Lesson Plan: Designing & Engineering a Fast Defroster for the Forgetful Chef

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.

Step 1: Instructions, Defining the Problem, Developing Solutions
You may want to start with the forgetful chef problem from the beginning of the Modeling Energy Transfer Lesson Plan:

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.

You will have a variety of materials to use.
1. Write down your initial ideas about the materials that you want to use and explain why you are choosing these materials based on the ideas that you uncovered in the first part of this session.
   Once again, we strongly encourage students to use their understanding of scientific principles to guide their design. Check to see that students have an explanation for their choices.

Step 2: Building
Using the plan you decided upon with your group, build your 2 prototypes.

If each group is made up of 4 people, then the group can be divided to build the prototypes so that more students are involved in building, and so that the prototypes may be tested 2 times.

Step 3: Optimizing: Testing Protocol
In your design teams, brainstorm testing strategies to present to the class. We will engage in a class discussion that will generate our testing protocol.

2. Record the protocol here:
   Answers will vary here. Be sure that the entire class is clear on the protocol, and clear on why it is essential that all of the prototypes are tested in the same way.
Step 4: Optimizing: Testing and Comparing Solutions
Test your prototype. Make sure your results are reliable and reproducible.

3. Record results and analysis of your testing.
   Answers will vary depending on the prototype. You may choose to have the students keep a record of the testing in their notebooks as well.

4. Describe any modifications you would make to your plate if you had any other necessary resources available.
   Answers may vary.

Repeat for a prototype from another team. Provide the other team with the data generated in testing, as well as any suggestions for improvement.
   Students will be asked to share their testing data and suggestions with the other team.

Step 5: Optimizing
Make modifications to your device, and re-test.
   The modifications should address the testing done by the inventors, and other team that tested the prototype.

5. Record your observations.
   Answers will vary.

6. Did the modifications help? Defend your answer.
   Answers will vary. Sometimes modifications don’t actually improve results, and that is FINE.

7. Do you think you could make more modifications if you had the time? If so, what would they be?
   Answers will vary, but they should be related to the results of the final tests.

Analysis Questions:

8. Based on your experiment and your models, describe how thermal energy is transferred. Insulators 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/cm-K. In this experiment we do just the opposite. The fast defroster needs to be made of materials that are excellent thermal conductors.
   
   In order for thermal energy to be transferred, molecules must come into contact with each other. The transfer of energy occurs continuously on a particulate/molecular level. Particles with greater kinetic energy collide with particle with lower kinetic energy and transfer some of that energy. The idea is that energy can move from one atom to another in a given system randomly until an equilibrium state exists.

9. Are there possible aspects of thermal energy transfer that your model did not account for?
   Other factors could include the area of contact, color, and the total mass of the defroster.
10. During the engineering process, did your ideas about thermal energy transfer change? Explain.
   Answers will vary.

Assessment:
11. Think again about the Forgetful Chef warm up question. Which of the following materials would you suggest the chef use to defrost the chicken? Use your model, ideas from this activity and the data in the table below to support your response.
   - Wooden Butcher Block
   - Granite countertop
   - Aluminum baking pan
   - Glass bowl
   - Plastic container with cold water
   - Kitchen towel

According to the data, aluminum is a good choice because it is the best thermal conductor. Water is a good choice because of its high specific heat capacity, so it will require more energy to change its temperature. Water also covers the food more effectively. Wrapping the food in something that feels warm like a dish towel is not a great choice because of the insulating properties.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Conductivity (W/mK)</th>
<th>Specific Heat Capacity (J/g °C)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminum</td>
<td>237</td>
<td>0.90</td>
<td>2.70</td>
</tr>
<tr>
<td>Water</td>
<td>0.6</td>
<td>4.18</td>
<td>1.00</td>
</tr>
<tr>
<td>Wood, white oak</td>
<td>0.209</td>
<td>2.39</td>
<td>0.83</td>
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<tr>
<td>Glass, pyrex</td>
<td>1.13</td>
<td>0.73</td>
<td>2.22</td>
</tr>
<tr>
<td>Granite</td>
<td>2.51</td>
<td>0.75</td>
<td>2.65</td>
</tr>
<tr>
<td>Wool, Felt</td>
<td>0.07</td>
<td>1.38</td>
<td>1.31</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.04</td>
<td>1.30</td>
<td>1.56</td>
</tr>
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