Youth Education & Interpretation It's in Our Nature

"Ice Capades" - The Power of Insulation

MISSOURI DEPARTMENT OF NATURAL RESOURCES

GRADE LEVEL:

Upper Elementary/Middle School/ High School (with extensions)

SUBJECT AREAS:

Sciences

DURATION:

Preparation Time: 30 minutes

Activity Time: one 50-minute class session

SETTING:

Classroom

SKILLS:

Application, Analysis, Synthesis, Evaluation

KEY WORDS:

Energy, Radiation, Convection, Conduction

SUMMARY

Students are given an ice cube to protect from the heat of a light bulb. Student groups use various insulation materials to keep the ice cube from melting. Students explore principles of thermal energy transfer and the application of insulation in minimizing energy loss.

OBJECTIVES

THE STUDENT WILL:

- Participate in cooperative problem solving in a group setting
- Use insulation materials to protect an ice cube from melting
- Evaluate the effectiveness of various insulation materials
- Discuss the application of insulation techniques in reducing energy loss from building

MATERIALS

- Heat source: A table lamp with a 100W or higher incandescent bulb (heat lamp or plant grow light is ideal)
- Various types of insulation materials: Newspaper, cloth, foam sheeting, aluminum foil, Styrofoam cups or packing peanuts, construction paper, wool or fur, feathers, plastic grocery bags, tissue paper, cardboard

Warning: Commercial fiberglass insulation is not recommended due to safety issues associated with fiberglass splinters and dust

- Ice cubes (1-2 per group)
- Clear Tape
- Small disposable plastic cups (preferably clear, 5-10oz)
- Large Disposable plastic cup (preferably clear, 12-16oz)
- Graduated cylinder or similar device to measure the amount of water resulting from the melting ice cubes
- Copies of the results table (one per group)
- Copies of the question sheet (one per group)

BACKGROUND

INTRODUCTION

What melts an ice cube? The answer is heat of course, but what is heat? What is cold?

Heat is a form of thermal energy and results from the motion of atoms and molecules. Warm objects have a greater amount of thermal energy than cooler objects. Cold can be described as the absence of heat (less thermal energy).

Heat will flow from areas of high thermal energy towards areas of low thermal energy. An ice cube melts as heat flows towards the ice from its surroundings. Swimming in cold water results in a similar process as your body begins to loose its heat to the cooler water. On a cold winter day one can actually feel the thermal energy (heat) leaving the body towards the cold surrounding air.

TRANSFER OF THERMAL ENERGY

Heat is transferred in three basic ways. The first is radiation and involves the transfer of heat by light energy. The heat we feel from the sun or a hot light bulb is transferred by this process.

Another way heat is transferred is by conduction. This occurs when two objects transfer thermal energy by physical contact. Different materials have different conduction abilities. Metals are very good conductors while wood, foam and rubber are poor conductors of thermal energy. This explains why a coin feels cool to the touch even though it may be at the same temperature as a wooden pencil.

A final way heat can be transferred is by convection and involves the transfer of thermal energy between two objects by flowing currents of air or water. Cold air pulled through an open window into a warm house is an example of convective processes.

USE OF INSULATIVE MATERIALS

Insulation materials are designed to interfere with thermal energy transfer. A jacket can keep you warm in winter by minimizing the movement of cold air currents over your body surface and reducing convective heat loss. Additionally, conductive heat loss can be reduced by adding layers of materials that are poor conductors of thermal energy to your clothing such as plastic fibers (fleece) or wool. The space suits worn by astronauts also include a silver foil lining designed to reduce energy transfer by radiation.

Insulation materials are used in homes and buildings to help minimize thermal energy loss and reduce the owner's energy bills. Home insulation not only reduces the loss of heat in winter but will also help keep a home cooler in summer.

How well an insulation resists heat flow is reflected in its "R-value". The higher the R-value the greater the resistance to thermal energy transfer. Some types of building insulation work by using materials with low conduction properties such as cellulose, plastic, rubber and wool. Other insulation materials such as styrofoam, fiberglass, blown-cellulose and mineral-rock-wool, work by reducing the flow of air and minimizing convective heat loss. Most commercial insulations also incorporate a reflective layer of metallic foil to prevent heat lost from radiation as well.

PROCEDURE

WARM UP

Set the stage by asking the students the following questions:

- *Why does a jacket keep you warmer in the winter?*
- *What causes ice to melt?*

Review with the class the basic concepts of thermal energy transfer such as radiation, conduction, and convection, along with the application of insulating materials. (see background section)

CONSTRUCTION OF AN "ICE PROTECTOR"

- Break the class up into several groups.
- Either assign or allow the groups to select one or more insulating materials (depending on class size and number of insulating materials at hand)

You can allow each group to make a choice of insulation type and compete with other groups to "protect" the ice cube. Alternatively, if a less competitive environment is more appropriate, each group can be assigned a specific insulating material and the results for each material discussed by the class.

- Give each group a large cup and smaller cup. Instruct the class that the smaller cup will be placed within the larger cup and ice placed inside the smaller cup. The group is free to apply their insulation(s) of choice to the space between the larger cup and the smaller cup. They should allow for access to the smaller cup, so that the ice can be placed into their device. The students may use clear tape to secure the insulation material.
- When the groups are ready, the instructor should place the ice cube(s) in each group's smaller cup.

Note: It is important to have ice cubes of the same size.

- Allow the students to close up their "ice protector" and place each under a mild heat source (light bulb).

Note: It is essential that each groups "ice protector" is placed the same distance from the heat source in order to achieve accurate results.

- The "ice protectors" are left in place for 5-20 minutes (depending on the heat source used).

Important: All the ice cubes should not be allowed to melt fully during the heat exposure period. The instructor needs to monitor the melting and stop exposure as soon as several of the ice cubes show clear signs of partial melting.

- Remove the "ice protectors" from the heat source and pour the resulting liquid from each design into a graduated cylinder. The students should record the results on the table provided (see appendix).

The group that generates the least amount of liquid is the winner!

ASSESSMENT

Instruct each group to discuss and answer the following questions (worksheet found in appendix).

1. What insulation material(s) worked best to minimize thermal energy transfer? Why?
2. Can you identify the role of radiation, conduction and convection in the insulation strategy used by your group?
3. What specifically is a jacket doing to keep you warmer in the winter?
4. What areas in a home could be insulated to prevent energy loss?
5. What are the advantages to insulating a home?

EXTENSIONS

Addition of insulation to homes and buildings is an important factor in conserving energy. More than half of the energy used by a typical residential home in America is used to generate hot water and provide heating and cooling needs.

Many homes suffer from poor weather stripping, especially around doors and windows. At these locations convective air currents pull in outside air defeating the efforts of heating or cooling systems.

Have the students construct a "convective infiltration meter" (Draft meter…see Energy Conservation Detective activity) by taping a piece of tissue to a pencil. With this high-tech tool the students can hunt down air leaks in the schoolroom, school building or at their homes.

The students can apply weather stripping to the air leaks they discover and help to reduce this form of convective energy loss.

GOING FURTHER

THE ULTIMATE "ICE PROTECTOR"

Have the class work together as a whole to build the ultimate ice cube protector. Allow the students to use multiple layers of the various insulation materials to really shield the ice cube from thermal energy loss! Place the classes contraption next to the heat source (light bulb) and time how long it takes to melt the ice cube.

(Note: the construction of the protector must allow you to "take a peek" at the ice cube periodically to determine if it is still intact) You may want to also place an uninsulated ice cube next to the ultimate ice protector for comparison purposes.

THERMODYNAMICS

A chemistry class could consider modifying the "ice protector" to create a simple "bomb-calorimeter". The students could use this to estimate the specific heat of water.

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MISSOURI DEPARTMENT OF NATURAL RESOURCES

MISSOURI LEARNING STANDARDS:

SCIENCE GRADE LEVEL STANDARDS:

Engineering, Technology, and Application of Science

ETS1 — Engineering Design

Concept A: Defining and Delimiting Engineering Problems

- **6-8.ETS1.A.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.

Concept B: Developing Possible Solutions

- **6-8.ETS1.B.1:** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- **6-8.ETS1.B.2:** 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.

Physical Sciences

PS3 — Energy

Concept A: Definitions of Energy

- **6-8.PS3.A.3:** Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.]
- **6-8.PS3.A.4:** Plan and conduct an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the temperature of the sample. [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.]

NGSS:

MS-ETS1 Engineering Design

- **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 and 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.

Physical Science

MS-PS3 Energy

- **MS-PS3-3:** Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]
- **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. [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 6-8 builds on grades K-5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.

- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1)

Engaging in Argument from Evidence

Engaging in argument from evidence in 6-8 builds on K-5 experiences and progresses to constructing a convincing argument that supports or refutes claims for other explanations or solutions about the natural and designed world.

- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-PS3-3)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. (MS-PS3-4)

Scientific knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS3-4), (MS-PS3-5)

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting Engineering Problems

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints include consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1)

ETS1.B: Developing Possible Solutions

- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)

PS3.A: Definitions of Energy

- Temperature is a measure of the average kinetic energy of particles o f matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (MS-PS3-3), (MS-PS3-4)

PS3.B: Conservation of Energy and Energy Transfer

- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (MS-PS3-4)
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3)

Crosscutting Concepts

Influence of Science, Engineering, and Technology on Society and the Natural World

- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ETS1-1)
- The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

Scale, Proportion, and Quantity

- Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. (MS-PS3-1), (MS-PS3-4)

“ICE” CAPADES

INSTRUCTIONS: Describe the insulation strategy used by each group and record the final volume of ice melt water generated by each group. The “ice protector” with the least amount of liquid produced is the *winner* and did the best job of protecting the ice with its insulation strategy.

INSULATION(s) USED	VOLUME OF ICE MELT WATER

"ICE" CAPADES

1. **What insulation material(s) worked best to minimize thermal energy transfer and why?**

2. **Can you identify the role of radiation, conduction and convection in the insulation strategy used by your group?**

3. **What specifically is a jacket doing to keep you warmer in the winter?**

4. **What areas in a home could be insulated to prevent energy loss?**

5. **What are the advantages to insulating a home?**