GENERATIONGENIUS
ALWAYS QUESTION. ALWAYS WONDER.

TEACHER GUIDE

HEAT: TRANSFER OF THERMAL ENERGY
GRADES 6-8

COMMON MISCONCEPTIONS

- **Temperature is a property of a particular material or object. (For example, students may believe that metal is naturally cooler than plastic.)**
  Temperature is not a property of materials or objects. Objects exposed to the same ambient conditions will have the same temperature.

- **Cold and heat are substances.**
  Heat is the transfer of thermal energy. Thermal energy always moves from hotter areas or objects to colder areas or objects. When we touch an object, thermal energy is transferred from the hotter object to the colder object. If the object feels cold to our touch, it's because thermal energy was transferred from our finger to the object (our finger "heated" the object). If the object feels warm to our touch, the object has transferred thermal energy to our finger (the object "heated" our finger).

- **The temperature of an object depends on its size.**
  Temperature does not depend on size. If the temperature doesn't change but the mass of the object increases, the thermal energy in the object increases.

HEAT, THERMAL ENERGY, AND TEMPERATURE

Heat is the transfer of thermal energy between objects that have different temperatures. Thermal energy always moves from an object with a higher temperature to an object with a lower temperature. Thermal energy is energy possessed by an object or system because of the movement of particles within the object or the system.

Heat and temperature are two different but closely related concepts. Note that they have different units: Temperature typically has units of degrees Celsius (oC) and heat has units of energy called Joules (J). Temperature is a measure of the average kinetic energy of the atoms or molecules in the system. Temperature is also an intensive property, which means that the temperature doesn't change no matter how much of a substance you have (as long as it is all at the same temperature!). This is why chemists can use the melting point to help identify a pure substance because the temperature at which it melts is a property of the substance with no dependence on the mass of a sample.

TRANSFER OF THERMAL ENERGY

There are three methods of thermal energy transfer: conduction, convection, and radiation.

Conduction transfers thermal energy through direct contact. If two objects are placed in contact with each other, thermal energy flows from the warmer object (with faster-moving particles) to the cooler object (with slower-moving particles). When the faster particles collide with the slower particles, they transfer some of their energy to the slower particles.

Convection transfers thermal energy through the movement of fluids or gases in circulation cells. A pot of water heated on a stove provides an example. The pot itself, and then water at the bottom, becomes heated by conduction. When water is heated, it expands, becomes less dense, and rises up through the surrounding cooler water. The cooler, denser water then sinks to the bottom of the pot where it, in turn, is heated. The convection current—the circulating path of hot water rising and cold water sinking—transfers thermal energy by actually moving the warmer water to a new area. It also forces the warmer water to mix with the cooler water and promotes further conduction by bringing the cooler water to the bottom of the pot.

Radiation transfers energy by electromagnetic waves, a method that operates even in the absence of matter (through outer space, for example). When electromagnetic radiation strikes an object, the energy carried by the electromagnetic wave is transferred to the object, causing the particle motion within the object to increase. A microwave oven, for example, emits microwave radiation to transfer thermal energy to food. Similarly, the reason that you can feel the warmth of an object at a distance, such as the Sun or a light bulb, is because of transfer of thermal energy by radiation. Although all matter emits and absorbs electromagnetic radiation, some materials are better at absorbing radiation than others. Shiny surfaces, for example, tend to reflect rather than absorb radiation.

HEAT CAPACITY

If a swimming pool and a wading pool, both full of water at the same temperature, were subjected to the same input of heat energy, the wading pool would rise in temperature more quickly than the swimming pool. The heat capacity of an object depends on both its mass and its chemical composition. Because of its much larger mass, the swimming pool of water has a larger heat capacity than the wading pool.

Different substances respond to heat in different ways. If a metal chair sits in the bright sunlight on a hot day, it may become quite hot to the touch. An equal mass of water in the same sunlight will not become nearly as hot. Water has a higher heat capacity than metal, which means it takes more heat to raise the temperature of water 1°C. The specific heat of a substance is the amount of energy it takes to raise the temperature of 1 g of a substance 1°C. For example, liquid water has a specific heat of 4.18 J/g°C and aluminum's specific heat is 0.897 J/g°C. It takes almost 5 times the amount of heat to raise the same mass (1 g) of water compared with 1 g of aluminum.

TEACHER TIPS

If the class hasn't generated criteria for sound experimental design, lead them in a quick discussion to create a list of criteria each group can use. The quality of the experimental design affects the validity and reliability of the data.

- Ask, "What materials can you test to see if they will keep the beverage in the can colder longer?" (This will be the independent variable. Students should suggest different materials to use to wrap the can in after it is removed from the refrigerator based on experience and ideas about insulators. You can focus their ideas by sharing the materials you brought for them to try.)
- Ask, "How can you measure that?" (Students should suggest measuring the temperature of the beverage in the can as soon as it is removed from the refrigerator and at different time intervals after the can has been wrapped in the material.)
- Ask, "What variables need to stay the same?" (The kind of can and the kind of beverage need to stay the same. One can should not be wrapped in any material to serve as a control for comparison.)

- Ask, “How many trials do you need to feel confident in the data?” Tell students that each group will be testing all the materials, so if they pool their data, they will have conducted (# of groups in class) trials. Ask students if they feel this number of trials is adequate? Why or why not?

Although students will say that heat is transferred from where this is more (higher temperature) to where there is less (lower temperature), they struggle to use their observations and data to explain thermal energy transfer. They may find it helpful to develop and use a model to help explain what is happening with the transfer of thermal energy in the beverage-can-material system.

ABOUT THIS LESSON

This lesson was created by the National Science Teaching Association (NSTA) to pair with the Generation Genius video and support *NGSS*.

They have requested we provide the following background with this lesson:

The Next Generation Science Standards (NGSS) are the national standards on how students learn science, and they are based on contemporary research presented in *A Framework for K–12 Science Education (the Framework).* The shift in science teaching and learning required by the Framework is summarized in this infographic: A New Vision for Science Education.

At the start of each Generation Genius lesson, students are presented with a phenomenon, then they try to explain it. Students will notice they have gaps in their knowledge and ask questions, which motivates them to build ownership of science ideas they need in order to explain how or why the phenomenon occurred. The way students build ownership of science and engineering ideas is through active engagement in the science and engineering practices (SEPs). This process of sensemaking, or doing science to figure out how the world works, is one of the major shifts the *Framework* encourages.

To engage in the SEPs, students should be part of a learning community that allows them to share their ideas, evaluate competing ideas, give and receive critiques, and reach consensus. Students can start by sharing ideas with a partner, then with a small group, and finally, with the whole class. This strategy creates opportunities for all students to be heard, build confidence, and have something to contribute to whole-class discussions. Each Generation Genius lesson provides conversational supports to facilitate such productive student discussions to contribute to sensemaking.

Excited to continue your shift toward the new vision for science education? Check out the Generation Genius Teacher Guide page on the NSTA website for resources and strategies to engage every student in your classroom in **doing** science.