

Thermal Energy-Save the Penguins

Teacher Lesson Plan



Background Information

Save the Penguins is a series of three activities investigating the transfer of thermal energy. This is done in the context of the changes to penguins' ecosystem in the southern hemisphere due to climate change. The earth's average temperature has risen 1.4°F over the last century. Scientists believe the earth's temperature will continue to rise over the coming decades. What is causing the climate to warm? Some claim we are in a natural warming cycle. Others maintain it is due to human's increased use of burning fossil fuels for transportation, electricity generation and industry. The carbon dioxide is a byproduct of burning fossil fuels. It has the ability to absorb heat and release it slowly over time. The annual rate of increase in atmospheric carbon dioxide over the past 60 years is about 100 times faster than previous natural increases, such as those that occurred at the end of the last ice age 11,000-17,000 years ago. (NOAA)

The goal of this lesson is not to debate climate change, but to encourage students to consider energy conservation and efficiency. Two truths are non-debatable in most circles:

- When we conserve energy, we also save money.
- When we use energy efficiently, we conserve earth's limited non-renewable resources (coal, natural gas, nuclear, petroleum, propane).

The lessons will study the transfer of thermal energy by exploring insulators and conductors. The culminating activity has students working cooperatively in a design challenge. At the completion of the unit, students will be encouraged to brainstorm ways to decrease their energy use and help reduce risks from a warming climate to both human and animal populations.

Student Activities

LESSON 1: Introduction and Insulation

Learning Targets:

1. Heat transfers from areas of high temperatures to areas of lower temperature.
2. Insulators slow down heat transfer.
3. Engineers must identify the problem in order to solve it.

Purpose of the Lesson:

- Introduce students to the environmental conditions affecting penguins, how global climate change has been tied to energy consumption, and the role engineering can play in helping both the environment and penguins as well as saving energy consumers money.
- Provide a series of demonstrations related to heat transfer that allow students to form an understanding of insulation, heat, and temperature.

Lesson Objectives:

At the end of this lesson, students will be able to:

- Explain that global climate change is related to warmer temperatures and loss of ice at the Earth's poles.
- Explain how humans may be contributing to global climate change.
- Brainstorm ways engineers might be able to reduce energy use through the design of more energy efficient buildings.
- Define heat as the transfer of thermal energy.
- Define temperature as an indication of how hot or cold it is in a particular location.
- Explain the difference between heat and temperature. Heat is the transfer of thermal energy. Heat moves from an area of high energy to one of lower energy until equilibrium is achieved. Temperature can be measured with many different scales such as Fahrenheit or Celsius, and it is a measure that indicates the thermal energy there is at a particular point.
- Demonstrate that some materials are better insulators than others, i.e. wool insulates better than cotton. Insulators reduce heat transfer.
- Apply knowledge that some materials are better than others at reducing the transfer of thermal energy than others.
- Compare different materials to determine which ones are better at reducing heat transfer.

Background:

Heat: Heat is the transfer of thermal energy. Thermal energy exists when something is in motion, and when the atoms or molecules in a substance vibrate. Atoms and molecules have kinetic energy, which produces thermal energy. The amount of thermal energy something has is the sum of the kinetic energy of all the particles. That's why a bathtub of water has more thermal energy than a sink of water when the water is the same temperature in both. As something loses thermal energy, these vibrations slow down. As something gains thermal energy, these vibrations increase. If enough thermal energy is added to a substance, the vibrations may even cause a solid material to lose its form and melt, or a liquid substance to evaporate, or a gaseous substance to expand as the distance between particles increases. Thermal energy can be transferred from one place to another when there is a temperature difference. Heat transfer always occurs from a place where there is a higher temperature to a place where it is cooler until equilibrium is achieved. Heat transfer in a bathtub occurs from the hot water to the cooler air, to the cooler floor, to the cooler tub sides, and to the cooler person in the water.

Heat is the study of:

- processes by which thermal energy is exchanged between two bodies
- related changes and resulting states of those bodies

Heat is primarily focused on:

- temperature differences between places or things
- flow, or the movement of thermal energy

Heat is driven by:

- differences in temperature; heat transfers from high to low energy regions

Temperature: Temperature is a measure of the average kinetic energy that the particles in a substance have at a particular location. We call high average kinetic energy “hot” and low average kinetic energy, “cold.” There are many scales used to measure temperature. In the Kelvin scale, 0 degrees Kelvin represents the absence of all kinetic energy, the absence of all molecular or atomic vibrations. A cup of boiling water may have a higher temperature than a bathtub of warm water because the average kinetic energy of the particles is higher. However, if you were to sum up the kinetic energy of all the water molecules in the tub, it would no doubt have a higher total thermal energy. Both the Celsius and Fahrenheit temperature scales are based on the boiling and freezing point of water. On the Celsius scale, water freezes at 0° and boils at 100°. On the Fahrenheit scale, water freezes at 32° and boils at 212°.

Heat Insulator: A material that reduces the rate of heat transfer.

Heat Conductor: A material that increases the rate of heat transfer.

Lesson Materials:

- 6 drinks (all the same), cooled in a refrigerator overnight; 6 water bottles or 6 cans of pop
- Refrigerator Thermometer
- 1 Wool Sock/Cloth
- 1 Cotton Sock/Cloth
- 1 roll Paper Towel
- 1 roll Plastic Wrap
- 1 material for “class choice” Bubble wrap was used at the teacher professional development.
- 6 Digital Thermometers
- Student Lab Sheet and colored pencils

Preparation:

- Refrigerate a six-pack of bottled water or soft drinks in a refrigerator overnight. Water bottles work best since they can be resealed. You may also measure the temperature of the refrigerator. Most are ~40 degrees F.

Procedures:

1. Pose the following dilemma to the students:
You are going on a field trip and must pack a lunch to take with you. You put a cold drink in your lunch bag in the morning, but when you opened your lunch later that day it was warm!
What happened?

2. Discuss the difference between heat and temperature. Have each group write the definitions of Heat and Temperature in the boxes on their lab sheets.
3. Tell students that you have designed an experiment with some things found around your house that you thought might be good at keeping a drink cold. Sample materials are suggested, or students can select their own. One bottle is the control.
4. Have students rank the materials from most effective to least effective at keeping the drinks cold and complete the question: Why do you think your top-ranked material will work the best?
5. Take the initial temperature as soon as you take the drinks out of the refrigerator. Have the students record on their worksheet. Then have the students wrap the drinks and place in the lunch bags. (*Teacher Note:* You want only one layer of each item wrapped as tightly as possible. You can use rubber bands to hold items in place.)
6. At the end of class (at least 30 minutes) record the final temperature, but do not unwrap the cans. Invite student volunteers to insert digital thermometers and record the temperatures on the data table.
7. Have them create a bar graph of their results. They should make a color-coded key for starting and final temperatures.
8. Discuss results with your students and have them answer the questions and discuss.
9. Show graphics of insulation in nature, around the home and for ourselves.
10. To reinforce that thermal energy always transfers from higher energy to lower energy, use the “*What is the Direction of Energy Transfer*” Graphic. Using the red arrows, have students show which direction thermal energy is moving.

Teacher Note: Now is a good time to address the following misconception students may hold about heat transfer.

“Keeping the Cold In” Misconception: A student may believe that their method will keep the cold in the can. To address this misconception, remind them that only heat (not cold) transfers. If only heat can transfer, what is their method really doing? Ultimately it is keeping the heat out of the can NOT keeping the cold in the can.

“Wool Adds Warmth” Misconception: A student may think that the wool sock will warm up the soda can. This misconception stems from the idea that warm clothing, like wool socks, supposedly warms up their feet in the wintertime. To address this misconception, explain to students that when you put on socks, your feet feel warmer because the socks are trapping in the heat your body is emitting, they are not producing their own heat. Ask students “How would this sock keep a soda warm?”

“Traditions” Misconception: A student may believe that aluminum foil will work the best because students may have witnessed their parent wrapping sodas in aluminum foil in the past. To address this misconception, remind students that traditions get passed down for generations without question and that today they will have the opportunity to question the tradition.



Teacher Note: All of the materials in the demonstration can be considered insulators to some extent because they all performed better than the control. However, wool and plush paper toweling are the best insulators because they trap air and prevent the air from moving around. In fact, paper is made up of dried up hollow cells from plant matter allows for many pockets of trapped air. Several real-world examples of insulators students may be familiar with include:

- Pink or yellow fiberglass insulation is used in houses because it has a great ability to trap air.
- Builders may blow paper pulp into attics to keep heat from transferring into or out of a house.
- Dog shelters line kennels with shredded newspaper or wood shavings to prevent the thermal energy from the animals' bodies from escaping.

Teacher Note: Some materials used in this demonstration may be equivalent insulators. Therefore, a second measurement may help discriminate the small differences between some materials. If you don't have time to repeat the measurements with your class, you can do it yourself or use the same water bottles all day with different classes and report the values the next day for further discussion.

LESSON 2: Heat Transfer by Conduction

Learning Targets:

1. Heat transfers by conduction.

Purpose of the Lesson:

1. Introduce students to the concept of heat transfer through conduction. Let them know there are two other methods of heat transfer: radiation and convection.
2. Provide a demonstration related to heat transfer that allows students to understand how:
 - a. Heat transfers from warmer to cooler objects
 - b. Certain materials are better heat conductors than others

Lesson Objectives:

At the end of this lesson, students will be able to:

- Define conduction as the transfer of thermal energy through a solid material.
- Explain that thermal energy moves from areas of higher temperature to areas of lower temperature.
- Demonstrate that some materials are better conductors than others, i.e. metals conduct heat better than plastic.

- Explain that thermal energy transfers through solid materials because vibrating atoms collide with each other.

Background:

Conduction: Conduction is the way thermal energy transfers from one substance to another by direct contact. It can be the direct contact between solids, or between a solid and a fluid. Kinetic energy is transferred as the higher temperature atoms or molecules vibrate and collide with cooler atoms or molecules, warming them up and increasing their kinetic energy. “Warmth” is an indication of how much kinetic energy is at the atomic level.

Convection: Convection occurs when fluids (gases or liquids) sink or rise because the cooler fluid is denser and sinks. When this happens, the cooler fluid pushes up the warmer fluid and it rises.

Radiation: Radiation is the transfer of energy in the form of electromagnetic waves. Visible light and infrared light are both forms of radiation that transfer heat.

Teacher Note: See diagrams of conduction, convection and radiation in *EnergyWorks Student Guide*.

Lesson Materials (for each group):

- 2 penguin-shaped ice cubes
- 1 metal spoon
- 1 plastic spoon
- Paper towels
- Student Lab Sheets

Preparation:

- Make penguin-shaped ice cubes the night before so they can be used in a demonstration. It is not necessary to freeze penguins using a specific amount of water for this demonstration. Be sure to freeze two penguins per group of students for each class.

Procedures:

1. Pass out a metal spoon and a plastic spoon to each group of students and ask students to place it on their cheek. Then ask the following two questions:
 - Which spoon feels cooler?
 - Which spoon do you think will work the best at keeping an ice cube cold?
2. Explain that metals (including silver or steel) are not insulators but have special properties that make them thermal conductors. Thermal conductors work just the opposite of insulators and speed up the rate of heat transfer from a warmer place to a colder place. When you touch a metal object that is colder than your body temperature, heat transfers away from your hand; thus, the metal feels cold.

Teacher Note: Both spoons are at room temperature, but students may believe the metal spoon to be colder. When posed with the second question many will predict that the metal spoon will keep the ice cube cooler because they believe the spoon to feel colder.

3. Pass out two penguin-shaped ice cubes per group. Place an ice cube in each spoon. Have each student hold one of the spoons with the ice cube on the spoon. Make observations of any change in the ice cubes and the rate the change occurred. Provide paper towels for drips.
4. Have a classroom discussion about the phenomenon students experienced. Ask students:
 - Which spoon made the ice melt faster?
 - Why do you think the metal made the ice melt more quickly?
 - What is causing the ice to melt?
 - Would a penguin shaped ice cube last longer sitting on a metal surface or a plastic surface? Why?
5. Have students complete Lab Sheet. Collect the spoons, ice cubes, and paper towels.

Teacher Note: The metal spoon feels colder because it is a good conductor. The metal is pulling heat from the students' hands thus giving them the feeling of being cold. This conduction from the hand to the spoon in turn heats up the spoon to a point that melts the ice.

6. Line six students up in front of the class to demonstrate conduction. Tell the student at one end that he is warm (perhaps a student with a red shirt), and tell the student at the other end that she is cold (perhaps a student with a blue shirt). Ask the warm student to shake from side to side and tell students that if they get bumped, they have to start shaking side to side too. Eventually all students will be shaking.
7. Ask students the following questions:
 - What do the students represent in this model?
 - What does this model tell us about the way heat transfers?

Teacher Note: This is a demonstration that allows students to model how heat transfers. The students represent atoms or molecules. The model shows students that heat transfers through solid materials because the atoms vibrate and collide with one another.

LESSON 3: Penguin Dwellings – Design and Construction

Learning Targets:

1. Materials can be combined with one another to affect the rate of heat transfer.
2. Different materials prevent different types of heat transfer.

Purpose of the Lesson:

- Design and construct prototype dwellings for penguin-shaped ice cubes based on the knowledge gained from experiments conducted on the materials that will slow down the rate of melting.

Lesson Objectives:

At the end of this lesson, students will be able to:

- Combine information about different materials to synthesize a unique design.
- Create a dwelling that reduces heat transfer and keeps a penguin-shaped ice cube from melting.

Background:

The Design Process Loop is a repetitive cycle that involves identifying a problem, brainstorming solutions, scientific research, design, testing, and re-design. There are many representations and descriptions of this process, and no one process is “right.”

Lesson Materials:

- Digital scale
- Rulers
- Penguin ice cubes (one per group)
- Tweezers or tongs
- Materials brought from home to build the penguin dwelling
- Glue, tape, scissors
- Plastic cup
- Student Lab Sheets

Preparation:

- Set up the weigh stations with tweezers or tongs.
- Determine where you will test your dwellings (outside on playground, in a sunny window, under heat lamps.)
- Make penguin-shaped ice cubes.
- Create chart on board to record the weight of the water that melted from each penguin ice cube.

Procedures:

1. Introduce challenge to class. Explain the challenge and requirements.
 - a. The penguin dwelling must be 10 cm x 10 cm x 10 cm or smaller.
 - b. The penguin ice cube will be placed in a plastic cup with a lid and must fit in the dwelling.
 - c. The dwelling must have a door to get the penguin easily in and out. It cannot be taped shut.

2. The student worksheet allows students to brainstorm different designs, make a materials list and determine who will be bringing in supplies.
3. Construct the dwelling.
4. Visit each team of students during the construction process. Discuss design decisions with each team and ensure that they are able to verbalize why they chose the materials they did for their design.
5. Draw and label your final dwelling after it is built.
6. Have students complete the pre-test measurements in Table 1.
7. Dwelling should remain on counter for at least 30 minutes or longer if not in direct sunlight or under a heat lamp.
8. Remove the cup with penguin from the dwelling and complete the post-test measurements in Table 2.
9. Answer the questions on your lab sheet.
10. Discuss the class results. What were some common elements of the best designs? What design problems did the dwellings of the most melted penguins have?

Helpful Tips (from teachers who have built penguin dwellings in their classroom):

- Consider not showing an example of a penguin dwelling. Otherwise they all tend to look the same as the example.
- A small Kleenex box is 11cm x 11cm x 12 cm. If the dwelling can fit inside the Kleenex box it is roughly the right size.
- Include a control of a penguin in the cup only (no dwelling).
- Have students practice using the balance before the “pressure” of having to do it quickly with their melting penguin.
- After all the measurements have been taken, work through the calculations together as a class.
- The school cafeteria may have condiments cups with lids that you can use.
- Possible Hut Supplies: Packing peanuts, bubble wrap, cups-styrofoam & plastic, fleece, felt, cotton batting, paper towel, aluminum foil, faux fur, faux feathers, paper, cardboard. I’ve seen pictures of kids working on the project that used carpet and grass. Allow them to be creative!

Teacher Note: You may include the following information during your discussion to help students build their dwellings.

- Define radiation as the transfer of thermal energy through space.
- Explain that when dark objects absorb radiation, this energy is transformed into thermal energy.
- Define convection as the way thermal energy gets transferred in a fluid (gas or liquid) when the fluid sinks or rises. (*Teacher note:* This is because cold fluids are denser than warmer ones, and they sink—pushing warmer fluids up.)

Acknowledgements:

These lessons have been adapted from the following project:

This curriculum and all imbedded documents can be found online at
<http://www.auburn.edu/~cgs0013/ETK/SaveThePenguinsETK.pdf>

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