National Aeronautics and Space Administration

NASA eClips™

Educator Guide

NASA's Our World:

Insulators

Educational Product	
Educators & Students	Grades 4-6

EG-2010-06-008-LaRC

INSULATORS

National Standards:

National Science Education Standards (NSES)

Science as Inquiry
Abilities necessary to do scientific inquiry
Understanding about scientific inquiry

Physical Science
Properties of objects and materials

Science and Technology
Understanding about science and technology
Abilities of technological design

National Council of Teachers of Mathematics (NCTM)

Measurement
Understand measurable attributes of objects and units, systems, and processes of measurement
Apply appropriate techniques, tools, and formulas to determine measurements

Data Analysis and Probability
Select and use appropriate statistical methods to analyze data

International Technology Education Association (ITEA)

Design
Students will develop an understanding of the attributes of design.
Students will develop an understanding of engineering design.
Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Grade Level:
4 – 6

Subjects:
Elementary science

Teacher Preparation Time:
20 minutes

Lesson Duration:
One and a half 55-minute lessons

Time Management:
Class time can be reduced by 20 minutes if students complete the EXPLAIN and EVALUATE at home.

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Lesson Overview:

In this lesson students learn about the thermal insulating properties of different materials. In the ENGAGE section, students review their understanding of insulators and conductors and extend this understanding to the Hubble Space Telescope's thermal blanket. In the EXPLORE and EXPLAIN sections, students work in teams to test the insulating properties of cups made of three different materials. In the EXTEND section, students use the design process to improve the insulating properties of the best performing insulator from their previous experiment. This lesson is developed using the 5E model of learning and utilizes NASA eClips™ video segments.

Icons flag five areas of interest or opportunities for teachers.

- **TECHNOLOGY** highlights opportunities to use technology to enhance the lesson.
- **MODIFICATION** denotes opportunities to differentiate the lesson.
- **RESOURCES** relates this lesson to other NASA educator resources that may supplement or extend the lesson.
- **CONNECTIONS** identifies opportunities to relate the lesson to historical references and other topics or disciplines.
- **CHECK FOR UNDERSTANDING** suggests quick, formative assessment opportunities.

Essential Questions

- How do scientists study insulators?
- How do engineers use science to develop new technology?

Instructional Objectives

Students will

- review the concept of insulators and conductors;
- test different materials to determine which is the best insulator; and
- use the engineering design process to improve a material's insulating properties.

Materials List

Explore
Per student

- Student Guide and science notebook

Per group of four students

- three cups each made of a different material
  - Suggested materials: foam, paper, plastic.
  - The cups you choose should be similar in size, shape, and capacity. Suggested size: 220 mL (8 oz) cups
- three thermometers
- three plastic wrap squares with a small slit in the middle to cover the top of each cup.
  NOTE: The slit should be just long enough to allow students to push the thermometer through the plastic wrap and into the cup.
- three rubber bands
- stop watch or clock with second hand
- one 100 mL beaker or 100 mL graduated cylinder
- three 400 mL beaker
- 300 mL of hot water
  SAFETY NOTE: Water should be hot, but not boiling. Students should not pour hot water.
  WARNING: 45 °C (113 °F - just a little over fever temperature), the "temperature of pain" is also the temperature of human tissue destruction. Exposure will result in burns and scarring! Watch out for procedures calling for use of this water temperature or higher with children.

5E Inquiry Lesson Development

ENGAGE (10 minutes)

NASA Background for the Teacher: Hubble Space Telescope's Thermal Blanket

"Thermal blankets are to spacecraft as clothes are to people," says Mike Weiss, Hubble Space Telescope's technical deputy program manager. "Just as clothes cover our skin and help protect us from nature's elements…the cold winter wind and the scorching summer sun, thermal blankets protect Hubble from the harsh environment of space."

Hubble orbits Earth at a speed of 8 km/s (5 mi/s). That means that it circles Earth every 97 minutes and completes about 15 orbits each day. As it travels between Earth's shadow and the side lit by the sun the telescope is exposed to extreme temperature differences; the extreme cold of deep space on the dark side and the powerful heat of the sun in rapid and constant cycles on the sun side. "The thermal blankets' outer layer swings about 100 degrees Celsius (212 degrees Fahrenheit) every 45 minutes," says Ben Reed, a group leader assigned to the Materials Engineering Branch at Goddard. The blanket must be able to insulate Hubble's equipment from the extreme temperature changes.

To provide adequate insulation for the Hubble Space Telescope the insulating material must be very effective. The blanketing material used on the telescope is approximately 16 layers of dimpled aluminum covered in a Teflon skin. When laid flat the blanket is incredibly thin, measuring less than three millimeters (about one-tenth of an inch). Despite this, it still protects the onboard instruments against the extreme temperature fluctuations.

"The space environment is extremely harsh," Reed says. "It begins to degrade the telescope's external surfaces from the first day in orbit. Hubble has been in orbit since 1990; the outer Teflon layer has started to crack." It is crucial to repair or replace the blanket from time to time. The New Outer Blanket layer (NOBL), covers the sections of Hubble's external blanket that are in need of repair. The NOBL layer prevents further degradation of the insulation and maintains normal operating temperatures of Hubble's equipment.

"Protecting Hubble from the harsh environmental effects of space with a thermal blanket is like protecting a mountain climber ascending a summit," Weiss says. "Over time, the wind and elements crack and tear the outer layer of the hiker's insulated clothing. Although the clothing looks tattered the hiker is still protected and able to continue the ascent. The current Hubble blanket and the ones that were installed during Servicing Mission 4 may look tattered and torn, but they still protect.

Resources

Custom-Made Blankets for a World-Class Observatory

http://www.nasa.gov/mission_pages/hubble/servicing/series/hst_blankets.htmL

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Procedure

1. Facilitate a student discussion about appropriate clothes for different seasons. These questions may help guide the discussion:
   - Why do people wear clothes? *(Answers will vary. Students may suggest that they wear clothes for cover and protection from temperature and sunburn.)*
   - How do your clothes change as the inside or outside temperature changes? *(Answers will vary. Students may suggest that they wear thin clothes when it is hot and many layers of clothes when it is cold.)*
   - Are all clothes made from the same material?
     (MODIFICATION) Have samples of different materials available for students who are unsure of the different types of materials used in clothing.
   - Can the same material be used to make clothes for different temperatures?
   - How do other living organisms or objects protect themselves? *(Answers will vary. Students may compare clothes to animal fur. They may also discuss pets wearing coats. Some may suggest wrapping pipes to protect them from freezing. Use this question to lead to the topic of thermal protection blankets for the Hubble Space Telescope.)*

2. Introduce the video segment with a question similar to this:
   - Do you know what protects satellites while they are in orbit? Did you know that the Hubble Space Telescope wears a blanket for protection from the extreme changes in temperature? You will find out more about this special blanket in this video segment.

   (TECHNOLOGY) Show the NASA eClips™ video segment *Our World: Hubble Clothing: Thermal Protection Blankets (4:57)* to the students. This video or a captioned version may be streamed or downloaded from the NASA eClips™ page of the NASA web site: http://www.nasa.gov/audience/foreducators/nasaeclips/search.htmL?terms="Hubble%2Clothing"&category=1000
   (MODIFICATION) This video may be streamed from the NASA eClips You Tube™ channel: http://www.youtube.com/user/NASAeClips#p/c/31002AD70975DC1B/42/wEtjkecqLvM

3. **(MODIFICATION)** For students in grades 5 or 6, you may want to show the NASA eClips™ video segment *Real World: Hubble Thermal Blanket (5:43)*. This video also integrates mathematics with the science. The video or a captioned version may be streamed or downloaded from the NASA eClips™ page of the NASA web site: http://www.nasa.gov/audience/foreducators/nasaeclips/search.htmL?terms="Thermal%20Blanket"&category=0100
   This video may be streamed from the NASA eClips™ You Tube™ channel: http://www.youtube.com/user/NASAeClips#p/c/887C1C3BAAD53F17/42/5bUgWoCix0c

Use these questions to summarize key points of the video and lead into the EXPLORE activity.

- How is Hubble's thermal blanket like the clothing you wear? *(Answers will vary but students may suggest that both protect the "wearer" from extreme temperatures and solar radiation.)*

- Is Hubble's thermal blanket a conductor or insulator? Defend your answer. *(Hubble's thermal blanket is an insulator. Insulators are materials that resist or slow the transfer of heat. Thermal blankets protect Hubble instruments from extreme temperatures as the Hubble orbits Earth.)*

4. **(RESOURCES)** More than 125 Hubble Education resources, activity products, and links can be found at the Hubble Education Resource site, www.nasa.gov/education/hubble

EXPLORE (30 minutes)

In this section, students are challenged to think like scientists as they compare different materials to determine the best insulator. Scientists make hypotheses based upon prior experiences, observations, and research. They set up controlled experiments which test only one variable. Scientists use math to analyze collected data. They look for patterns and trends in data to draw conclusions.

Pre-teaching preparations are listed below.

1. Gather the materials listed in the Educator Guide.

2. Students will follow the procedure outlined in the Student Guide. Students will record data in the student guide on pages 3-5. Discuss each person's role in the team to determine how four students will work together to complete this activity.
   a. One way to divide the team might be to assign tasks this way:
      - Students could take turns reading the thermometers and timing the two-minute intervals.
      - One student could hold the cup steady while another pulls the thermometer out of the cup to read the temperature.
      - One student could record the data initially and then share the data with the rest of the team.
      - Caution students NOT to pull the thermometer out of the cup entirely.

   (MODIFICATION) Students can also be grouped heterogeneously, academically and randomly.

3. Direct students to raise their hand when they are ready for you to pour hot water for them. **SAFETY NOTE:** In the student guide, students are directed to place the Styrofoam cup in 400 mL beaker for added stability. Emphasize to students that you will not pour the hot water for them if they have not completed this step.

   WARNING: 45 °C (113 °F - just a little over fever temperature), the "temperature of pain" is also the temperature of human tissue destruction. Exposure will result in burns and scarring! Watch out for procedures calling for use of this water temperature or higher with children.

4. **(CHECK FOR UNDERSTANDING)** Students are asked to calculate the temperature difference in the table on page 5. If students are unsure how to calculate this ask them to think about the mathematical meaning of "difference."

EXPLAIN (20 minutes)

In this section, students analyze the data gathered in the EXPLORE section.

1. Ask students to complete the questions in the Student Guide.

2. **(MODIFICATION)** Questions in the Student Guide may be completed outside of class.

3. **(CHECK FOR UNDERSTANDING)** Use these questions to help facilitate a discussion concentrating on the previously collected data.
   - Examine the beginning and ending temperatures for each cup. What is the difference between these numbers? *(Numbers will vary, but the water in paper and plastic cups should lose more heat than water in the foam cup.)*
   - Did you notice a trend in the temperature? *(All temperatures will decrease, but some will decrease faster. The water in the foam cup will not lose heat as quickly as the water in the paper and plastic cups.)*
   - Did the results of the experiment support your hypothesis? *(Answers will vary based on students' original hypothesis.)*
   - How were you thinking and acting like a scientist during the EXPLORE activity? *(Remind students that they formed a hypothesis BEFORE the experiment based upon prior experiences. Students controlled the variables of the experiment by using cups that were the same size, shape, and capacity. They used tools to collect elapsed time and changes in temperature, placed it in a table and analyzed it for patterns and trends.)*
   - Based upon evidence, what material proved to be the best insulator in this activity? How would you improve this material's insulating properties? *(Students should have evidence that the foam is the best insulating material. Ideas for improvement may include adding other materials or increasing the thickness.)*

EXTEND (50 minutes)

In this section, students are challenged to think and act like engineers. Engineers use science and math to create new products which solve problems and improve one's quality of life.

Based upon the data collected and prior conversations, challenge your students to increase the R-value of the best insulator. Limitations are found in the student guide. Students need to understand that as engineers there are certain criteria that must be met in real world design. This may include size, cost, and available resources. Other limitations may be added. For example, materials can each be given a unit cost and the students are given a budget amount that they cannot exceed. Another example of a limitation would be to tell the students that the new container must maintain a constant temperature for a certain period of time.

1. Students read the introduction to the EXTEND activity in the Student Guide. Here they learn the concept of the R-value rating system for building materials. The thermal resistance of building materials is given an R-value; the higher the R-value number, the better the insulator.

2. **(MODIFICATION)** Depending upon the ability of the students, you may make this a guided or open-inquiry experience. You may choose to set additional criteria and constraints for the EXTEND based upon student interest and abilities. Some possible ways to guide the inquiry include:
   - Model stacking cups. The criteria and constraints suggest that students may only use four cups. You may modify that constraint.
   - Model mixing and stacking cups.
   - Allow students to use other materials to wrap the cups. Possibilities may include aluminum foil, paper towels, cloth, coffee filters, plastic wrap, packing peanuts, etc.
   - Establish criteria and constraints as to ways to connect materials such as using glue, tape, staples, or rubber bands.
   - Determine if students can cut or change cups in the EXTEND activity.

3. Stress to students that following the same procedure as the one used in the EXPLORE activity is a key part of scientific investigation. Different procedures could lead to different results.

4. **(CONNECTIONS)** Use the NASA eClips™ Design Process Packet to guide your students through the engineering design process. The Design Process Packet can be downloaded at: http://www.nasa.gov/pdf/324205main_Design_Packet_I.pdf. This packet provides students with pages to keep track of the entire engineering design process and contains a rubric to assess the project.

5. Explain that students will follow the EXPLORE procedure to test their design. It may be wise to allow students to test their insulated apparatus in the sink PRIOR to filling it with water to be sure it is water tight.

6. **(CONNECTIONS)** As students discuss improving the insulating quality of the cup, discussion may lead to adding a layer of aluminum foil. Adding the foil creates a material similar to Tyvek® used to insulate houses. Another real world example would be blankets used to insulate water heaters.

7. **(CONNECTIONS)** Have students read the career clip on page 9 of the Student Guide to learn more about what aerospace engineers do.

EVALUATE (10 minutes)

1. Through discussion and the results of the EXPLORE and EXPLAIN experiences, determine if your students have an accurate understanding of insulators.

2. Ask students to answer these journal prompts to assess their understanding of the essential questions.
   a. How do scientists study insulators?
   (Answers will vary, but students should discuss the steps they used to test the insulating properties of the different cups. They should discuss that they made a hypothesis, then ran a controlled experiment, where they gathered, organized and analyzed data. Based upon this data, the students determined the best insulating material tested.)

   b. How do engineers use what scientists learn to develop new technology?
   (Answers will vary, but students may steps in the design process that extended what they learned in the EXPLORE activity.)

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Essential Questions

- How do scientists study insulators?
- How do engineers use science to develop new technology?

Background

Heat describes the transfer of **thermal energy** between two systems of difference temperatures. It moves through solids, liquids, gases and space.

Heat transfer is the movement of energy from a warmer object to a cooler object. When heat moves between two solids that are touching, it is called **conduction**. When heat travels through liquids or gases it is called **convection.** Sunlight is an example of heat transfer through space and is known as **radiation.**

Movement of heat depends on the materials. **Conductors** are materials which allow heat to transfer easily while **insulators** resist the transfer of heat.

As a scientist in this lesson, you will test different materials and compare them as insulators. As an engineer you will design a better insulator.

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Vocabulary

absorb – **Absorb** means to take in. Light energy that is absorbed is not given off, it is taken in by the object that absorbs the light. As a result, the object may become warmer.

Conduction – Conduction is the transfer of heat between two solid objects that are touching.

Conductors – Conductors are materials that easily transfer heat or electricity.

Convection – Convection is the transfer of heat between flowing gases or liquids.

Insulators – Insulators are materials that resist or slow the transfer of heat.

R-value – The **R-value** measures a material's insulating properties.

Radiation – Radiation is the transfer of heat through space.

Thermal energy – Thermal energy is the kind of energy associated with the increased movement of molecules in a substance. The higher the heat, the faster the particles are moving.

Trend – A **trend** is a general direction of movement. On a graph, the trend is the overall direction (either increase or decrease) of the values graphed.

EXPLORE

You and your team will test cups made of different materials to determine which material is the best insulator.

Follow this procedure.

1. Gather these materials:
   a. one 8 oz. plastic cup
   b. one 8 oz paper cup
   c. one 8 oz Styrofoam cup
   d. three thermometers
   e. a 100 mL beaker or 100 mL graduated cylinder
   f. three 400 mL beakers
   g. three plastic wrap squares with a small slit in the middle to cover the top of the cup
   h. three rubber bands
   i. stop watch or clock with second hand
2. Number each cup by assigning the foam cup #1, the paper cup #2 and the plastic cup #3 then place on a solid surface.
3. Now that you have gathered and examined your materials, write a hypothesis for this experiment.

Hypothesis:

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4. Place the each cup in the 400 mL beaker and raise your hand to let your teacher know you are ready for hot water. SAFETY NOTE: You will not receive any hot water if the cups are not in the beakers.
   WARNING: 45 °C (113 °F - just a little over fever temperature), the "temperature of pain" is also the temperature of human tissue destruction. Exposure will result in burns and scarring! Watch out for procedures calling for use of this water temperature or higher with children.
5. Once your cups have hot water in them cover the top of the cup with the plastic wrap which has a small slit in the middle and use a rubber band to secure it. Slide the thermometer into the cup through the slit in the middle of the plastic wrap.
6. Once all three cups have thermometers and are sealed, record the initial temperature of each numbered cup in Chart A below. Carefully remove the thermometer far enough out of the cup to read the temperature. Then carefully and quickly return the thermometer to the water
7. Read the temperature of each cup of water every two minutes for the next 20 minutes. Record each temperature in Chart A.

Chart A: Cups as Insulators

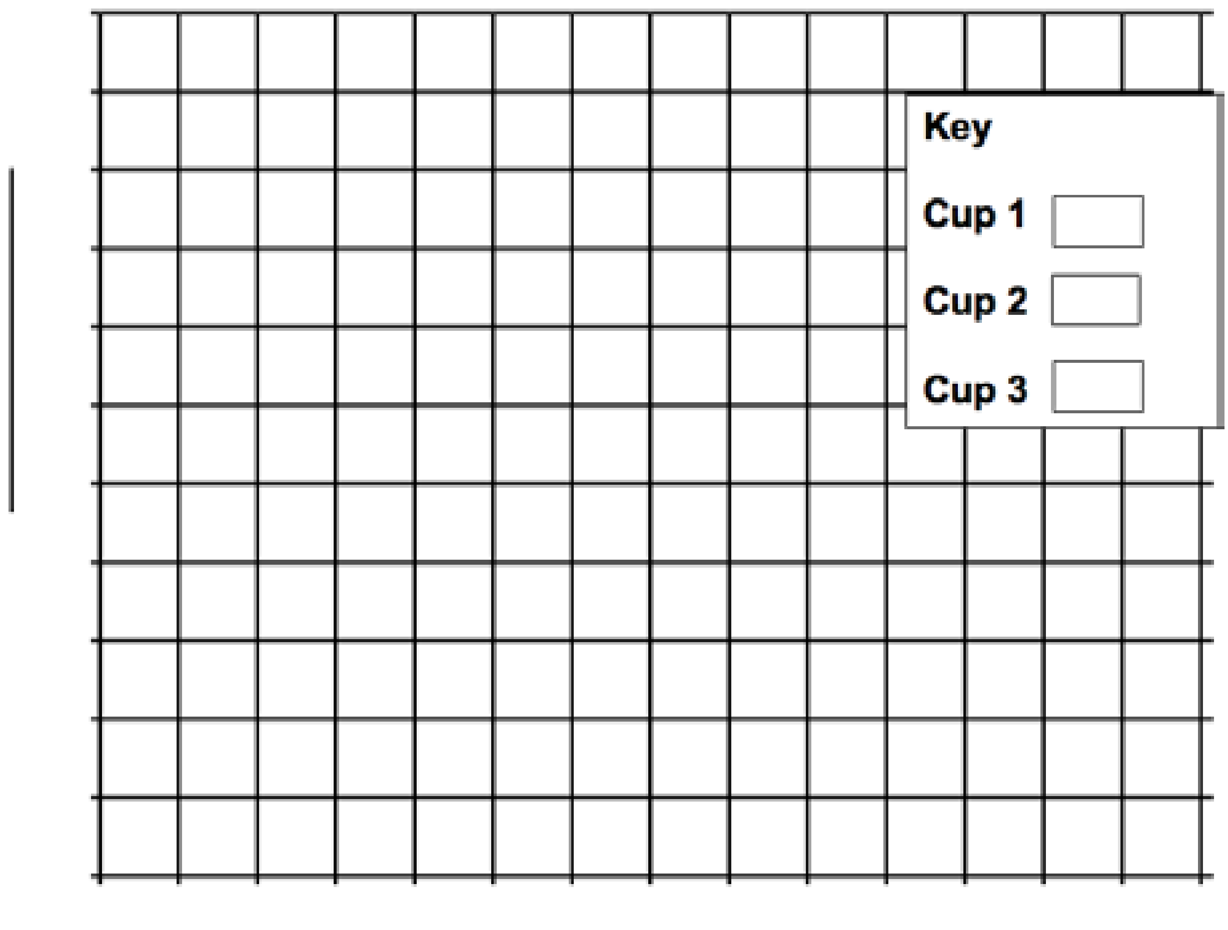
TIME (minutes)	CUP 1: Foam Temperature (˚C)	CUP 2: Foam Temperature (˚C)	CUP 3: Foam Temperature (˚C)
Initial Temperature			
2			
4			
6			
8			
10			
12			
14			
16			
18			
20			

What is the difference between the starting and ending temperature for each cup?

	CUP 1	CUP 2	CUP 3
Starting (initial) Temperature (˚C)			
Ending Temperature (˚C)			
Difference (˚C)			

Use the data in Chart A to complete Graph 1.

Graph 1: Cup Insulators



Graphing Checklist:

a. Did you label each axis?
b. Did you use three different colors to represent the data from each cup?
c. Did you color code the key?
d. Did you plot the points and create a line graph for each cup?

EXPLAIN

1. Compare the data with your hypothesis. Was your hypothesis correct? Explain.

2. What changes did you observe in the temperature of cup #1?

3. What changes did you observe in the temperature of cup #2?

4. What changes did you observe in the temperature of cup #3?

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5. What caused these changes? What process is taking place; conduction, convection or radiation?

6. Which cup was the best insulator? What is it made of? What evidence do you have to support your answer?

7. Which cup was the best conductor? What is it made of? What evidence do you have to support your answer?

EXTEND

Insulators are used in construction projects to save energy. For example, when a house is built insulation is added to help keep the inside temperature constant. In other words, keep the warm air in and cold air out during winter and vice versa during summer.

Ceilings, walls and curtains can also be made out of insulating materials. Building materials are assigned an **R-value** which is the measure of the insulator's ability to resist heat travelling through it. A high R-value means it is a better insulator.

You and your team are challenged to increase the R-value of the best insulator from the EXPLORE activity.

Your teacher will help you work through the design process.
These limitations must be considered as you work to improve the R-value of the cup.

- You may use up to 4 cups from the EXPLORE activity.
- You may use any additional materials available.
- The same procedure used in the EXPLORE activity must be used here as well.
- The variables will change as you test your design and the cup which was the best insulator in the initial experiment.
- Create a data chart similar chart A found on page 4 of the student guide to fit this experiment.

Be sure to use the Engineering Design Packet to keep track of your work.

Career Clip

In this lesson, you have been a scientist and an engineer. Read this Career Clip to find out more about Mike Weiss, a NASA Aerospace Engineer at NASA Goddard Space Flight Center.

1. How is the work you did in this lesson similar to the work Mike Weiss does every day?

2. What can one do today to prepare for a career as an engineer?

Mike Weiss
Aerospace Engineer
NASA
Goddard Space Flight Center

My training …

I have a Masters of Science in Aerospace Engineering from the University of Maryland.

Best part of my job...

Is working with many talented people from so many backgrounds to solve complex engineering problems.

For me …

It was watching Ed White perform our Country's space walk when I was about nine years old. From that moment on, I knew that I wanted to be an aerospace engineer and work for NASA on the U.S. Space Program.

My advice to students *would be to get a broad-based education, get field experience working internships and co-operative opportunities. Don't worry early on about finding your specific interest; you will know it when it happens.*

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EXPLORE

Hypothesis:
I think that the temperature in the water in the *(Answers will vary but may include foam)* cup will not change as quickly or as much as the water in the other cups because *(foam material holds heat better than plastic of paper.)*

Chart A: Cups as Insulators *(Answers will vary)*

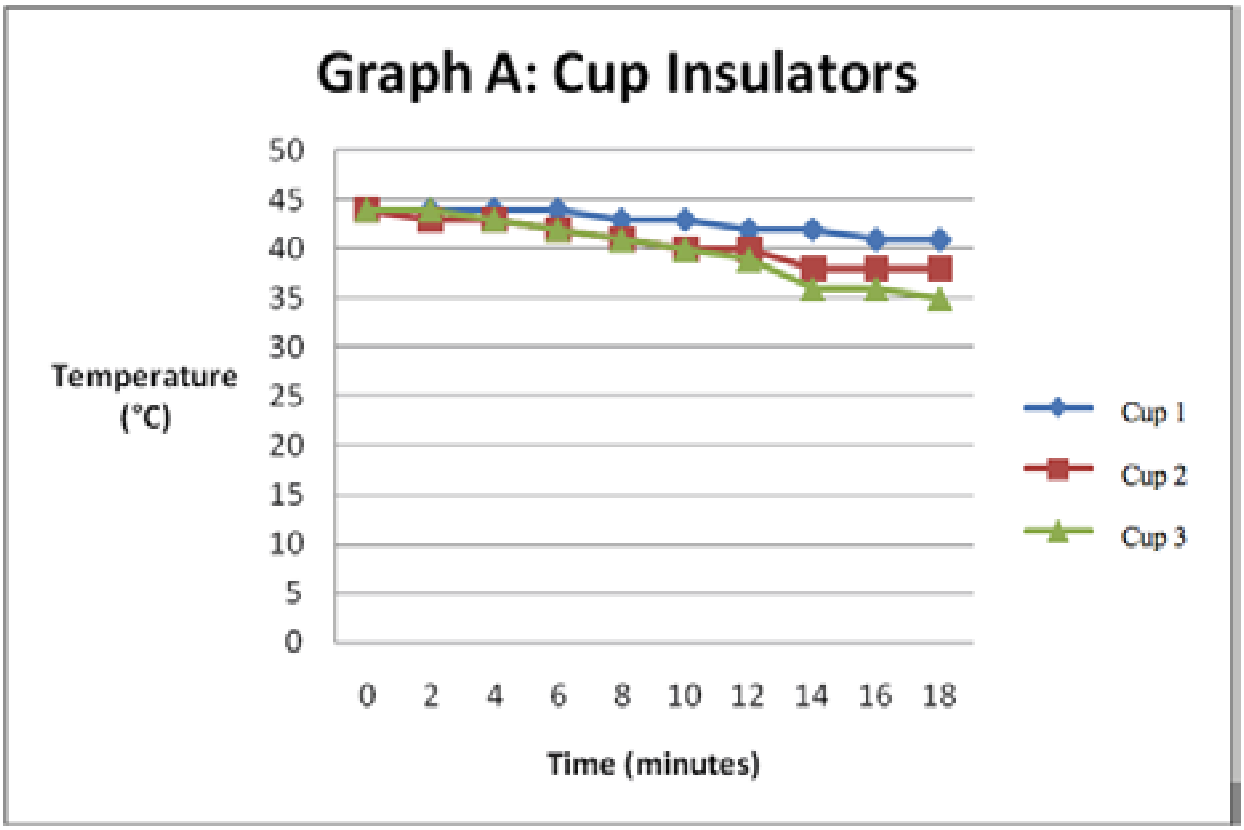
TIME (minutes)	CUP 1: Foam Temperature (°C)	CUP 2: Foam Temperature (°C)	CUP 3: Foam Temperature (°C)
Initial Temperature	*44*	*44*	*44*
2	*44*	*44*	*44*
4	*44*	*43*	*44*
6	*44*	*43*	*43*
8	*44*	*42*	*42*
10	*43*	*41*	*41*
12	*43*	*40*	*40*
14	*42*	*40*	*39*
16	*42*	*38*	*36*
18	*41*	*38*	*36*
20	*41*	*38*	*35*

answerkey

What is the difference between the starting and ending temperature for each cup? *(Answers will vary)*

	CUP 1	CUP 2	CUP 3
Starting (initial) Temperature (˚C)	*44*	*44*	*44*
Ending Temperature (˚C)	*41*	*38*	*35*
Difference (˚C)	*3*	*6*	*9*

Graph 1: Cup Insulators



answerkey

EXPLAIN

1. Compare the data with your hypothesis. Was your hypothesis correct? Explain.
   (Answers will vary. If students' hypotheses are NOT correct, the important piece is that the students explain how their thinking has changed. An example of one response might be: I was wrong. Heat got out of the paper and plastic faster than the foam.)

2. What changes did you observe in the temperature of cup #1?
   (Answers will vary, but students should discuss different rates of change as the temperature drops in each cup.)

3. What changes did you observe in the temperature of cup #2?
   (Answers will vary, but students should discuss different rates of change as the temperature drops in each cup.)

4. What changes did you observe in the temperature of cup #3?
   (Answers will vary, but students should discuss different rates of change as the temperature drops in each cup.)

5. What caused these changes? What process is taking place; conduction, convection or radiation?
   (Answers will vary, but students may discuss how different materials "hold" heat. This is a good time to discuss that heat is a form of energy that can move between objects. Heat always moves from a warmer object to a cooler object. The cups are made out of different materials. Foam does NOT let heat travel through as easily as paper and plastic.)

6. Which cup was the best insulator? What is it made of? What evidence do you have to support your answer?
   (Answers will vary, but students should discuss what they have observed during this experiment. Ask students to return to their observations and identify evidence for their statements. Students should observe that foam is a better insulator than plastic or paper. An example of a response might be: Tin foil and foam. The Hubble used dimpled tin foil.)

7. Which Which cup was the best conductor? What is it made of? What evidence do you have to support your answer?
   (Answers will vary, but students should discuss what they have observed during this experiment. Ask students to return to their observations and identify evidence for their statements. Students should observe that paper and plastic conduct heat better than foam.)

answerkey

EXTEND

Example of a student-designed data chart.

Chart B: Cups and Designed Cups as Insulators

TIME (minutes)	Cup 1 Foam Cup Temperature °C	Cup 2 Foam Cup Temperature °C
2	*50*	*50*
4	*48*	*50*
6	*47*	*49*
8	*46*	*49*
10	*46*	*48*
12	*45*	*47*
14	*44*	*47*
16	*43*	*47*
18	*43*	*47*
20	*42*	*44*
Difference	*8*	*6*

1. Describe the layers of insulating materials in your design.
   (Answers and designs will vary in this EXTEND activity. Students should explore how multiple layers and a variety of materials create effective insulators.)

Career Clip

1. How is the work you did in this lesson similar to the work Mike Weiss does every day? *(Answers will vary but may include that students are brainstorming, problem solving, making models, testing, and re-testing in similar ways to the way Mike Weiss works through the engineering design process.)*
2. What can one do today that may help you prepare for a career as an engineer? *(Answers will vary but may include making connections between math and science, testing ideas, taking things apart and putting them back together.)*

answerkey