Thermal Energy – Save the Penguins

Unit	Utah SEEd Standard / NGSS Performance Expectation	Estimated Lesson Time:
Thermal Energy	**Standard 8.1.7** **Design, construct,** and **test** a device that can affect the rate of a phase change. *Compare and identify the best characteristics of competing devices, based on **data analysis**, and modify them to improve the device to better meet the criteria for success.*	Four 50-minute class periods

Lesson Overview

Learning Objective

Students will be able to create a penguin shelter that will keep a penguin ice cube frozen overnight.

Anchor Phenomenon

Video of penguins and their adaptations to the cold.

Driving Question

How can I use insulators to help keep ice cold overnight?

Lesson Level Performance Expectations

Design and optimize solutions to demonstrate the **cause and effect** of limiting **thermal energy transfer.**

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Lesson Snapshot

Lesson Summary:			
	Estimated Time	**Section Overview**	**How are students answering the driving question or meeting the learning objectives?** (Highlight **SEPs**, **DCIs**, and **CCCs**)
Experience the Phenomenon	10 minutes	Students discuss heat energy transfer and penguins at the Hogle Zoo.	What natural adaptations do penguins have that help them keep warm in the cold? How can we use these adaptations in **designing a solution** for keeping an ice cube cold?
Research	30 minutes	Students research good insulators and good cooler designs and come up with three possible solutions.	Students research how different materials **affect** thermal **energy** transfers.
Build the Prototype	45 minutes	Students choose one design, budget their materials, and build their first prototype.	Students **design a solution** for keeping ice frozen overnight.
Test the Prototype	45 minutes	Students measure the melted water and review which coolers worked best. They make necessary changes to their prototype for a second trial.	Students review data and **optimize their designs,** incorporating some of the best elements from other designs.
Final Data Analysis	45 minutes	Students analyze the data to determine whether they protected their ice penguin.	Students record how their devices **affect** thermal energy transfer and the phase change.

Disciplinary Core Ideas	Science & Engineering Practices	Crosscutting Concepts
DEFINITIONS OF ENERGY Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. A system of objects may also contain stored (potential) energy, depending on their relative positions. Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. The term "heat" as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures.	DESIGNING SOLUTIONS Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.	CAUSE AND EFFECT Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.
Related knowledge and skills from prior grades		
Disciplinary Core Idea: The faster a given object is moving, the more energy it possesses.	Science and Engineering Practices	Crosscutting Concept:

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Energy can be moved from place to place by moving objects or through sound, light, or electric currents.	Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem. Apply scientific ideas to solve design problems. Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.	Cause and effect relationships are routinely identified, tested, and used to explain change. Events that occur together with regularity might or might not be a cause and effect relationship.

Materials

Link to all materials on the 3DRST website (3drst.byu.edu): https://3drst.byu.edu/8th-8-1-7-penguins
Link to all materials on Canvas Commons: https://tinyurl.com/3DRSTeighth

Student Materials	Teacher Materials	Other Resources
- Save the Penguins Student Worksheet - Science Dollars	- Save the Penguins Teacher Slides - Insulator Research - How Conductors and Insulators Work reading - Utah Heatwave Video - Bill Nye Heat Video	Collected boxes, Styrofoam, bubble wrap, newspaper, etc., or purchase supplies such as those below: - Ice cubes or Penguin Ice Molds – Amazon - Jars – Amazon - Beakers – Amazon - Bubble Wrap – Amazon - Newsprint or shredded paper – Amazon - Foil – Amazon - Plastic Wrap – Amazon - Glue Guns – Amazon - Duct Tape – Amazon - Boxes – Amazon Other possible supplies include hamster bedding, felt, fleece squares, broken-down cardboard boxes, etc.

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Lesson Preparation

Material Preparation:
Collect recycled boxes and packaging materials as needed.

Required Previous Knowledge:
This lesson builds on students' prior understanding of the following DCIs developed in standard 8.1.5:
Develop a model that uses computational thinking to illustrate the cause and effect relationships in particle motion, temperature, density, and state of a pure substance when heat energy is added or removed.

Supports students will need/adaptations:

Vocabulary Definitions:
Thermal Energy: the total energy of tiny, invisible particles (atoms and molecules) in an object that are constantly moving.
Temperature: a way to measure how hot or cold something is.
Energy transfer: when energy moves from one object to another or from one place to another.
Conductor: is when energy moves from one object to another or from one place to another.
Insulator: A material that acts like a "blocker" or "shield," preventing things like electricity or heat from passing through it easily
Constraints: Anything that limits or restricts how you can solve a problem or design something.
Criteria: The specific things you look for or the standards a solution must meet to be considered good or successful.

Experience the Phenomenon/Problem (Engage)

What Students Are Doing	Teacher Tips
Students watch the penguin video and discuss how penguins are adapted to living in cold environments. Students will watch a Bill Nye video to obtain information about Thermal Energy. Students will fill in the blanks on their worksheet while watching the video.	Bill Nye Heat Video Have students read the questions before watching the video.
What Teachers Are Doing	**Teacher Tips**
Ask questions that prompt students to discuss the method of insulation. Walk around the classroom as students watch the Bill Nye video, answering questions and ensuring students fill in the blanks.	Example questions: - What environment are penguins naturally in? - What did you notice about how penguins stay warm in the cold environment? - How can the penguin's feathers and blubber cause problems in a warmer environment?

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INVESTIGATE THE PHENOMENON (EXPLORE)

What Students Are Doing

Day 1: Cooler Research (Pages 1-2 of the student worksheet)

Cooler Design Project: Student Checklist

Before Building

- I can explain the challenge in my own words.
- I wrote down all the rules and materials I can use.
- I listed what makes a cooler work best (keeps ice cold, uses insulation, etc.).
- I sketched at least two ideas for my cooler.
- I chose my best idea and explained why I picked it.
- I know how much money my group can spend.
- I checked the cost of each material.
- I made a list of materials and their prices for my design.
- My design stays within the budget.

Research: What materials are good conductors and good insulators? Write in the boxes below the definition of conductors and insulators, and list examples for each.

Define Insulator-	Define Conductor-
What is it about the structure of insulating material that causes it to be a good insulator?	What is it about the structure of conductive material that causes it to be a good conductor?
Examples of Insulating Materials: 1. 2. 3. 4. 5. 6. 7.	Examples of Conducting Materials: 1. 2. 3. 4. 5. 6. 7.
What material will your team use to create your design? Why?	What material will your team not use in creating your design? Why?

Teacher Tips

Start gathering the materials, in advance needed, to create the insulated enclosure for the ice.

Freeze the ice penguins in advance.

Make sure to review thermal energy transfer, insulators, and conductors.

For sixth grade students, you may want to have the students write group names or numbers on the back of their money.

This lesson could be completed as an overnight experiment or could be done with the addition of a day.
Day one: research
Day two: build:
Day three: place coolers near heaters or under heat lamps and check water volume.
Day four: modifications
Day five: retest with heaters and heat lamps

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Define Problem			
Criteria			
Constraints			
Background research Summarize one thing you learned from your research that CAUSES a material to be a good insulator.			
Solution Design Design three possible solutions for this problem.	<u>SOLUTION 1</u>	<u>SOLUTION 2</u>	<u>SOLUTION 3</u>

Day 2: Cooler Design: Pages 3-5 of the student workbook

While Building

- I worked with my group to build our cooler.
- We used the materials carefully and did not waste supplies.
- We followed our plan or made improvements if we found problems.
- Everyone in my group helped and shared ideas.
- We only used the materials we “bought” with our budget.
- We kept track of our spending so as not go over budget.

Item	Cost	# Needed	Amount
1 sq. ft Bubble Wrap	$2		
Newsprint (1 sq foot)	$0.50		
1 sq. ft Aluminum Foil	$1		

Item	Cost	# Needed	Amount
Tape (1 foot)	$1		
1 sq. ft Plastic Wrap	$0.10		
Foam Panel	$2		

Use a guided research paper with struggling students (attached).

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Cotton Balls (per 10)	$0.50			Glue Sticks (each)	$0.50		
Zipper Bag	$0.50			Cardboard Box	$3		

Prototype Design As a group, select one of your proposed designs to build and test. This will be your prototype. Describe it here.	
Test prototype and record data for your test and at least two other designs in the class	

Day 3: Prototype Testing and Redesign: Page 6 of the student worksheet

- We placed the penguin in our cooler.
- We checked the penguin the next day.
- We wrote down the amount of liquid H_2O from our penguin.
- We kept our data neat and easy to read.

Analyze data and critique your design	
Predict how you think your current insulator affected your ice cube?	
Proposed modifications based on data	

Day 4: Pages 7-8 of the student worksheet
Cooler Design Project: Student Checklist

After Testing

- I looked at our results and compared them to our predictions.
- I thought about what worked well and what could be improved.
- I wrote down at least one idea to make the cooler better next time.
- I explained (in writing or out loud) how insulation and heat transfer affected our results.
- I helped my group share what we learned with the class.

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Retest and record data Test number: **2**	
What was the effect of your modifications?	
Final Analysis & Critique	
FINAL CONCLUSION **Identify some characteristics of the most successful models. Make sure to use the following words in your conclusion: structure, function, cause, and effect.**	

Item	Quantity	Cost per Item	Total Cost
Original Amount Spent			$
Amount Spent on Modifications			$
Total Spent			$
Bonus Money			$
Money Left			$

Criteria	4—Excellent	3—Good	2—Developing	1—Beginning
Understanding the Problem	I clearly explain what the challenge is and what my cooler needs to do. I think about the rules and what makes a cooler work best.	I mostly explain the challenge and what the cooler should do. I consider most of the rules.	I give a basic idea of the challenge or rules.	I do not explain the challenge or rules clearly.

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Design & Creativity	My design is creative and uses materials effectively. I think of more than one idea before building.	My design works well, and I try at least one idea before building.	My design is simple, and I do not try different ideas.	My design has little effort, and I do not try new ideas.
Testing & Data	I test my cooler carefully, record all results, and keep my data accurate and neat.	I test my cooler and record most results. My data is mostly correct.	I tested my cooler, but my data is missing parts or contains errors.	I do not test or record results, and my data is very incomplete.
Improving My Design	I think about what worked and what didn't, and I give specific ideas to make my cooler better next time.	I share some ideas for improvement and explain my thinking.	I give a basic idea for improvement.	I do not suggest any improvements.
Explaining the Science	I clearly explain how insulation and heat work in my cooler and use science words correctly.	I explain how insulation and heat work, but I may miss a few details.	I give a basic or incomplete science explanation.	I do not explain the science, or my explanation is incorrect.
Teamwork & Sharing Ideas	I work really well with my group, listen to others, and help share our ideas and results.	I work well with my group and mostly share ideas.	I sometimes work with my group, but don't always share ideas.	I do not work well with my group or share ideas.

What Teachers Are Doing

Day 1: **Slides 1-10** of the presentation

1. Introduction (20 min)
    a. Discuss heat transfer (conduction, convection, radiation).
    b. Explore how insulation slows down melting.
2. Challenge Brief (5 min)
    a. Goal: Build a cooler that keeps an ice cube from melting for the longest time.
    b. Allowed materials: cardboard boxes, bubble wrap, newspaper, plastic wrap, tape, etc.
3. Research

Teacher Tips

Material Prep:

Precut materials before the lesson

Print off the sheets of the dollars and have them cut them out as they use them.

Stand with the materials and have the students buy the materials to keep students from taking extra.

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Present the problem to the students by playing the video. They will create a penguin shelter. The student's task is to design and build a shelter for the ice penguin that is energy-efficient. Explain that they will test their designs by placing an ice penguin in a jar overnight and determining how well it keeps the ice frozen.

Engineering Project	
Problem	The Hogle Zoo is creating a new Penguin Habitat and needs your help
Criteria	Has to keep something frozen for 24 hours.
Constraints	• Each group must design a Penguin Shelter using their knowledge of insulating and conducting materials. • The box must be no bigger than 12"x 5" x 5" • There must be a lid that easily opens and closes • The box can not be brought home • The building of the penguin shelter can only be performed at school • The material can only be from the table of supplies • Each team can only spend $15 on supplies • The shelter must be designed or decorated to fit in the penguin's habitat at the zoo. • Must be penguin safe.

Students will research good insulators.

Research. In this activity, students will use the internet to **obtain information** about ways other people have used to make their homes energy-efficient and prevent the transfer of heat to or from the interior of the house. Use the student sheet as a guide. Students need to find information from three sources, **evaluate the information** to determine whether it will be useful for their project, and cite their sources.

Exploring Insulators: Ask if any of the students came across the terms "insulation, or insulator" during their research. Review the definition of an insulator and discuss how it affects heat transfer. Have the students brainstorm a list of materials that could be used to insulate their home.
It is good to have the students list the materials they think would be effective, but since they will be testing these in class, you may also need to weed some out, like fiberglass insulation.

Day 2: Slides 11-22 of the presentation

1. Design Phase:
    a. In teams, sketch cooler designs and choose insulation strategies.

Assign one person in each group to be the purchaser to avoid confusion.

Possible discussion questions:

- Which designs kept the ice frozen the longest? What features did those designs have in common?

- Did any design surprise you with how well or poorly it worked? Why do you think that happened?

- What patterns do we notice across all of our results?
- What modifications can you make to your design to help it be more effective?

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    b. Predict which materials will work best and why.
2. Build (30–45 min)
    a. Construct coolers using provided materials.
    b. Place one ice cube in each cooler.
3. Test 1 (overnight)
    a. Check and record the ice cube.
    b. Observe which cooler keeps the ice frozen longest.

Present the materials you have available to the class. You may include some of the following: newspaper, plastic wrap, foil, bubble wrap, thin cork, felt, cotton batting, styrofoam, etc. You may also want to allow students to bring in some materials from home that they think would be effective.

As a class, discuss ways that you could test how well these materials work as insulators. Go with the students' ideas as long as they are reasonable. Run the tests and have them record their data on their student worksheet.

Day 3: Slides 23-31 of the presentation

1. Test 1 (overnight)
    a. Check and record the ice cube.
    b. Observe which cooler keeps the ice frozen longest.
2. Analyze & Reflect 1 (15 min)
    a. Discuss results and what design features worked best.
    b. Relate findings to real-world coolers and insulation.
3. Modifications Day 1
4. Test 2 (overnight)
    a. Check and record the ice cube.
    b. Observe which cooler keeps the ice frozen longest.

Testing the prototypes

The students will analyze the results of **testing** their designs. Students will get **$5 Science dollars** for any modifications they need to make.

Reason

When the tests are complete, students will discuss their results with at least two other groups and record a brief description of the other models and their final change in temperature.
As a class, discuss the success of the first test. Which group saw the smallest change in temperature? What materials did they use?

Communicate

Each group will analyze the test results by writing a brief sentence or two on their engineering form about how well their house performed compared to the other groups' houses.

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Day 4: Slides 32-37

1. Test 1 (overnight)
    a. Check and record the ice cube.
    b. Observe which cooler keeps the ice frozen longest.
2. Analyze & Reflect 1 (15 min)
    a. Discuss results and what design features worked best.
    b. Relate findings to real-world coolers and insulation.
3. Analyze and Reflect Day 3

Reason
Students will analyze their results, critique their designs, and compare them to the results of the other students in the class. You may want to give each team one or two minutes to briefly explain what they did and how well it worked.

Communicate:
Ask students to write a final statement identifying the characteristics of the most successful designs.

POSSIBLE EXTENSIONS/ALTERNATIVE ADAPTATIONS

Extensions (for enrichment or challenge)

1. Data Analysis Extension
- **Activity:** Students graph melting rates for each design and perform basic statistical analysis (mean, median, outlier identification).
- **Purpose:** Builds data literacy and higher-order thinking per Marzano's strategies for analyzing and representing data.

2. Real-World Connection
- **Activity:** Research and present on real-world insulation (e.g., spacesuits, Antarctic research stations, or green building design).
- **Purpose:** Connects classroom content to authentic STEM careers and applications (Ten Steps to Complex Learning, Step 10: Transfer).

3. Iterative Engineering Challenge
- **Activity:** Add a third round of redesign, requiring teams to incorporate feedback from another group AND one "wild card" material.
- **Purpose:** Deepens engagement with the engineering design cycle and collaborative problem-solving (PLC at Work).

4. Environmental Impact Analysis
- **Activity:** Compare the environmental impact of chosen materials. Propose modifications for a "green" penguin shelter.
- **Purpose:** Develops systems thinking and cross-curricular links to sustainability.

5. Communication & Persuasion

- **Activity:** Prepare a brief pitch to "sell" their shelter design to the Hogle Zoo, including data and visual aids.
- **Purpose:** Builds communication, argumentation, and presentation skills (Marzano: Generating and Testing Hypotheses).

Modifications (for accessibility and support)

1. Scaffolded Instructions
- **Modification:** Provide step-by-step checklists with visual icons for each phase.
- **Purpose:** Supports executive function and task management (UDL Principle: Multiple Means of Representation).

2. Sentence Starters & Word Banks
- **Modification:** Offer structured sentence stems and vocabulary banks for all written responses.
- **Purpose:** Lowers language barriers and supports ELLs or students with IEPs.

3. Visual Supports
- **Modification:** Include diagrams or photo exemplars of shelters and insulation methods.
- **Purpose:** Supports visual learners and students with reading challenges.

4. Flexible Grouping
- **Modification:** Allow for pairs instead of groups, or assign specific roles (designer, builder, recorder, presenter) to ensure participation.
- **Purpose:** Increases engagement and equity in collaborative work.

5. Alternative Output
- **Modification:** Permit oral explanations, video submissions, or illustrated explanations instead of written reports.
- **Purpose:** Supports diverse learning preferences and students with writing disabilities.

6. Material Adaptations
- **Modification:** Pre-cut materials or provide adaptive tools (e.g., easy-grip scissors) as needed.
- **Purpose:** Increases physical accessibility for students with fine motor challenges.

7. Guided Data Collection
- **Modification:** Provide data tables partially filled in, or use color-coded measuring tools.
- **Purpose:** Reduces cognitive load and aids students who struggle with math or organization.

This lesson was created by Megan Sitterud, Karen Pineda, Westen Miller, Kris Ericksen, and Maggie Grindstaff

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