Lesson Plan: What Makes Something Feel Warm?
Modeling Energy Transfer: A Macroscopic and Particulate View

FOR THE TEACHER

Instructional Notes and Answers
Refer to subsequent pages for possible responses to the student questions. Keep in mind that in many of the questions, the answers may vary and are not limited to what is provided in this teacher's guide. Student answers are shown in red. Instructional notes are bold.

Warm up:

1. **The Sweater:** This winter was soooo cold. My mother told me to “put on a sweater, because I'm cold”. Why do mothers tell their kids to put on a sweater? What is it about the sweater that keeps them warm? 
   
   *Initial answers will vary, but this question is designed to get students thinking about energy, heat, temperature and thermal energy transfer. Sweaters are constructed of materials with low rates of thermal conduction. The fibers or fabric generally allow for plenty of air spaces or pockets in the garment. The air pockets in the sweater provide insulation so that the thermal energy is not transferred to the atmosphere. The thermal conductivity of air is only 0.00025 W/cmK*

   **NOTE:** This first question is an elicitation activity. When you listen to the answer it is likely that you will find out who knows something about insulation and who has the view that the sweater “contains” heat.

2. **The Forgetful Chef** has a problem. The chef needs to thaw the chicken as quickly as possible, but doesn’t want to heat it in the microwave or in hot water because it might pre-cook the meat. Below is a list of materials the chef has in his kitchen that he is considering placing the chicken on. Which one do you think might be the best option? Explain your choice.
   - Wooden Butcher Block
   - Granite countertop
   - Aluminum baking pan
   - Glass bowl
   - Plastic container with cold water
   - Kitchen towel

   *Initial answers will vary, but this question is designed to get students thinking about energy, heat, temperature and thermal energy transfer. This is where you can segue the conversation by indicating that we need to explore some properties of materials in order to figure out what the best solution is for our chef.*
Exploration #1: Observe the Properties of Materials

Step 1: Observe each of the tiles. Consider how you can use different senses to make observations.

3. Record your observations.
   *Students will probably feel that one feels “colder” than the other.*

4. Which tile feels warmer? ______________
   Plastic tile

5. Based upon your initial idea about the sweater:
   a. Predict which tile (A or B) has a higher temperature, if either: ________________
      Plastic tile
      *It is a good idea to check that all students have individually made predictions BEFORE giving them the thermometers*

   b. Predict the actual temperature of each tile:
      Tile A: ________________ Tile B: ________________
      *Initial answers will vary; most students will predict that the plastic tile has a higher temperature than the aluminum tile.*

Step 2: Test your temperature predictions. **Flip the tiles over** and use an IR thermometer to test the temperature of each tile. Record the temperatures:

   Tile A: ________________ Tile B: ________________
   *Answers will vary, but the temperatures should be the same or nearly the same for both tiles.*

   **NOTE:** Students should flip the tiles, because the temperatures will change as the touch them.

6. Did your prediction match the actual temperatures of each tile?
   *Answers will vary.*

7. What do you think temperature measures?
   *Answers will vary. Here it may be difficult for them to answer. Many students think that temperature is the measure of how hot or cold something is which isn’t wrong if we are talking about keeping the material the same. However, it should be clear from the data that temperature is related to how hot or cold something is, but there must be something more*

8. Try to explain your results. Consider both drawing a picture and writing your ideas about what may be happening.
   *Hopefully students will consider that there is a transfer of energy from something that is hot to something that is cold. It appears that the tile that felt cold transfers the energy more effectively.*

9. Share your ideas with a partner. Try to come to a consensus about your explanations. Record any new ideas that support your initial explanation about what may be happening.
   *Students initially think the aluminum tile is cold because it feels cold. But the aluminum tile is at room temperature. However their fingers are warmer*
(~98°F) so there is thermal transfer from the hotter finger to the ‘colder’ tile. When this happens our finger feels ‘cold’. The same thing happens with the other tile, but the big difference is the rate of thermal energy transfer.

IMPORTANT NOTE: Temperature is not a measure of heat. If it were, both tiles would melt the ice equally. So, this is the place where you can define temperature as the measure of average kinetic energy of the particles. See the “What is Temperature? Demonstration” to help students with this concept. At this stage it is ESSENTIAL that all students are clear that temperature is a measure of average kinetic energy, and not a measure of heat.

Step 3: Prediction
10. Suppose you were going to place an ice cube on each tile. Based on your explanation in the previous step, predict which tile (A or B) will melt the ice cube faster, if either. Describe your prediction.
   Students typically predict that ice will melt faster on the polystyrene tile because it feels warmer.

NOTE: It is a good idea to check that all students have individually made predictions BEFORE distributing ice.

Exploration #2: Observe Ice on Material

Step 4: When your teacher indicates, place one ice cube on each tile. Make observations of the ice on each of the tiles.
11. Record your observations.
   The ice cube melts much more quickly on the aluminum tile.

12. Record the temperature of the Tiles, after 2 minutes.
   Tile A: _____________ Tile B: _____________
   **Tile A temperature is lower than Tile B**

NOTE: This evidence that the temp of the metal tile is much lower shows that there was more kinetic energy transferred to the ice.

13. Individually.
   NOTE: Provide students time to think about these questions individually; you will like find that the discussion is richer when more students have had time to think about these things.

   a. Summarize the results of all your observations so far in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Tile A</th>
<th>Tile B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling</td>
<td>Feels cool</td>
<td>Feels warm</td>
</tr>
<tr>
<td>Temperature (before ice)</td>
<td>Answers will vary, around room temp</td>
<td>Around room temp</td>
</tr>
<tr>
<td>Ice melting (Relative rate of melting)</td>
<td>Melts very fast</td>
<td>Melts very slowly</td>
</tr>
<tr>
<td>Temperature (after ice)</td>
<td>Temp of tile is lower than room temp, much lower than Tile B</td>
<td>Temp of Tile B is lower than room temp, but not by much</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------------------------------------------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>Other observations:</td>
<td>Students might record observations about density, color, texture</td>
<td>Students might record observations about density, color, texture</td>
</tr>
</tbody>
</table>

b. Given temperature is a measure of average kinetic energy of the particles. What can you conclude about the average kinetic energy of Tile A and Tile B before the ice was placed on them?

Average KE is the same before the ice is placed on the tiles.

c. What do you think happened to the kinetic energy of the particles in Tile A compared to Tile B after the ice was placed on them?

Tile A is the aluminum tile, and the temperature will be much lower than that of Tile B. Therefore Tile A lost more KE.

d. Refine your explanation (about the tiles you made in question 9) in light of these new observations.

Answers will vary, though most students should have some idea that there was more KE transferred to the ice placed on Tile A. Some may even begin to discuss how the particles of ice are increasing in energy so they will melt; and the particles in the tile are slowing down.

Step 5: Explanation

Now share your ideas with your group. As a group, think about how the difference in melting time can be explained in terms of the behavior and interaction of the particles that make up the tiles and the ice. The model you develop should explain your observations.

Use the questions below as a guide for developing your model. Represent your model using a set of particulate drawings that describe the interactions between ice particles and tile particles. A written explanation should be included.

- How do the particles that make up the ice interact with the particles that make up the tile?
- How does the behavior of the particles that compose the tile change when the temperature of the tile changes?
- Consider the role that energy plays in your model. How is energy transfer represented in your model?

Be prepared to share out your models and discuss your group’s ideas with the class.

Note: Answers will vary. As you observe the responses, some students will think about the particles of the Tile A, and consider that they are more dense, so that they can transfer the KE more easily. This is partially true. Some students will think that Tile A has a high Conductivity than Tile A which is also true. Guide students to coming up with the idea that the Particles in the tile must be in contact with the particles in the ice in order to transfer the energy. When the energy goes from the tiles to the ice the particles slow down, losing KE to the ice. In Session 2 we will model the ice melting. :)
NOTE: Here is a good place to introduce the concept of specific heat capacity if appropriate for your students. Please see “Dramatic Demonstration of Thermal Conductivity and Specific Heat Capacity” or “Measuring Heat Demonstration” for ideas on how to extend.

Analysis Questions:
NOTE: These questions can be used as formative assessment, in class discussion or homework.

14. Why do you think it was necessary to flip the tile over after feeling the tiles and before measuring the temperature?

Students’ hands may provide localized regions of higher temperature. Since there is a transfer of Thermal energy from the hand to the tile, we might see a change in the tiles temperature after the students have been feeling it.

For the next two questions, use macroscopic ideas (like temperature, phase change, etc.) to help with your explanations.

15. Tile A conducts thermal energy better than the tile B. (We call Tile A a thermal conductor) What does it mean to conduct thermal energy? Your explanation can include a written description or well-labeled drawing.

Thermal energy is transferred from a warmer object (Higher temperature) to a colder (lower temperature) object. A better conductor has a faster rate of transfer. The particles of tile A will hit the colder objects, and impart energy to those colder particles. The result is on average, the kinetic energy of the particles in Tile A will lose KE at a faster rate. (If the particles in Tile A are in contact with something warmer, then they will gain KE as the particles collide)

At the most basic level, it is hard to explain why one substance is more able to conduct thermal energy. It has to do with the atoms that make up the substance interact.

16. A good insulator is the opposite of a conductor. What do you think it means if something is a good insulator? Your explanation can include a written description or well-labeled drawing.

Thermal energy is not rapidly transferred from the hotter to the colder object.

17. Do you think something that feels warm, like the sweater, is a conductor or an insulator? Explain your answer.

If you hand is at a higher temperature than the “thing” energy will transfer from your hand to the “thing” If there is a warm feeling, the energy from your hand is not leaving as efficiently, so the warm thing must be an insulator?