SAVE THE PENGUINS STEM TEACHING KIT

An Introduction to Thermodynamics and Heat Transfer

Teacher's Guide

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

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UNIT OVERVIEW

Introduction and Background

Students' alternative conceptions of heat and temperature begin at a young age and persist through school. Because of the young age at which children experience warmth, experience being cold, and experience touching hot or cold things, naïve conceptions of heat, temperature and heat transfer are often resistant to change. Even young children intuitively develop a "framework theory of physics" to describe and explain the world they experience. The once-popular caloric theory that heat is a substance made of particles that flow still dominates children's thinking, and they rely on their senses to measure temperature, not understanding the kinetic theory and its implications in heat transfer. The belief that cold is a substance that moves is prevalent with middle and high school students. These students also think that metal objects are naturally colder than plastic ones because metal attracts the cold. The directionality of heat transfer is not understood because heat is not seen to be a form of energy. Without explicit interventions designed to target these alternative conceptions, chances are that they will persist into adulthood.

This STEM Teaching Kit (STK) is designed to help middle grades students with science concepts related to heat and energy as well as teach them the basics of engineering design. They also come away with a sense of how engineers are people who design solutions to problems. The students' goal is to design and build a shelter for an ice cube-shaped penguin that reduces heat transfer and keeps the ice from melting.

In *Save the Penguins*, the broad context is global climate change. Students learn that the energy we use to heat and cool our houses comes from power plants, most of which use fossil fuels to convert chemical energy to electrical energy. The burning of fossil fuels has been linked to increased levels of carbon dioxide in the atmosphere, which in turn has been linked to increases in global temperature. This change in temperature has widespread effects upon life on Earth. Penguins live in the southern hemisphere, primarily on the icy continent of Antarctica. As the Earth warms and ice melts, penguins lose habitat. Therefore, students see that better-designed houses that use less energy for heating and cooling can have an effect on penguins. Energy efficient houses that minimize unnecessary heat transfer will draw less electricity from the fossil fuel burning power plants and not contribute as much to global climate change.

Design-based science learning reflects the social constructivist theory of learning by having students work collaboratively in groups to solve problems and construct solutions, but learn certain skills through the modeling of their teacher. When students are involved in engineering design-based activities, they are not being told what to do- they are creating and innovating, making decisions with their peers based on their underlying knowledge. The role of the teacher is to guide students through their decision-making processes and model new skills to be learned.

Through engineering design activities, students create their own knowledge of scientific principles through active manipulation and testing of materials and ideas. But because students come to school with their own understandings about the world and how it works, their understandings may not resemble those of scientists. The teacher must provide the opportunities for students to challenge and internally modify their prior beliefs. Therefore, social constructivists see that the role of the teacher is to help learners construct their knowledge through scaffolding and coaching. Social constructivists see that learners construct meaning through active engagement, not passive listening. Learners use and apply their knowledge to carry out investigations and create artifacts that represent their understanding. Learners work within a social context as they use language to express and debate their ideas. Learners engage in authentic tasks that are relevant to the student and connected with their lives outside of the school setting.

Teaching Strategies

Design-Based Science

In design-based science activities, the teacher does not tell the students what to build. Instead, the teacher serves as a facilitator and allows students to take the primary lead in their own learning as they apply scientific concepts to engineering design problems. Problem solving through authentic tasks that relate to students' lives increases student interest and deepens conceptual knowledge.

Whole-class demonstrations

While you may be tempted to jump into the design activity and skip over the demonstrations, please do not. The demonstrations provide the cognitive scaffolding necessary for students to link the design challenge with the complex science of heat transfer. They present students with cognitive dissonance through discrepant events; the opportunity to face their conceptions of heat and refine any incorrect ones is imperative for the success of this STEM Teaching Kit. Without the demonstrations and discussions that surround them, students will take away a fun activity that may or may not help them understand the science, or understand what engineers do. With the demonstrations, students will gain increased conceptual understanding about thermal energy, heat transfer, and temperature.

Cooperative Learning Groups

Ideally, students should be placed in small groups of three or four. Each student should be assigned a role in the group, such as material collector or money handler. Either allow students to pick their own groups, or assign them based on what you know about how your students get along and work together. Since students will be working with the same group members for the duration of this unit, it is best if the students like one another and work well together. Have students sit together with their group members from the beginning of this unit, ideally around a table where they can each see and talk to one another.

Assessment

In the *Save the Penguins* STEM Teaching Kit, assessment is an integral part of instruction and consists of two types:

A. Formative assessment – embedded within the lessons, providing continual feedback to the teachers and students for improving instruction. In this unit, formative assessments include:
   - Whole-group discussions involving students' predictions of what will happen during demonstrations and feedback from students/groups following each demonstration.
   - Measuring the amount of penguin ice cube that is 'saved' as a result of students' designing an energy efficient penguin dwelling.
   - Storyboarding during each lesson. A storyboard is like a comic strip in that it tells a story through drawings and words divided up into sections that flow logically. Each time students learn a new concept, do an experiment, create a design, or test a design, it should be recorded on the storyboard for teachers and students to see and comment on. Ideally, the storyboard is on the wall for easy viewing.

B. Summative assessment – an evaluation of cumulative performance, given as written tests before and after the unit to determine students' content knowledge gains on heat transfer concepts. Teachers should have each student complete the "Heat Transfer Evaluation" at the start of the unit, collect the assessments, score them, but do not return or discuss them with the students. The "Heat Transfer Evaluation" instrument is based on misconceptions research and has been assessed for face and content validity, construct validity, and reliability. The same evaluation will be given to each student at the end of the unit. Collect the post-tests, score them, and compare each student's pre- and post-test scores. The assessment will provide the teacher with information about students' misconceptions about heat. For more information about this instrument and correct answers, contact Christine Schnittka at Schnittka@auburn.edu.

Safety considerations

Caution students not to touch heat lamps during any of the demonstrations or during the testing of designs or materials. The surface of the heat lamp and surrounding dome can cause significant skin burns if touched during or immediately after use. If you use heat lamps with clamps, consider clamping them to ring stands or other stationary devices to reduce the need for handling them.

Technology

A computer with speakers, an LCD projector and screen will be needed to show PowerPoint presentations and videos. If laptops or tablets are available, encourage the use of the social networking educational space, Edmodo. Go to www.edmodo.com and set up an account for yourself and a "space" for your students to dialogue with each other, share ideas, photos, videos, websites, etc. It's also a good way for you to post questions and encourage students to respond.

Correlation to Standards

The *Save the Penguins* STEM Teaching Kit is based on standards derived from the Next Generation Science Standards, the National Science Education Standards, the Benchmarks for Science Literacy, and Standards for Technological Literacy.

STANDARD	GRADE LEVEL	CONTENT RELATED TO *SAVE THE PENGUIN* ETK
Next Generation Science Standards	Grades 3-4	3-ESS3-1. Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard. 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. 3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved. 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
NGSS	Grades 6-8	MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. 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-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. MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

		MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
NSES	Grades 5-8	Physical Science Content Standard B 1. Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature. 2. Light interacts with matter by absorption or reflection.
Benchmarks for Science Literacy	Grades 6-8	Chapter 4E 1. Energy cannot be created or destroyed, but only changed from one form into another. 2. Most of what goes on in the universe… involves some form of energy being transformed into another. 3. Energy in the form of heat is almost always one of the products of an energy transformation. 4. Heat can be transferred through materials by the collision of atoms or across space by radiation. 5. If the material is fluid, currents will be set up in it that aid in the transfer of heat. 6. Heat energy is the disorderly motion of molecules.
Standards for Technological Literacy	Grades 6-8	Standard 8: Design is a creative planning process that leads to useful products and systems. There is no perfect design. Requirements for a design are made up of criteria and constraints. Standard 9: Design involves a set of steps which can be performed in different sequences and repeated as needed. Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum. Modeling, testing, evaluating and modifying are used to transform ideas into practical solutions. Standard 10: Troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system. Invention is the process of turning ideas and imagination into devices and systems. Some technological problems are best solved through experimentation.

UNIT SUMMARY

UNIT BIG IDEAS

- Heat transfers in predictable ways
- Engineers follow a general process to design solutions to problems.

LESSON 1 – Learning Targets
Introduction and Insulation

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

LESSON 2 – Learning Targets
Conduction, Radiation, and Convection

- Heat transfers in three different ways.
- Engineers must research and understand the problem in order to solve it.

LESSON 3 – Learning Targets
Review of Heat Transfer and Introduction to Experimental Design

- Materials affect the rate of heat transfer.
- Different materials vary in their ability to reduce heat transfer.
- Engineers must use their knowledge of science to brainstorm possible solutions to the problem.

LESSON 4 – Learning Targets
Design and Construct Penguin Dwellings

- Materials can be used in conjunction with one another to affect the rate of heat transfer.
- Different materials prevent different types of heat transfer.
- Engineers work within constraints (time, materials, space, money) and use scientific knowledge and creativity to design solutions to problems.

LESSON 5 – Learning Targets
Test Penguin Dwellings, Re-design and Final Testing

- Scientific knowledge can be used in the design, construction, and evaluation of a device.
- Engineering is an iterative process of designing, testing, re-designing, and re-testing.
- Engineers must document their process of design and present their solution to the problem.

Each Lesson is designed for 70-80 minutes of instruction. Lessons do not necessarily correspond to a single day of instruction and may need to be adjusted depending on length of class periods.

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

1. Introduce students to the environmental conditions affecting penguins, the way global climate change has been tied to energy consumption, and the role engineering can play in helping both the environment and penguins.
2. Provide a series of discrepant event demonstrations related to heat transfer that allow students to form an understanding of insulation, heat, and temperature.
3. Introduce students to storyboarding.

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, by definition, moves. 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. felt insulates better than foil. 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.

Lesson in a Nutshell

1. Pre-assessment on Heat Transfer (10 minutes)
2. *Save the Penguins* Introduction PowerPoint (30 minutes)
3. Introduction to Storyboard poster (15 minutes)
4. Demonstration 1 – Soda Can Demo (20 minutes)

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 creates 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 the place where there is a higher temperature to the place where it is cooler. 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 that thermal energy

Heat is driven by:

- differences in temperature; heat transfers from high to low temperature 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. If you imagine a room full of people with candy in their pockets, temperature is like counting the candy that one person in the room has in his or her pocket. Total thermal energy is like counting all the candy that everyone in the room has and adding it all up. Heat transfer is like the flow of candy from a candy store to people who fill their pockets!

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

Teacher Materials

- *Save the Penguins* PowerPoint
- Computer connected to LCD projector and speaker system
- Six-pack of canned soda, cooled in a refrigerator overnight
- 1 Wool Sock
- 1 Cotton Sock
- 1 roll Aluminum Foil
- 1 roll Paper Towel
- 1 roll Plastic Wrap
- 6 Instant Read Digital Thermometers

Student Materials (for each group)

- ½ sheet poster board
- 1 box colored markers or pencils

Preparation

1. Photocopy the Heat Transfer Evaluation Pre-Test for students (download from Internet or see Appendix B).

2. Prepare Demonstration #1 -
    a. Cool a six-pack of canned soft drinks in a refrigerator overnight. Also, measure the temperature of the refrigerator. Most are ~40 degrees F.
    b. At least one hour before class, remove the cans and wrap each one in one of the following materials: wool sock, cotton sock, aluminum foil, paper towel (secured with scotch tape), plastic wrap, and nothing (your control).
    c. Place each can in a paper lunch bag and label each bag.

3. Prepare a data table for recording temperatures. The data table can be written on the board, on an interactive whiteboard, or you can use the provided Excel Document.

4. Review the slide notes in the Save the Penguins PowerPoint.

Procedures

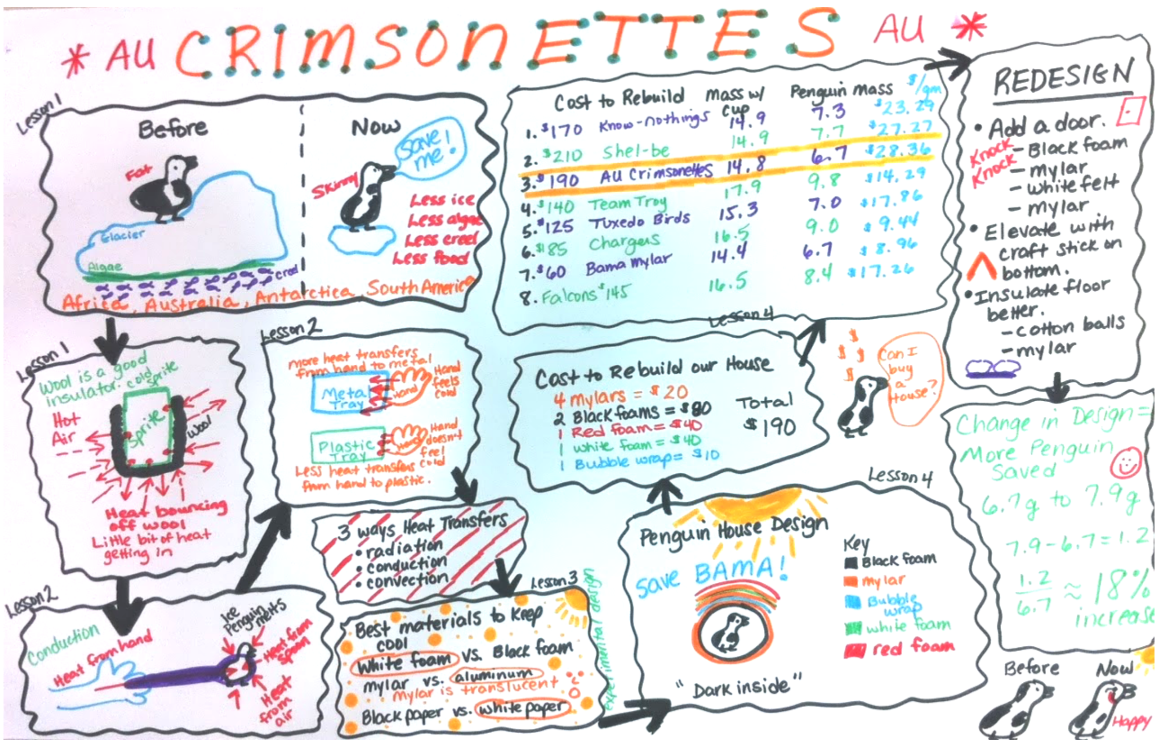
1. Have students complete the Heat Transfer Evaluation Pre-Test.

2. Present the Save the Penguins PowerPoint. Engage students in a teacher-guided discussion using the discussion prompts in the slide notes of the PowerPoint.

3. Distribute one blank poster board to each group and show students an example of a completed storyboard. Have groups develop a team name and write it at the top of their storyboard. Explain that each time students learn a new concept, do an

experiment, create a design, or test a design, it should be recorded on the storyboard for teachers and students to see and comment on.

Teacher note: *Use of storyboards in the engineering design process provides a visual experience that helps students conceptualize each of the steps needed to understand each part of the entire "Save the Penguins" project. The storyboards allow the students to break down each important concept and provide key formative assessments throughout each of the lessons. Three points are covered in the engineering design process with the use of the storyboards: Finding Solutions, Developing an Initial Design and Presenting your Design at the end of the lesson.*



Sample Storyboard

4. 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 can of cold soda in your lunch bag in the morning, but when you opened your lunch later that day the soda was warm! What happened?

   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.*

5. Discuss the difference between heat and temperature.

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

   "Heat and Temperature are the Same Thing" Misconception: *Some students may think that temperature gets transferred since temperature changes. Many use the words interchangeably and do not understand their true meaning. Use the below descriptions (and information provided in the background section) to help students understand heat and temperature and the difference between the two.*

   - Heat – The transfer of thermal energy
   - Temperature – An indication of the amount of energy in a location

6. Have each group write the definitions of Heat and Temperature in the first box on their storyboard.

7. Tell students that you have designed an experiment with some things found around your house that you thought might be good at keeping a canned drink cold. Bring out the six lunch bags and show students what is inside each bag.

The Cans Demo

8. Ask students to work with their team to make predictions. Use the following questions on a piece of paper (or in their science journals):
   - Rank the materials from most effective to least effective at keeping the cans cold.
   - Why do you think your top-ranked material will work the best?
   - Why do you think your lowest-ranked material will not work?

9. Have groups present their predictions and explanations. As the groups present, address any misconceptions students may have about heat transfer.

   Teacher Note: *Below is a list of common misconceptions students may hold.*

   "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, 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.*

10. Open the tops of all soda cans, but do not unwrap the cans. Invite student volunteers to insert digital thermometers and record the temperatures on the data table.

The Effect of Different Insulators on Soda Temperature

Material	Temperature of soda after Refrigeration (°F)	Temperature of soda after one hour of insulation (°F)
Wool sock	40.0	59.6
Paper towel	40.0	60.4
Aluminum	40.0	61.3
Plastic wrap	40.0	62.1
Cotton sock	40.0	63.5
Nothing	40.0	64.2

Sample Template
Template for Recording Temperatures

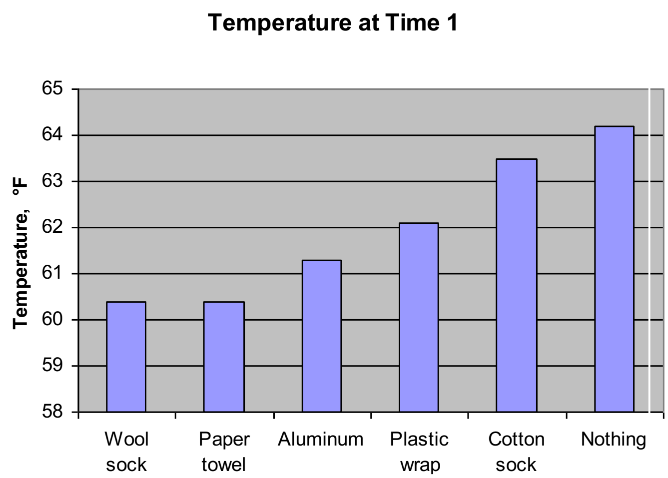
Extension

Math Connection: The data acquired from Lesson 1 provides the opportunity to discuss Fahrenheit to Celsius conversions. Have students develop graphs to determine:

- Box and whisker plots for each can over time
- The relationship between time and temperature

11. You may want to ask students if they know why you decided to compare the results with a bare soda can. You may want to discuss the value of having a control when experimenting with materials. This discussion could help students later in the curriculum when they start testing materials for their penguin dwellings.

12. Once all temperatures are entered, create a bar graph. If you are using an Excel spreadsheet to record the data, you can use the graph utility to create a bar graph and record temperatures at different times.



Soda temperatures after several hours outside refrigerator in paper bag

13. Discuss results with your students and ask them the following questions:
    - Why do you think the wool sock reduced heat transfer better than the cotton sock?
    - Materials that can decrease the rate of energy transfer are called insulators. What properties might the wool sock and paper towel have in common that make them good insulators?
    - Why is it better to wear wool in the winter than cotton?
    - Based on our results, which materials can be called insulators?

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.*

14. Have each group record the results from Demonstration #1 as the first illustration on their storyboard, and record the definition of insulators on their storyboards.

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

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 cans of soda all day with different classes and report the values the next day for further discussion.*

Wrap-Up

Wrap up the lesson with a review of the learning targets. Ask students:

- Some people say that heat transfer always occurs from "where it is to where it a'int." What does this really mean?
- Some things slow down the rate of heat transfer. Can you name some?
- Which is better at slowing down the rate of heat transfer, a wool sock or a cotton sock?
- Next time you bring a cold drink or an ice cream sandwich to school for lunch, what can you wrap it in to keep it cold?
- The wool sock… what did it slow down?
- Did the wool sock trap "coldness"?
- Could there be any sources of error measuring the can temperatures? How could we find out?
- Why did we include a can with no wrapping in the experiment?
- Why do people wear wool in the winter, and cotton in the summer?
- What does any of this have to do with penguins?

LESSON 2

Conduction, Radiation, and Convection

Learning Targets

1. Heat transfers in three different ways.
2. Engineers must research and understand the problem in order to solve it.

Purpose of the Lesson

1. Introduce students to the concept of heat transfer through conduction, radiation, and convection.
2. Provide a series of discrepant event demonstrations related to heat transfer that allow students to understand how:
    a. Heat transfers from warmer to cooler objects
    b. Certain materials are better heat conductors than others
    c. Certain materials reflect or absorb radiation
    d. Convection happens when fluids (liquids or gases) sink or rise.

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 wood.
- Explain that thermal energy transfers through solid materials because vibrating atoms collide with each other.
- Define radiation as the transfer of thermal energy through space.
- Explain that when dark objects absorb radiation, this energy is transformed into thermal energy.
- Demonstrate that materials that are light colored or shiny reflect radiation.
- Demonstrate that some materials are better at reflecting radiation than others.
- 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.*)

Lesson in a Nutshell

1. Review insulation demonstration from day before (10 minutes)
2. Demonstration 2 – Trays demo (10 minutes)
3. Demonstration 3 – Spoons demo (15 minutes)
4. Demonstration 4 – Black-roofed house demo (20 minutes)
5. Demonstration 5 – Space blanket demo (5 minutes)
6. Documenting learning on storyboard (10 minutes)

Background

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

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

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 Materials

- 1 wooden or plastic tray
- 1 silver tray
- 2 aquarium thermometer strips
- 1 cardboard house
- 1 metal light bulb encasement
- 1 60W light bulb

Student Materials (for each group)

- 2 penguin-shaped ice cubes
- 1 silver or stainless steel spoon (silver or silver-plate is preferred)
- 1 plastic spoon
- Paper towels
- 1 storyboard (from Lesson 1)
- 1 box colored markers or pencils

Preparation

1. Prepare for Demonstration #2:

    a. Tape an aquarium thermometer strip to the underside of each tray. Ensure that each strip displays room temperature.

2. Prepare for Demonstration #3:
    a. Make penguin-shaped ice cubes the night before so they can be used in a demonstration on this day. 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.

3. Prepare for Demonstrations #4 and #5:
    a. Construct a cardboard house with a roof.
    b. Paint the roof black.
    c. Cut a flap in the bottom so you can cool the house off quickly.
    d. Insert a thermometer in the attic space and another near the floor of the house.
    e. Cut a piece of Mylar space blanket so that it drapes over the roof and covers all the black paint.
    f. Draw a data table on the board (or use Excel or interactive white board)

4. Copy the Exit Card on page 27 (one per student) for distribution at the end of this lesson.

Procedures

1. Pass around both trays (metal and plastic). Allow all students to feel the trays and ask students, "Which tray is colder?" Accept all answers.

2. Show students the thermometer strips taped to the back of each tray. Have students look at the strips and verify that the trays are the same temperature.

3. Engage students in a discussion and ask students the following:
    - If both trays are at the same temperature, what happened that made you think it was colder?
    - This tray is made of silver (or steel). Do you think this material would have kept our soda can cold yesterday? Why or Why not?

4. Have students watch the following YouTube video. It shows adults being posed the same situation and thinking metal is naturally colder. http://www.youtube.com/watch?v=vqDbMEdLiCs

5. 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.

6. Pass out a silver 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?

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

7. Pass out two penguin-shaped ice cubes per group. Place an ice cube in each spoon and have students take turns holding the spoons in their hands for three minutes. Provide paper toweling for drips.

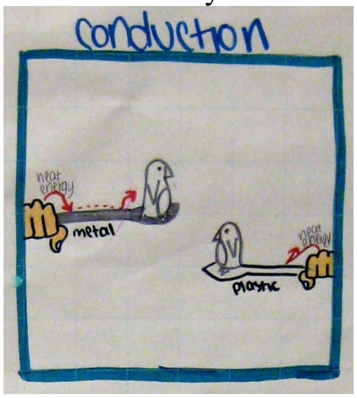
Silver and plastic spoons with penguin-shaped ice cubes

8. Have a classroom discussion about the phenomenon students experienced. Ask students:
   - Which spoon made the ice melt faster?
   - Why do you think the silver spoon 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?

   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.*

9. Collect the spoons, ice cubes, and paper towels. Have students work on their storyboards by writing the definition of conduction and adding a drawing of the spoons with arrows showing the direction of heat transfer. Ask students:
   - If you had the most powerful microscope in the world, what do you think you would see when heat transfers from your hand to the ice cube?
   - If heat is not a substance or a fluid, as people used to think, what is it?

Conduction: Conduction is the way thermal energy transfers from one substance to another by direct contact.



Student drawing of spoon demonstration

10. 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.

11. 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.*

12. Show students the cardboard house. Insert thermometers into the attic space and the first floor space. Show them the thermometers and have someone record the temperatures in the attic and lower floor.

13. Position the shop light above the cardboard house approximately 12 – 18" above the roof, but do not turn on the light.

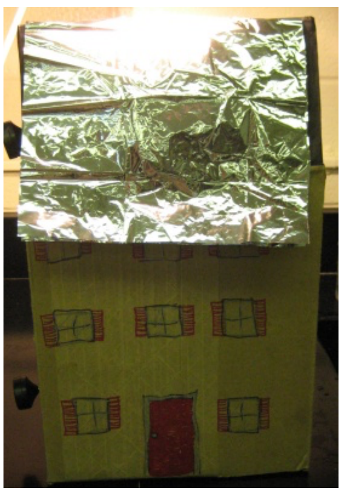
14. Turn on the shop light so that it shines on the black roof. Take the temperature of the attic after 30 seconds. Then, ask students the following:

    - What is causing the temperature of the roof to increase?
    - Do you feel warm outside when you are wearing black?

- In the wintertime, would you rather have a black roof or a white roof on your house?

Teacher Note: *The reason that dark colors get hot is the same reason that dark colors are "dark." They absorb so much light that it's not reflected back to your eyes! Dark colors absorb more of the visible spectrum. Light colors are "light" because they reflect light so well. They reflect more of the visible spectrum. Red things just reflect red light, and absorb the other colors of the rainbow. Black things absorb all the colors of the rainbow, all the colors in light, all the light energy, and transform the light energy into thermal energy.*

15. Air out the house (by opening up the bottom and turning the house upside down). Then drape the roof of the cardboard house with a piece of Mylar space blanket. Explain that you are going to turn on the hot lamp again and ask students to predict what will happen to the temperature of the roof after the addition of the Mylar blanket.



The demo house with Mylar draped over black roof

16. Turn on the lamp and take the temperature of the roof after 30 seconds. Ask students the following:

    - Why did the roof not get as hot after the Mylar was draped on top?
    - Why is Mylar shiny?
    - If Mylar reflects light, how does that explain why the roof stays cool?
    - Would the results be the same if we draped a white cloth over the roof?

    Teacher note: Mylar is a plastic that contains aluminum. The Mylar is a shiny surface because it reflects light. Its ability to reflect light slows the transfer of radiant energy (heat) to the roof and thus the roof stays cooler. A white cloth should have a similar effect. Try it if you have time!

17. Have student volunteer place their hand under the hot lamp. Then block the light with the space blanket, and ask the student to describe to the class what they felt. You can try with a white cloth too, to see if it feels any different. Then ask students:
    - What happened to the light from the lamp?

18. Have students draw what they have observed on their storyboards in a new square.

19. Introduce the vocabulary of the second method of heat transfer, radiation. Tell students that the black roof absorbed the radiation from the light source, but that the Mylar space blanket reflected the radiation away, keeping it out of the house. One way to illustrate this is to have students with a variety of shirt colors come to the front of the classroom. Throw paper balls to the students and tell them that you are throwing pretend light particles. Tell students wearing dark colors to catch the imaginary particles of light, and tell students wearing light colors to swat them away. Ask:
    - Why do dark colors get so hot in the sun? Dark cars, parking lots, roofs?
    - Why do light colors stay cooler in the sun? Light cars, sidewalks, and roofs?
    - Why do you think this occurred?
    - How could a homebuilder use this information when building a new home?

20. Ask students the following questions:
    - How does Earth get its heat?
    - How does the heat from the sun get to Earth?
    - Does the Earth reflect radiation from the sun?
    - Which parts of the Earth reflect the most radiation? (the light parts… snow, water, ice, clouds)

Teacher Note: *The Earth gets its heat from the sun. It is transferred from the sun through radiation. The clouds, snow, and water are all effective at reflecting the radiation from the sun.*

21. While the roof cools down, have students complete a section of their storyboard with the definition of radiation and a drawing of the house with arrows showing how radiation was reflected off the Mylar space blanket.

    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. X-rays and gamma rays and microwaves are other forms of electromagnetic radiation, but they are **not** produced by light bulbs (the sun produces them!)

22. Take the off the roof of the house. Air it out to get rid of the warm air inside. Use the digital thermometers to take and record the initial temperature of the air inside the attic and air inside the first floor on your data table for all students to see.

23. Turn a shop light on over the cardboard house. Invite two student volunteers to read the temperature of the attic and of the floor in 30-second intervals out-loud to the class while a third volunteer records the results on a data table for the class to see for three to five minutes.

24. Ask students, "Why is the attic of the house getting so hot?"

    Teacher Note: *The attic is getting hot because the black roof is absorbing infrared and visible light radiation from the light. This radiation is converted into thermal energy on the roof. The air in the attic is getting hot because of conduction through the cardboard. The hot roof transfers its energy to the air next to it inside through conduction too.*

    Some students may say that hot air is rising. The next demonstration will address this phenomenon (convection), but it is important that students realize that in this case, hot air rising is not causing the hot attic. Remind students that all air in the house (at both the level of the floor and the roof) was the same temperature before starting the experiment. Energy is being transferred from the light source to the black roof, and thermal energy is conducting through the roof into the air of the attic. The hot air does not fall and heat the lower part of the house because hot air is less dense than cooler air.

25. Tell students, "In Lesson 1 when we discussed insulators we were talking about preventing heat transfer in attic spaces. What type of heat transfer does attic insulation prevent?"

26. Explain that you are going to turn the house upside down. Ask students to predict what will happen to the temperature of the attic and the first floor.

27. Turn the house over. Then, have volunteers call out the falling temperature of the attic space and the rising temperature of the first floor space in 30-second intervals until the attic and the floor reach equilibrium. Ask students the following questions:

    - What happened to the temperature of the attic? The floor?
    - Why did this change in temperature happen?

28. Tell students that heat transfers in any direction depending on where it is hot and where it is cold. In the house, the hot air in the attic was rising because the cooler air was sinking and pushing the hot air up. Tell students that this is called convection.

    Teacher Note*: Below are two critical misconceptions among students with regards to convection. Be sure to address them now.*

*"**Heat Rises Misconception**" – Students will often state that **heat** rises. To address this misconception, remind the student that heat is not a substance. Explain that while hot air can rise, heat is the transfer of thermal energy. Thermal energy transfer can occur in any direction (from hot areas to cooler areas). Hot air does not rise unless it is pushed up (displaced) by sinking cooler air.*

***"Cold Transfers Misconception"** – Students may think that because cold air sinks, that "coldness" transfers. Remind them that cold substances can move, but cold itself does not transfer. Energy transfers. Thermal energy transfers.*

29. Explain that conduction was one way that heat transfers, that radiation is another, and that convection is the third way heat can transfer.

30. Have students complete a section of their storyboard with the definition of convection and a drawing of the house with arrows showing the direction heat transferred when the house got flipped upside down.

Convection: Convection occurs when moving fluids (gases or liquids) rise and fall due to differences in density. Warmer fluids are less dense than colder ones, because the particles in a warmer fluid are more spread out.

Wrap-Up

1. There are three ways heat transfer occurs. They are conduction, convection, and radiation.
2. Conduction is what we saw during the silver spoon/tray demonstrations. Heat was transferred through direct contact from our warm hands through a conductor (the metal tray or metal spoon).
3. Convection is what we saw during the upside-down house demonstration. Hot air rises because cooler air sinks. Gravity pulls the cooler air down.
4. Radiation is what we saw during the Mylar house demonstration. Radiation is the transfer of energy in the form of electromagnetic radiation.
5. Pass out the exit card below and have students answer the questions. Encourage them to draw in order to illustrate their answers. Use this exit card as a form of formative assessment (do not "grade" it, but provide feedback).

Exit Card **Name** ______________________________

Answer the following questions with words and drawings.

1. Why does the sun make you feel warm?	2. How does meat get heated in a frying pan?	3. Why does the handle of a saucepan get hot when it is on the stove?	4. Why do smoke and hot air go up a chimney?
5. Why does the outside of a bowl of soup get hot?	6. Why does the roof of your car get hot in the sun?	7. On a bright, sunny day, why does the pavement get very hot?	8. Why do you get warm standing in front of a fireplace?
9. Why is the second floor of a house usually hotter than the first floor?	10. On a hot day would you rather have a black umbrella to keep cool or one made of Mylar? Why?	11. Why is the black pavement in a parking lot hotter to walk on than the concrete sidewalk?	12. In a fish tank, a small heater in one corner makes all the water warm. How?

There is often no one right answer to the twelve questions above. Sometimes, multiple methods of heat transfer explain the phenomenon. Use this formative assessment to determine your students' current level of understanding.

LESSON 3

Introduction to Experimental Design

Learning Targets

1. Materials affect the rate of heat transfer.
2. Different materials vary in their ability to reduce heat transfer.
3. Engineers must use their knowledge of science to brainstorm possible solutions to the problem.

Purpose of the Lesson

1. Review the three methods of heat transfer
2. Introduce students to the materials
3. Model how to conduct experiments with the materials
4. Allow students to experiment with materials

Lesson Objectives

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

- Compare the different materials to determine which ones are better at preventing heat transfer
- Discern which type of heat transfer each material prevents

Lesson in a Nutshell

1. Review exit card on methods of heat transfer (15 minutes)
2. Introduce students to kit of materials (5 minutes)
3. Model how to conduct experiments at experimentation stations (15 minutes)
4. Students test materials and keep records of their work on storyboard (30 minutes)
5. Teacher and students discuss all the experiments done in class this day (10 minutes)

Background

Encourage cooperation, not competition. Student groups could cooperate by testing different materials or combinations of materials and sharing the results with the class.

The hot box is not needed until the dwellings are constructed and ready for testing, but it is good for students to see the hot box in action and brainstorm ways to prevent heat transfer given the conditions in the hot box.

Teacher Materials

- 7 Shop lights with clamp attachment (one for each student group)

- 1 lg. black plastic tub (or spray-painted box)
- 7 Instant Read Digital Thermometers
- 7 digital timers
- 7 sponges or paper towels (dampened)
- 1 roll heavy-duty aluminum foil

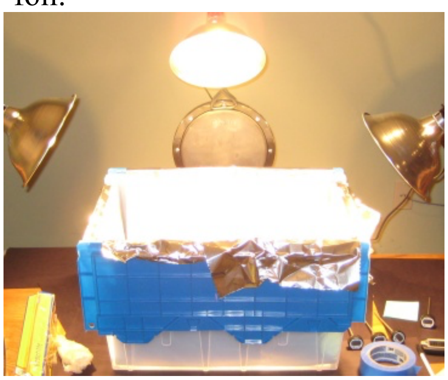
Student Materials (for each group)

- 1 material kit box that contains a sample of each material
- 1 Storyboard (from Lesson 1)
- 1 box colored markers or pencils

Preparation

1. Prepare experimental baggies for each of your student groups. Each baggie should include two 3"x3" square samples of each material available, including two cotton balls and two wood sticks.

2. Prepare the "hot box" that will be used to test the students' designs. To do this, use a black storage bin (or black-spray painted box) and line the inside with heavy-duty aluminum foil. Keep the black floor exposed. Then position four shop lamps around the outside of the hot box so that they shine on the bottom and the foil.



The hot box

3. Set up at least three experimentation stations- it is preferable to have one for each student group. Each station will need:
   - 1 shop lamp clamped to a stand or cabinet 18" off the countertop
   - 1 digital timer
   - 2 instant read digital thermometers
   - 1 sponge or paper-towel (dampened)

Procedures

1. Review exit cards from day before. Have students make corrections and glue the card onto their storyboard once corrected.

2. Pass out material baggies to each student group.

3. Explain that they are going to design and build an igloo that will keep a penguin-shaped ice cube from melting. But first, they will work as engineers to test the different materials provided to see which materials they may want to use in their igloo designs.

Sample materials

4. Show students the "hot box" that will test their designs. Ask the students to identify all the forms of heat transfer that might take place and explain where the heat transfer will occur.

Teacher Note: *The hot box allows for all three forms of heat transfer to occur:*

Radiation *– From the four shop lights, light reaches the little penguin dwellings, and is also reflected off the foil sides onto the little penguin dwellings*

Conduction *– The black-painted floor gets hot from the radiation, and then when the little igloos sit on it, the heat conducts up into the dwelling.*

Convection *– Currents form as hot air rises off the black floor and falls into the hot box from the cooler room.*

5. Model how to properly conduct experiments at experimentation stations. Explain to students that you will be measuring the temperature underneath each material (or multiple materials simultaneously) as the light shines on the material.

Teacher Note: *It is recommended that teachers model common errors students should avoid.*

Error 1- The sample is not blocking radiation.

To demonstrate this error, place samples on the counter and place a thermometer on top of each. Students will frequently try this. Ask them what is wrong with doing it this way?

Error 2- The temperature may be higher under one sample because more time has elapsed.

To demonstrate this, use only one thermometer and take the temperatures at different times. Students will often not control for time. Encourage the use of a timer.

Error 3- The tabletop has gotten hot and is now also transferring heat.

To demonstrate this, show students how hot the counter or tabletop gets when a light has been shining on it for a period of time. Encourage them to TURN OFF the light between trials, and move the testing area slightly to a room-temperature testing location.

Error 4- The thermometers are too hot. They won't cool down to room temperature.

Explain to students that the thermometers will get hot. Provide a wet sponge on a plate, or a wad of wet paper toweling to quickly cool the thermometers to room temperature after every use. You could provide a cup of room temperature water, but it might spill!

Error 5- The thermometers are taking the temperature of the table.

Explain to students that if they elevate the thermometers slightly with cotton balls or sticks, they will measure the temperature of the air underneath the sample, and not the table surface.

6. Have students set up their data table. Explain that each group will keep track of their own experimental data. The data table may look like this, with each trial representing two materials being tested at the same time with two thermometers:

Materials Testing Data

Trial	Material	Starting Temperature (°F)	Temperature after 1 min. (°F)
1	White Foam		
	Black Foam		
2	Mylar		
	Aluminum		
3	Black Paper		
	White Paper		

Sample Materials Testing Data Table

7. After each group has experimented for 10 minutes, give students hints or suggestions for testing as needed:
   - Students can test combinations of different materials
   - Students can test combinations of the same material
   - Students will share their results with the class, so encourage them to test something different than the other groups
   - Students can add combinations to their data table as demonstrated below:

Materials Testing Data

Trial	Material	Starting Temperature (˚F)	Temperature after 1 min. (˚F)
4	White Foam with Mylar on top		
	Black Foam with Mylar on top		
5	Two sheets of Mylar		
	Two sheets of Aluminum		
6	Black Paper on top of Bubble Wrap		
	White Paper on top of Bubble Wrap		

8. Discuss the experiments with the class. Be sure to discuss the following:
   - Which materials performed better than others?
   - Why do you think these materials performed better?

Wrap – Up

1. Have students to create another box on the storyboard in which they list the three materials that best prevented heat transfer and the three materials that were least effective at preventing heat transfer.

LESSON **4**

Penguin Dwellings – Design and Construction

Learning Targets

1. Materials can be used in conjunction with one another to affect the rate of heat transfer.
2. Different materials prevent different types of heat transfer.
3. Engineers work within constraints (time, materials, space, money) and use scientific knowledge and creativity to design solutions to problems.

Purpose of the Lesson

1. Design and construct prototype dwellings for penguin-shaped ice cubes based on the knowledge gained from experiments conducted on the materials.

Lesson Objectives

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

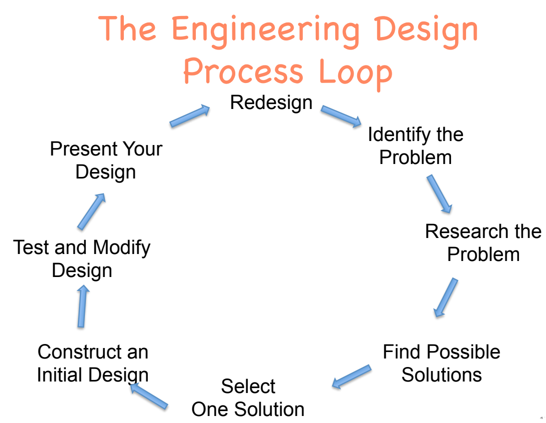
- Combine information about different materials to synthesize a unique design.
- Create a device that reduces heat transfer and keeps a penguin-shaped ice cube from melting.

Lesson in a Nutshell

1. Students discuss engineering and what engineers do. (15 minutes)
2. Students conduct additional experiments as needed and share results (10 minutes)
3. Students design initial dwelling (15 minutes)
4. Students purchase additional materials necessary from Igloo Depot (10 minutes)
5. Students construct dwelling (40 minutes)

Background

The Engineering Design Process Loop is an iterative 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." However, the following cycle is a good model for what students will be doing in this unit.



Engineering Design Process Loop

Teacher Materials

- What is Engineering PowerPoint
- 7 Shop lights with clamp attachment
- 1 lg. black plastic tub (or spray-painted box)
- 7 Instant Read Digital Thermometers
- 7 plaster of Paris penguins- made by putting wet plaster into the penguin ice cube tray, drying overnight, and removing.
- Play money ($100 of play money per group)

Student Materials (for each group)

- 1 sample of each material.
- Glue, tape, scissors
- 1 Storyboard (from Lesson 1)
- 1 box colored markers or pencils

Preparation

1. Photocopy the Engineering Design Process handout.

2. Review the What is Engineering PowerPoint in order to engage students in a discussion about what the world would be like without engineers, and what some engineers are doing to make the world a better place.

3. Set up Igloo Depot station with construction materials that students can 'purchase'.

4. Set up at least three experimentation stations, but one for each group is preferable. Each station will need:
   - 1 shop lamp clamped to a stand or cabinet 18" off the countertop
   - 1 digital timer

- 2 instant read digital thermometers

Procedures

1. Show the What is Engineering PowerPoint in order to engage students in a discussion about what the world would be like without engineers, and what some engineers are doing to make the world a better place. Have students complete a storyboard square on engineering.

2. Distribute one plaster of Paris penguin and a box with only one sample of each material to each group. These materials are "loaners" from the Igloo Depot, and the cost of each material used must be included in the cost of the house. (It cuts down on shopping time to have some materials already with each group).

3. Distribute $100 of play money to each group. Explain to students that they can use all loaner samples they have been given, and will be allowed to purchase additional materials from the Igloo Depot using their $100 play money. They will need to decide which materials are worth purchasing for the construction of their igloo.

4. Show students the following price chart.

   Teacher Note: This guide is suggested prices. These prices are based on actual cost (1000% markup!)

   Construction materials at Igloo Depot (suggested prices)

Item	Price at *The Igloo Depot*
Cotton ball	$10
Wood stick	$20
Construction paper	$5
Foam sheet	$40
Felt fabric	$40
Bubble wrap	$10
Aluminum foil	$5
Mylar sheet	$5

5. Students should keep a running list of the materials they purchase and use in the design of their igloo. Tell students that at the end of the lesson, they will have to have a list of each material that went into building the igloo and calculate the "cost" of their igloo.

6. As students determine which materials they will use to construct their igloo, have them add the list on to their storyboard.

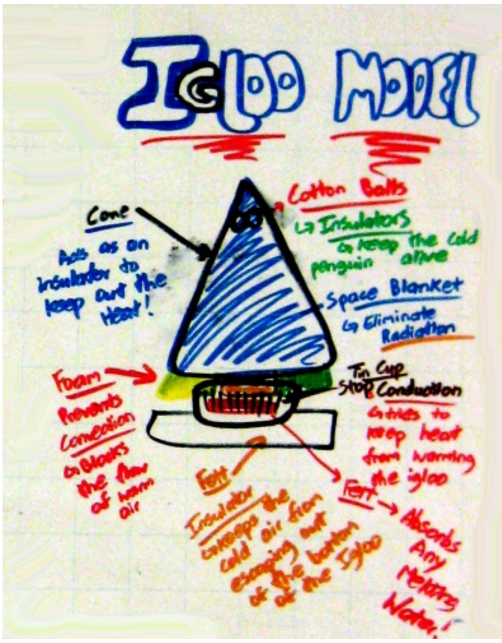
7. Allow students to begin construction of their prototype igloo and go shopping at the Igloo Depot.

8. 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. The following questions will help you aid them in this verbalization of their creative and logical thinking:

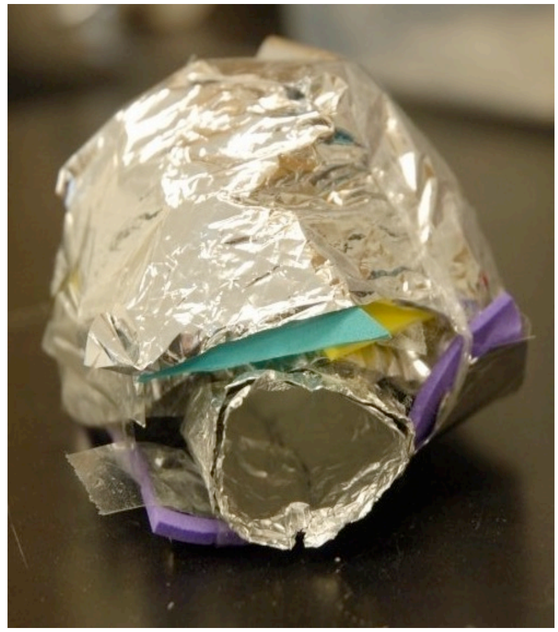
    - Could light get into the igloo and melt the penguin?
    - Can convection currents rise and fall and enter your igloo?
    - How is the heat from the black floor going to transfer into your igloo?
    - What are some ways to slow radiation? convection? conduction?
    - What are some design features of your own house that keep heat out in the summer time? (Seals around windows keep drafts out, and the attic keeps radiation from reaching the bedrooms, and roof overhangs keep light from shining into the windows all day, and basements help prevent conduction between the first floor and the ground, and insulation in the walls slows down conduction between the outside and the inside through the walls.)
    - Why did you choose that color?
    - Did you do a test on that material to make sure it works like you want it to?
    - How does one layer of that material compare to two layers?
    - If air is such a good insulator, how can you trap more air?
    - Is it better to have bubbles up or down with bubble wrap?

Wrap-Up

1. Have students document their design on their storyboard. Have students label the materials they used and indicate which type(s) of heat transfer is being prevented. See below for sample design on a storyboard and a sample first iteration "igloo" designed by a team of eighth grade students.



Sample student drawing on the storyboard



Sample student design- first iteration

LESSON 5

Penguin Dwellings – Design Testing and Retesting

Learning Targets

1. Scientific knowledge can be used in the design, construction, and evaluation of a device.
2. Engineering is an iterative process of designing, testing, re-designing, and re-testing.
3. Engineers must document their process of design and present their solution to the problem.

Purpose of the Lesson

1. Students will test their penguin dwellings in a hot box with radiant, conductive, and convective heat.
2. Students will analyze their penguin dwellings and determine which features were most successful at reducing heat transfer.
3. Students will identify the type(s) of heat transfer reduced by their penguin dwelling.
4. Students will re-design their penguin dwellings based on results, and re-test the dwelling.

Lesson Objectives

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

- Evaluate devices designed to reduce heat transfer, compare them, and determine how they work
- Judge the effectiveness of devices designed to reduce heat transfer

Lesson in a Nutshell

1. Test designs in hot box. (20 minutes)
2. Have students research innovations in building materials on computers while penguins melt. Or use PowerPoint presentation, Innovative Building Materials.
3. Analyze and discuss results. (20 minutes)
4. Have students record modifications they would like to do on their design, and then use their remaining money to purchase more supplies, or re-configure the materials already purchased. (20 minutes)
5. Test re-designed igloos in hot box. (20 minutes)
6. Administer the post-test and work on their storyboards. (10 minutes)
7. Analyze and discuss the results. (20 minutes)

Background

Encourage cooperation, not competition. Have students share their successes and failures with each other and learn from them. The objective is to save the penguins, not win a competition. The redesign phase is the most important. After the first testing in the hot box, invite the student groups to talk about their designs with each other, and use the lessons learned to improve. If students insist on "a winner" say that anyone who can improve their design and save more penguin the second time around is a winner.

Teacher Materials

- 4 Shop lights with clamp attachment
- 1 lg. black plastic tub (or spray-painted box)
- Penguin ice cubes (1/group)
- Timer
- Electronic balance (accurate to 0.1 g)
- 1 roll heavy-duty aluminum foil

Student Materials (for each group)

- 1 material kit box
- 1 Storyboard (from Lesson 1)
- 1 box colored markers or pencils
- 1 small plastic Dixie cups (massed)

Preparation

1. The day before Lesson 5, prepare penguin ice cubes.
    a. Using the medical syringe, distribute equal amounts of water into each ice cube well (10 -16 ml depending on your particular ice cube tray).
    b. Ensure that each well is filled the same so that all ice penguins will have identical masses, noting that the density of water is 1g/ml (i.e., 16 ml of water equals 16 grams).

2. Prepare the plastic Dixie cups by massing each one and writing the mass on the side of each cup with a permanent marker (most will have a mass of ~ 2.8 grams). Prepare enough cups for each group to have one cup. Cups can be dried and re-used over and over again.

3. Prepare the "hot box" that will be used to test the students' designs. To do this, use a black storage bin (or black-spray painted box) and line the inside with heavy-duty aluminum foil. Keep the black floor exposed. Then position four shop lamps around the outside of the hot box so that they shine on the bottom and the foil. If you use an electric power strip to plug in the lights, you can turn all the lights on and off with one switch.

4. Prepare a chart on the board or on a piece of poster paper for students to fill in their results. This could also be done digitally in Excel or on an interactive whiteboard and projected for the class to use.

5. Prepare a 15-minute activity for students to participate in while the designs are in the hot box. Suggested examples:
   - Have students research modern engineered building materials online.
   - Watch penguins using one of the many penguin cams on the Internet from zoos and other habitats. Google penguin webcams and let students watch some live penguins in action!
   - Deliver PowerPoint presentation, Innovative Building Materials provided with this STK.

Procedures

1. Turn on the lamps over the hot box and pre-heat for about 20 minutes. By pre-heating, the surface on the bottom of the hot box will be uniform before proceeding to the next step.

2. Distribute one plastic Dixie cup to each group. Have one student from each group lined up with their Dixie cup ready to receive their ice penguin.

3. Retrieve the ice penguins from the freezer and quickly distribute one ice penguin to each Dixie cup.

4. Instruct students to place their ice penguin in their igloos as quickly as possible and place their igloos in the hot box (all at the same time) so they are evenly spread apart from each other. Turn the lamps off for these few seconds to reduce the risk of burns. Turn the lamps back on and set the timer for 20 minutes to begin 'cooking' the igloos.

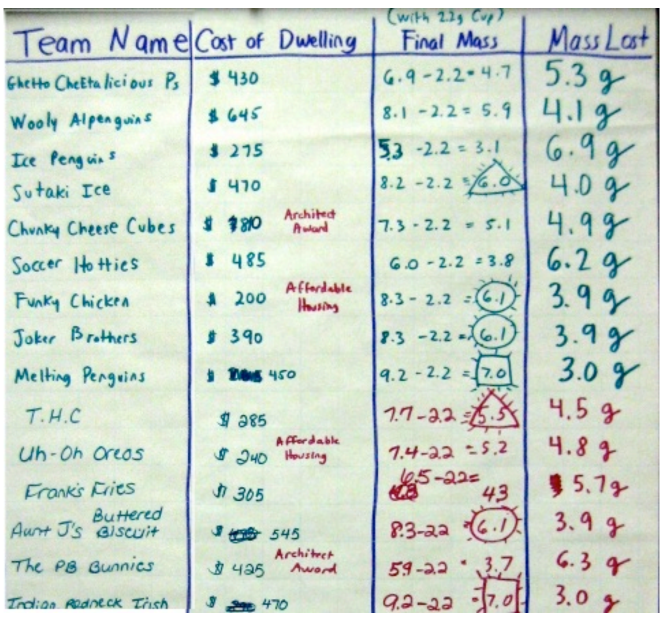
   Teacher Note: *Note that 20 minutes is approximately the time it takes for a "homeless" ice penguin to totally melt. Be sure to add a "homeless" penguin as a* *control. Simply place an ice penguin on the floor of the hot box. After 20 minutes it will be a very tiny morsel of ice.*

5. While the igloos are cooking, engage students in a 15 minute lesson. For ideas see Lesson 5 Preparations.

6. When the timer sounds after 20 minutes, turn off the heat lamps without touching the bulb or the dome as they will be VERY HOT! Move the lamps out of the way and invite students to quickly retrieve their igloos.

7. Instruct students to quickly retrieve the remainder of the ice penguin and place it in the Dixie cup.

Teacher Note: *Make sure students do not pour liquid "penguin juice" into the rescue cup!*



Sample chart of results

8. Have students place the cup on the digital scale and record the mass of the cup + remaining ice penguin. Students will then find the final mass of their ice penguin by subtracting the mass of the Dixie cup from the total mass recorded.

Teacher Note*: If students are concerned that their ice penguin continues to melt while they wait in line to find the mass, remind students that the ice and melted ice remaining in the cup still represent the total mass of penguin saved.*

9. Invite students to write their results on the board, along with the total cost of their igloo dwelling.

10. Have students record their results on a new square on their storyboard.

11. Have the class analyze the results of the test by doing the following:

    a. Analyze the igloos that prevented the most heat transfer (which igloos had the greatest amount of ice penguin remaining).
    b. Tactfully analyze the igloos that did not perform as well and offer suggestions of what could be adjusted to improve performance.
    c. Ask students the following questions:
        - Which design features were most effective at preventing heat transfer?
        - Why were these design features effective at preventing heat transfer?
        - Which types of heat transfer were reduced in each design?

12. Have students record their ideas for design modifications on their storyboard. If time permits, ask them to sketch the new, improved design on their storyboard.

Extension

Algebra Connection: The data acquired from Lesson 5 provides the opportunity to discuss slope and linear equations and the value of interpolating and extrapolating data points. Have students develop graphs to determine:

- Is there a relationship between total igloo cost and final mass of the penguin (an effective igloo design)?
- Is there a relationship between the cost of the dwelling and the final mass?
- If we determined the mass of each dwelling, would there be a relationship between the igloo mass and the final mass of the penguin?

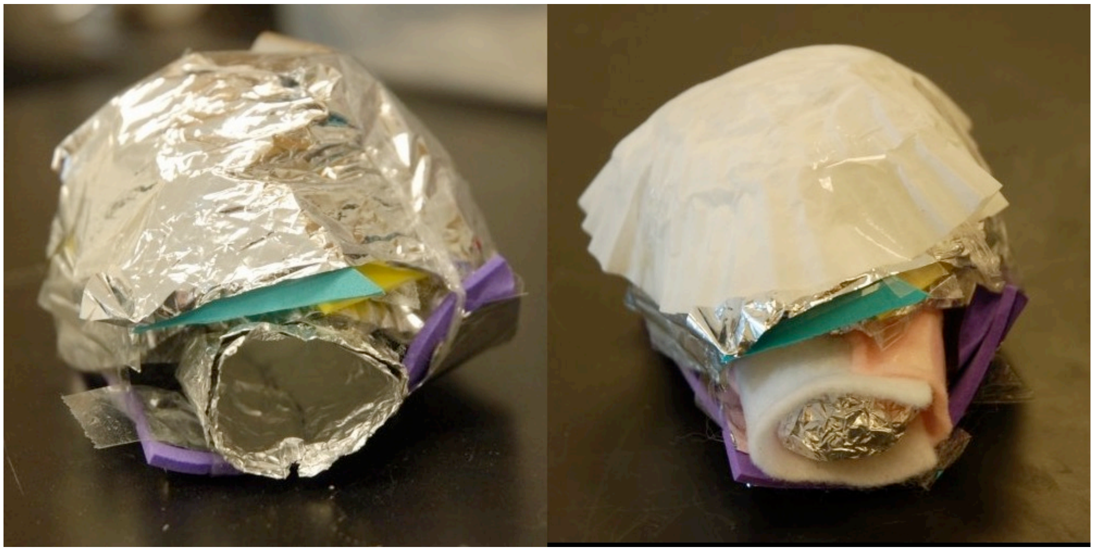
Re-Design Phase

Preparation

1. Make a fresh supply of penguin ice cubes the night before this lesson, or a double batch if the re-design takes place on the same day as the initial testing. Since ice will sublimate over time and lose mass, you should make a fresh batch each evening before testing. Use the medical syringe to ensure each penguin has the same mass when frozen.
2. Print the award certificate sheets so you can fill in the names of "winners" during class if you desire.
3. Copy the post-test assessment (Appendix B) and distribute to students while redesigned dwellings are in the hot box for re-testing.

Procedures

1. Allow students 15-20 minutes to make revisions to their designs.



Example of a redesigned penguin dwelling

2. Repeat the testing process as before.

3. While the igloos are in the hot box, administer the post-test assessment to the students (Appendix B). If students finish early, have them work on finalizing their storyboard.

4. When the timer goes off, repeat the process of massing the penguin remains and recording the results on a chart for discussion.

5. Have students record their final design and results on their storyboard.

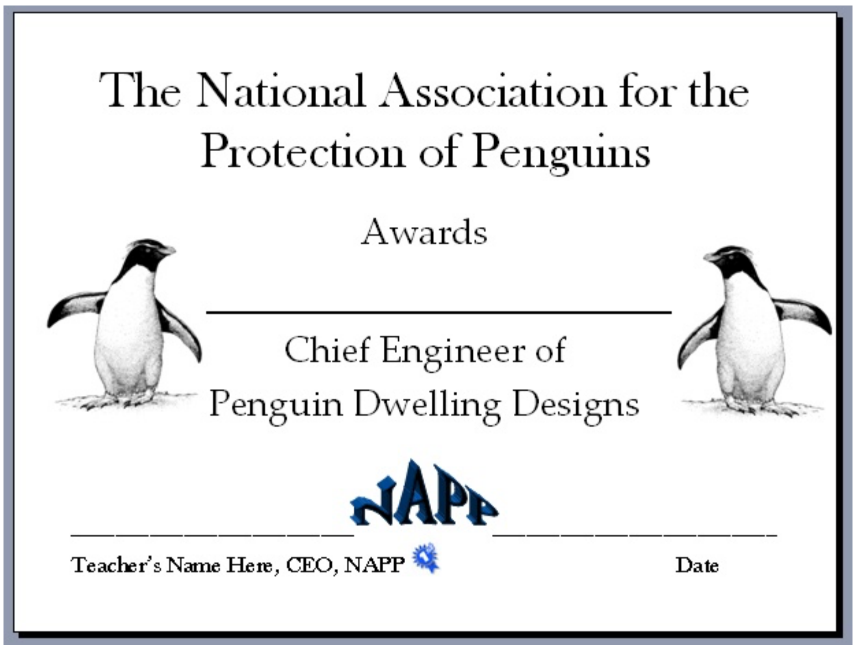
   Teacher Note*: Any team that saves a greater mass of penguin than during the original test deserves acclaim for being an engineer.*

6. Ask students what they liked and disliked about this unit. Use this information to help you plan future units that combine engineering design with science.

7. Determine winning teams and distribute an award certificate to each member of the team. An award template is provided in this STK.

   Teacher Note: Below is a list of suggested awards.
   - ***Effective Design*** – Awarded to the teams that saved the most penguin. (1st, 2nd, and 3rd place awards can be given)
   - ***Most Improved Design*** – Awarded to the team that improved the most from Test 1 to Test 2

- ***Affordable Housing Award for Financially Challenged Penguins*** – Awarded to the team that spent the least amount of money but still saved at least half of the penguin.
- ***Improved Design*** – Awarded to every team that actually improved their design and saved more of the penguin during the second test
- ***People's Choice*** – Awarded by students to the design they liked the best determined by popular vote



Award sample

Wrap-up

1. Wrap up this unit with a discussion of lessons learned. Here are some possible question prompts:

   Engineering Prompts: Engineers follow a general process to design solutions to problems.

   - What process did you use to design a solution to a problem?
   - Why was this unit called "Save the Penguins"?
   - How does saving energy at home help animals that live so very far away?
   - What do engineers do that help people and animals?
   - What were the science concepts you had to know in order to be a good engineer in this unit?
   - What constraints did you have when you designed your igloo?
   - Why was it important to do a re-design?

- What were some engineering practices you had to know in order to design and build the best penguin igloo you could?

Science Prompts: Heat transfers in predictable ways

- What are some rules about heat transfer? (it transfers from warm to cold, it is thermal energy moving, it transfers three different ways)
- Describe three ways heat can transfer.
- What is the difference between an insulator and a conductor?
- Why does a silver tray feel colder than a plastic tray?
- If you sat on a metal bench in the wintertime, what would it feel like? Why?
- If you sat on a plastic bench in the wintertime, would it feel different? Why?
- Which materials were best at preventing radiation? Conduction? Convection?
- Which combinations of materials worked best? Why?
- What was the most interesting part of this unit to you?

The materials listed in Table 1 will supply one teacher with four classes of students- approximately 112 students. Some materials will be left over for future classes. Most materials can be purchased from a grocery store, hardware store, craft store, or large shopping mart. The entire kit can also be purchased from www.stemteachingkits.com
Suggested sites are provided below.

Table 1
Supplies needed for *Save the Penguins*

Quantity	Item	Source
1 bag	100% cotton balls, 100 count	Pharmacy
1 pack	craft sticks, 150 count	Craft store
1 pack	Black construction paper	Craft store
1 pack	Green construction paper	Craft store
1 pack	Pink construction paper	Craft store
1 pack	White construction paper	Craft store
12 each color	Foam sheets in white, black, pink and green	Craft store
12 pieces	White felt fabric, polyester, 9” x 12”	Craft store
12 pieces	Pink felt fabric, polyester, 9” x 12”	Craft store
12 pieces	Black felt fabric, polyester, 9” x 12”	Craft store
12 pieces	Green felt fabric, polyester, 9” x 12”	Craft store
1	Duck bubble wrap, 12" x 10 feet	Office supply store
1	Heavy duty aluminum foil, 75 sq. feet	Grocery store
3 sheets	Mylar 18” x 30” Sheets	Craft store
1	Hefty One Zip gallon storage bags, 12 count	Grocery store
7	Scotch tape	Office supply store
7	Aileen's Original Tacky Glue, 4 fl. Oz	Craft store
28	Plastic shoebox, 6 qt. size,	Hardware store
1	Black tote bin, 108 quart capacity	Hardware store
7	Dixie cups, white plastic	Grocery store
1	Play money	Online
2	Silicone penguin ice cube trays	Online
14	Digital thermometers	Online
7	Desk lamps or Shop lamps	Hardware store
7	Light bulbs, 100W	Hardware store
1	6 pack of soda	Grocery store
1	Wool sock	Sporting goods store
1	Cotton sock (charcoal/black)	Sporting goods store
1	Plastic tray	Home goods store
1	Metal tray (silver or silver plate is best)	Home goods store
2	Top Fin flexible aquarium thermometers , large	Pet store
14	Poster boards	Office supply store
7	Metal spoons (silver or silver plate is best)	Home goods store
7	Plastic spoons	Grocery store
1	Homemade cardboard house with black painted roof	
7	Digital timers	Online

1	Medical syringe 20 ml	Pharmacy

Preparation of Materials

Prepare the felt, foil, construction paper, foam, Mylar, and bubble wrap by cutting the materials into uniform squares. If you have a quilting ruler and cutting board, 3” x 3” pieces are convenient. If you want each piece to be sized metrically, you can cut the pieces into 10cm x 10cm squares. Store each material in separate one gallon storage bags for easy retrieval.

Materials cut and packaged

2

Supplies in large tote bin

APPENDIX B

ASSESSMENT ON HEAT TRANSFER

Name ________________________ Date _________________ Block/Period _____

- This questionnaire is about your understandings of heat transfer.
- For each question, circle the answer that is closest to your understanding.
- Be sure to read all the choices before selecting one.

1. You pick up a can of soda off of the countertop. The countertop underneath the can feels colder than the rest of the counter. Which explanation do you think is the best?
   a. The cold has been transferred from the soda to the counter.
   b. There is no heat energy left in the counter beneath the can.
   c. Some heat has been transferred from the counter to the soda.
   d. The heat beneath the can moves away into other parts of the countertop.

2. After cooking an egg in boiling water, you cool the egg by putting it into a bowl of cold water. Which of the following explains the egg's cooling process?
   a. Temperature is transferred from the egg to the water.
   b. Cold moves from the water into the egg.
   c. Energy is transferred from the water to the egg.
   d. Energy is transferred from the egg to the water.

3. Why do we wear sweaters in cold weather?
   a. To keep cold out.
   b. To generate heat.
   c. To reduce heat loss.
   d. All of the above.

4. Amy wraps her dolls in blankets but can't understand why they don't warm up. Why don't they warm up?
   a. The blankets she uses are probably poor insulators.
   b. The blankets she uses are probably poor conductors.
   c. The dolls are made of materials which don't hold heat well.
   d. None of the above.

5. As water in a freezer turns into ice,
   a. the water absorbs energy from the air in the freezer.
   b. the water absorbs the coldness from the air in the freezer.
   c. the freezer air absorbs heat from the water.
   d. the water neither absorbs nor releases energy

6. On a warm sunny day, you will feel cooler wearing light colored clothes because they
   a. reflect more radiation.
   b. prevent sweating.
   c. are not as heavy as dark clothes.
   d. let more air in.

7. If you put a metal spoon and a wooden spoon into a pot of boiling water, one will become too hot to touch. Why?

a. Metals conduct heat better than wood.
b. Wood conducts heat better than metals.
c. Metals pull in heat because heat is attracted to metals.
d. Wood isn't as strong as metals.

8. On a hot day, the upstairs rooms in a house are usually hotter than the downstairs rooms. Why?

a. Cool air is less dense than hot air.
b. Warm air rises and cool air sinks.
c. The upstairs rooms are closer to the sun.
d. Heat rises.

9. You have a can of soda in your lunchbox that you want to keep cold. Which material will work best to keep it cold?

a. Aluminum foil wrapped around the soda because metals transfer heat energy easily.
b. A paper towel wrapped around the soda because paper soaks up the moisture.
c. Wax paper wrapped around the soda because wax paper traps the moisture.
d. Your wool sweater wrapped around the soda because wool traps air.

10. When you hold a metal coat hanger in a camp fire to roast a marshmallow, the coat hanger might get too hot to hold. Why might the coat hanger get too hot?

a. The heat radiates along the coat hanger.
b. The heat builds up near the flame until it can't hold it anymore and then moves along the coat hanger.
c. Metal atoms vibrate with more energy when they get hot, and they collide with atoms near them, which makes the neighboring atoms vibrate too.
d. Since metals melt in fire, they react very strongly to fire and get hot easily.

11. An aluminum plate and a plastic plate have been in the freezer all night long. When you remove them the next morning,

a. The plates have the same temperature.
b. The plastic plate has a higher temperature.
c. The plastic plate has a lower temperature.
d. The aluminum plate has a lower temperature.

12. When placed in direct sunlight, which object will absorb the most radiation?

a. a white sweater
b. a snowball
c. some aluminum foil
d. a black sweater