications and NSTA Journal Articles

- American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy*. New York: Oxford University Press.
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- Driver, R., A. Squires, P. Rushworth, and V. Wood Robinson. 1994. *Making sense of secondary science: Research into children's ideas*. London: RoutledgeFalmer.
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Related Curriculum Topic Study Guides

(Keeley 2005)

“Energy”

“Heat and Temperature”

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