A Watched Pot

LESSON OVERVIEW

Students learn about thermal energy transfer and energy efficiency first by watching a three minute Inside Energy video that puts the concepts in terms of their daily lives (*A Watched Pot: What is the Most Energy Efficient Way to Boil Water?*). Students then dig deeper as they explore how thermal energy transfer varies for different materials in a hands-on lab and connect their new understanding to the video and the real world through a class discussion and/or lab write-up. Finally, students are challenged to apply their new knowledge to design an energy-efficient product to boil water. The lesson is organized using the 5E Instructional Model. While each section builds upon the previous, educators may find that they only need to use one or two sections to meet their teaching goals.

LEARNING OBJECTIVES

Students will:

- Explore the concept of thermal energy transfer.
- Understand that thermal energy transfer depends upon the material.
- Connect the physics concept of thermal energy transfer to real world cases and problems and consider the impacts of engineering choices on efficiency, energy use, and the environment.
- Apply new understanding to design a product that reduces thermal energy transfer.

GRADE LEVELS: 6-8

KEY VOCABULARY/CONCEPTS

- Energy transfer
- Energy transformation
- Heat
- Heat Conduction
- Heat transfer
- Thermal Conductivity
- Metal electrode

CREDITS: Lesson developed by Tiffany Kapler. Multimedia developed by Inside Energy.

MULTIMEDIA RESOURCES

A Watched Pot: What is The Most Energy Efficient Way to Boil Water? [Video]

SUGGESTED TIME: 3-4 days*

- Day 1: Engagement and Exploration
- Day 2: Explanation
- Day 3: Elaboration
- Day 4: Elaboration (student feedback with possible redesign)

  **Timing may vary if part of the Elaboration phase is assigned as homework.*

MATERIALS

- Metal electrodes of different compositions (copper, aluminum, iron, stainless steel, etc.) *Electrodes should be the same size.*
- Fine-tip permanent markers
- Styrofoam coffee cups with lids
- Infrared thermometers
- Rulers
- Boiling water (or sufficiently hot water)
- Scissors or razor blades

LESSON PREP

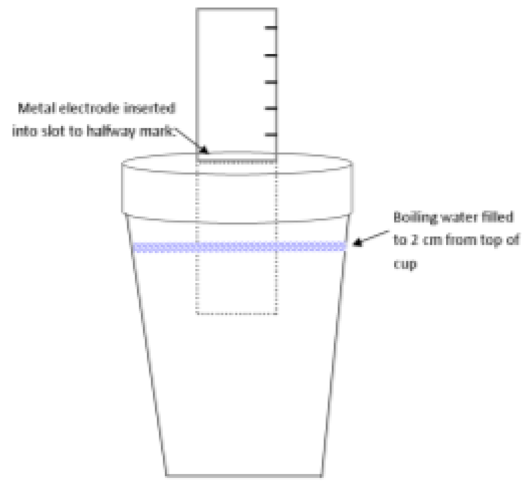
Heat water ahead of time, so that water is at boiling temperature when students are ready to begin the Exploration investigation. If safety is a concern, teachers may also want to cut slots in coffee cup lids ahead of time.

THE LESSON

Engagement	View the video *A Watched Pot: What is the Most Energy Efficient Way to Boil Water?* Also have students read the text that accompanies the video. Discuss the following: • What is happening when water boils? • How is energy transferred and/or transformed in each of the methods discussed for boiling water? Ultimately, how is the water heated? • What is heat? How does heat transfer? • Why might the efficiency of an electric stovetop depend so much on the type of kettle used? **Evaluate** the discussion for current understanding as well as misconceptions. Use these points to focus and redirect during the Exploration and Explanation phases.
Exploration	Allow students to explore heat transfer (conduction) through various metals. 1. Assign student groups between one and four materials to investigate for heat conduction and distribute metal electrodes. 2. Have students prepare metal electrodes by measuring and marking the middle of the electrodes with a fine-tip permanent marker. On one half of the metal electrode,

students should also make small marks to indicate 1, 2, 3, 4, and 5 cm away from the center mark.

3. Students should also prepare coffee cup lids by cutting a slit just long enough for the metal electrode to slide through. The fit should be snug so that the electrode does not slip down once the lid is fitted on top of the coffee cup. See diagram for final set-up.



4. Before filling cup with boiling water, set up the cup with lid and metal electrode and have students use the infrared thermometer to measure the temperature of the metal electrode at each of the centimeter marks. Data should be recorded at Time=0 minutes in a chart similar to the example:

		Temperature °C					
Metal	**Distance**	**0 minutes**	**1 minute**	**2 minutes**	**3 minutes**	**4 minutes**	**5 minutes**
Copper	1 cm						
	2 cm						
	3 cm						
	4 cm						
	5 cm						
Steel	1 cm						
	2 cm						
	3 cm						
	4 cm						
	5 cm						

5. ***Remind students that the water will be hot and that they should use caution when filling and/or transporting the water around the classroom.***

6. Fill cups with hot water to 2 cm from the top. *Water level should be consistent for all groups and should be high enough that the metal electrode dips at least 1 cm into the water.* Tightly fit the lid with a metal electrode inserted snugly in the slot.

	7. Begin timing immediately, and use the infrared thermometer to measure temperatures at each of the centimeter marks every minute. Take temperature readings and record data for 5 minutes. 8. If groups received different metals, have groups share out all data. 9. Students should study the data and consider different ways of presenting the information graphically. Does it make the most sense to compare all of the different metals at the same distance to show the difference over time? Or does it make more sense to compare the different metals at the same point in time, but show the difference at the various distances? Once they have chosen one or more comparisons to show, they should create one or more graphs to demonstrate their data. Teacher can use lab time to observe and converse with students to **evaluate** their understanding of heat transfer and energy transfer, as well as their understanding of their results.
Explanation	In a class discussion and/or lab write-up students should be able to explain their results. Guiding questions and discussion prompts might include: • Did the various materials vary in how heat transferred from the water and through the material? In what way(s)? • Define “heat conduction.” How did the lab activity demonstrate heat conduction? • The characteristic of a material that describes how well it conducts heat is known as its thermal conductivity and is expressed as a value *k*. Consider the chart of thermal conductivity values in the Teacher Resources section of this lesson. Compare the chart to your lab results. What kind of results would you expect if you used other materials to conduct heat? • How could you apply this information and understanding if you were challenged to engineer a product that requires that heat be transferred quickly? Slowly? Give examples. • Based on your data, which material would you choose to construct an efficient stovetop tea kettle? Why? • Even if you could create a highly efficient tea kettle, explain why there would still be a loss of heat energy when you boiled water. Where would the heat go? • Why does this information matter? What are the impacts of inefficient energy use for something as simple as boiling water? Teacher and students should **evaluate** student understanding of the concepts with a specific focus on heat/energy, heat transfer, and conduction.
Elaboration	Challenge student groups to design a product that would be as efficient as possible in boiling water. They may choose to design a stovetop tea kettle or something else. They should consider their Exploration results, the Explanation discussion, and the information presented in the *A Watched Pot* video and text. Students may also choose to complete additional internet or library research to inform their design. While students will not actually construct their products, their designs should be complete and include appropriate diagrams and/or a prototype with dimensions, specification of building materials, and explanations of their choices.

	Have students present their designs in small groups for feedback from other students. The feedback can be used to update/redesign the product given concerns and other considerations. The final assignment should include the original design, notes on why changes were made, and the final design. **Evaluate** student understanding of concepts as they apply what they have learned and consider what they still do not know. Student feedback groups are also a good time to check for understanding.
Evaluation	Teacher and students should evaluate student learning throughout the lesson.

TEACHER RESOURCES

BSCS 5E Instructional Model[1]
The BSCS 5E Instructional Model: Personal Reflections and Contemporary Implications[2]

Thermal Conductivity	
Material	**k (W/m/ºC)**
Solids	
Aluminum	237
Brass	110
Copper	398
Gold	315
Cast Iron	55
Lead	35.2
Silver	427
Zinc	113
Polyethylene (HDPE)	0.5
Polyvinyl chloride (PVC)	0.19
Dense Brick	1.6
Concrete (low density)	0.2
Concrete (high density)	1.5
Ice	2.18
Sand	0.06
Cellulose	0.039
Glass Wool	0.040
Cotton Wool	0.029
Sheep's Wool	0.038
Cellulose	0.039
Expanded Polystyrene	0.03
Wood	0.13
Liquids	
Acetone	0.16
Water	0.58
Gasses	
Air	0.024
Argon	0.016
Helium	0.142
Oxygen	0.024

[1] https://bscs.org/bscs-5e-instructional-model
[2] http://static.nsta.org/files/sc1408_10.pdf

STANDARDS ALIGNMENT

Colorado State Science Standards

SC09-GR.8-S.1-GLE.2 There are different forms of energy, and those forms of energy can be changed from one form to another – but total energy is conserved.

Next Generation Science Standards

MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

MS-PS3.A: Definitions of Energy

- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

MS-PS3.B: Conservation of Energy and Energy Transfer

- When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3)

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

National Standards – Benchmarks for Science Literacy

4E/M2 (Grades 6-8): Energy can be transferred from one system to another (or from a system to its environment) in different ways: 1) thermally, when a warmer object is in contact with a cooler one; 2) mechanically, when two objects push or pull on each other over a distance; 3) electrically, when an electrical source such as a battery or generator is connected in a complete circuit to an electrical device; or 4) by electromagnetic waves.

4E/M4 (Grades 6-8): Energy appears in different forms and can be transformed within a system. Motion energy is associated with the speed of an object. Thermal energy is associated with the temperature of an object. Gravitational energy is associated with the height of an object above a reference point. Elastic energy is associated with the stretching or compressing of an elastic object. Chemical energy is associated with the composition of a substance. Electrical energy is associated with an electric current in a circuit. Light energy is associated with the frequency of electromagnetic waves.