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Lesson Title: Design A Cup

Concepts: insulation, vacuum, heat transfer, engineering design

Grade Level: Sixth Grade

Date/Time Frame: 1 week (45 min class periods)

Rationale:
This lesson lets students explore how engineers design and test a system when given criteria and constraints.

NGSS:
Students who demonstrate understanding can:
MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
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.

Practices
Constructing Explanations and Designing Solutions
Asking Questions and Defining Problems
Engaging in Argument from Evidence

Disciplinary Core Ideas
Definitions of Energy
Conservation of Energy and Energy Transfer
Defining and Delimiting Engineering Problems
Developing Possible Design Solutions
Influence of Science, Engineering, and Technology and the Natural World

Crosscutting Concepts
Energy and Matter: Flows, Cycles, and Conservation
Systems and System Models

Objectives:
Content Objectives:
Students will demonstrate their knowledge of insulation, heat transfer, and vacuums by designing a cup.
Students will design, test, and redesign their cup based on collected data.

Math and Science Process Skill Objectives:
Students will recognize and apply mathematics in contexts outside of mathematics.
Students will measure in an orderly and systematic fashion with labeled units of measure.
Students will generate graphs and tables with computer software.
Students will apply numbers and their mathematical relationships to make decisions.

Students will collect data to serve as the basis for evidence to test a design.
Students will communicate their ideas with other students.

Application Objectives:
Students will explore how engineers work in a team to design a product.

Unifying Concepts:
Change, constancy and measurement: Students are trying to keep the water given to them at a constant temperature.

Materials, Resources, Technology
Rosie Revere, Engineer by Andrea Beaty
Deck of Playing Cards
Various building materials: 9oz cups of different materials (plastic, Styrofoam, paper), aluminum foil, cotton balls, wax paper, paper clips, tape, fabric, cardboard, string, wire, packing peanuts, and rubber bands
PASCO Airlink 2 for each student group
PASCO temperature probe for each student group
iPad mini with the SparkVUE app for each student group
Water cooler filled with water and ice
Student's individual Pencil Pouches
Plastic bags
Markers
Projector

Management/Organizing for Instruction
Students will randomly be placed in pairs. Students will be given a playing card. Those that draw a King will be a group, those that draw a Queen will be a group, etc. Student pairs will be given a plastic bag. They need to use a marker to label it with their names. Their materials will be kept in the bag. There will be a designated spot in the room for bags for each class period.

Lesson Delivery

Key Question: How can we keep a liquid cool? (This will be written on the board.)

ENGAGE

Introduction: The teacher will begin the unit by reading the book, **Rosie Revere, Engineer** by Andrea Beaty to get students thinking about engineering, persistence, and perseverance. (This book does have a few details that were made up to entertain the reader. These details can be discussed after reading.) Also after reading, the teacher will lead a short discussion on what engineers are and do. An engineer is someone who uses science and math to develop solutions to problems. A few different types of engineers are: traffic engineer, architectural engineer, agricultural engineer, mechanical engineer, electrical engineer, and software engineer.

The teacher will then ask students: Do you have a favorite cup at home for cold beverages? Why is it your favorite cup? Teacher will facilitate a short discussion.

Clarify Purpose/Objectives of the lesson:
The teacher will share the lesson objectives with the class. In this lesson students will demonstrate their knowledge of insulation, heat transfer, and vacuums by designing a cup.

Student groups will design, test, and redesign their cup based on collected data. These objectives will also be written on the board).

EXPLORE (#1 - #6 below)

Teacher Procedures

Instruction and Modeling

1. In the book we read, Rosie Revere was an engineer. Today we will be engineers. We will be designing a cup to keep liquid cool. You are sitting with your engineering team. The teacher will distribute packets to each group. Before you begin to design your cup, I would like you to read a resource called, "Keep it Cool". Pass out articles. Students should highlight and annotate the article as they read, focusing on ideas they would like to incorporate into their design.

Guided Practice

2. After students are done reading show students the table of materials. Then have students discuss in their groups if they could incorporate anything from the article into their design.

3. **Formative Assessment**: Whole group discussion where each team shares ideas that they will be incorporating into their design. The teacher should use this discussion as a guide to know which groups need guidance before building their cup.

Student Practice

4. As they are discussing they can sketch a preliminary diagram and a list of materials they think they would use. Remind them that a temperature probe must fit into their design in some way. Show them what the probe looks like.

5. After they have completed their sketches, they are free to begin building their prototype. The teacher will announce some constraints that might change their plans. They may only use two cups, and they may only select two "insulation" materials. (cotton, foil, wax paper, packing peanuts, paper clips, string, recycled packing foam, rubber bands)

6. As students finish their initial design, they may test. There will be stations set up in the front of the room with iPads, Airlink 2's, and temperature probes. These will all be set up and ready to go. Students will get cold water from the teacher, put it in their cup, insert the probe, and begin testing. One partner will need to hold the cup to prevent spilling. The other will press play and record temperatures on their group's data table for Practice #1. (Teacher will model when appropriate.) The probe will automatically stop collecting data after five minutes.

7. ELABORATE After the first test, students need to discard their water into the dump bucket. They may then make changes to their design and do a second practice test (if time).

8. Final testing will be done for 15 minutes. After testing, students can finish their packet questions, and make their final drawing/list of materials.

9. EXPLAIN After each group has data, a short discussion will take place answering the question: Why during minute 1 did the temperature go down instead of up? (Students should conclude that at minute 0 the temperature probe was at room temperature.) Students will then calculate their change in temperature to see which group designed the cup that best met the objective. The teacher will project results on the board for students to see.

10. EXPLAIN Students will present their design to the class, and explain why they designed their cup the way they did.

Student procedures: See Group Packet EVALUATE (questions #1 - #3)

Discussion questions: See Group Packet

Application:
Students will incorporate their knowledge of insulation, vacuums, and heat transfer,

Closure:
Ask students: Could you see yourself in some type of engineering field? Why or Why not?

Assessment:
Teacher will assess the engineering process by grading the group packets, and their group presentation. See Rubric.

Accommodating Individual Learners:
Students who struggle with reading may need help with the "Keep it Cool" article.

Extending the lesson:
Discussion about STEM (Science Technology Engineering and Mathematics). The teacher can show video clips to build interest in STEM.

My Robot is Better Than Your Robot
http://safeshare.tv/w/FtKULDahRO

Amanda Parkes – Design Engineer (video)
http://science360.gov/obj/tkn-video/040f6bc5-2d4f-4cee-ba47- 93ce804aeb35/profiles-scientists-engineers-design-engineer

i.am.FIRST: Science is Rock & Roll (President Obama discusses the importance of STEM.)
http://safeshare.tv/w/kpLFiaMvGg

Integration with other Literacy:
Students may read articles or biographies about different types of engineers in language arts.

Design A Cup

Names______________________

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Engineering Teamwork and Planning
You are part of a team of engineers given the challenge of building a container to keep a cup of chilled water from warming up. You'll have lots of materials to use such as aluminum foil, cotton balls, additional paper cups, tape, cups, paper clips, string, recycled packing foam, rubber bands, and other readily available materials. Your team's challenge is to develop a device to keep chilled water cooler than other teams' devices at the end of the class period. You will need to devise a way to have a temperature probe rest in the water.

Research Phase
Read the article provided to you by your teacher, including those that discuss heat transfer.

Planning and Design Phase
Think about the different ways you can use the materials provided to keep the chilled water cold. Remember that you need to leave a space for a temperature probe to measure the chilled temperature after your design is built. In the box below, draw a diagram of your planned insulated cup and include a list of the materials you think you might need. You can adjust this later and also add more materials during construction.

Practice #1

Time	Temperature °C
Initial 0 minute	°C
1 minute	°C
2 minute	°C
3 minute	°C
4 minute	°C
5 minute	°C

Practice #2 (if time)

Time	Temperature °C
Initial 0 minute	°C
1 minute	°C
2 minute	°C
3 minute	°C
4 minute	°C
5 minute	°C

Final Testing

Time	Temperature °C
Initial 0 minute	°C
1 minute	°C
2 minute	°C
3 minute	°C
4 minute	°C
5 minute	°C
6 minute	°C
7 minute	°C
8 minute	°C
9 minute	°C
10 minute	°C
11 minute	°C
12 minute	°C
13 minute	°C
14 minute	°C
15 minute	°C

Temp. at 15 minute ___________°C

-

Temp. at 1 minute ___________ °C

Change in Temp. ___________ °C

Design A Cup

Names______________________
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1. What ideas from the "Keep it Cool" handout did your team try to incorporate in your design?

2. What changes did you make between your first and second designs?

   Why did your team make these changes?

3. If your team could have used one additional material in your design that was not provided, what would you choose and why?

Sketch of Final Design:

List of Materials Used:

Keep it Cool

Student Resource:
Insulation, Heat Transfer, and Vacuums

◆ Insulation and Vacuums

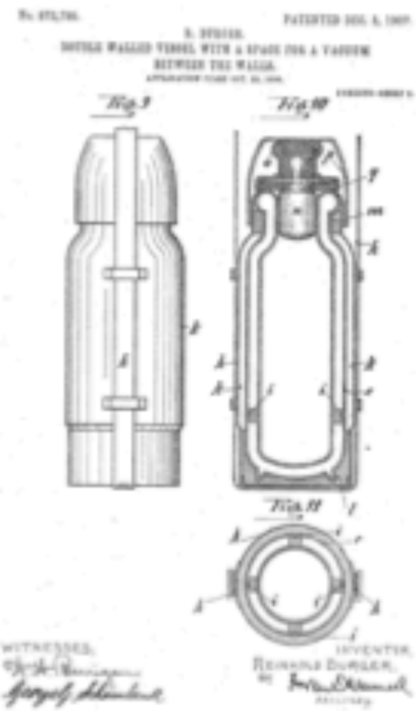
Insulation is used for many purposes. Insulation is needed to protect fragile items from being damaged during shipping. It is used to keep cold air out of houses in the wintertime, it is used to separate electric wires, and it is used to keep cool items cool and hot items hot in a vacuum flask. Many materials are used as insulation from fabric to moss to plastic to fiberglass to animal skins. In the case of a vacuum flask, a vacuum serves as the insulation. A vacuum is created when a volume of space is essentially empty of matter; usually when air is pumped out. Light bulbs contain a partial vacuum, usually backfilled with argon, which protects the tungsten filament.

◆ Heat Transfer

Heat can transfer in three ways: conduction, convection, and radiation. Conduction is the transfer of heat by direct contact of particles of matter. Metals such as copper, platinum, gold, and iron are usually the best conductors of thermal energy. Convection is the transfer of thermal energy due to the movement of molecules within fluids. Radiation is the transfer of heat energy through empty space.

◆ Vacuum Flasks

Invented in 1892 by Sir James Dewar, a scientist at Oxford University, the "vacuum flask" was first manufactured for commercial use in 1904, when two German glass blowers formed Thermos GmbH. They held a contest to name the "vacuum flask" and a resident of Munich, Germany submitted "Thermos," which came from the Greek word "Therme" meaning "heat."



A vacuum flask is a bottle made of metal, glass, or plastic with hollow walls. The narrow region between the inner and outer wall is evacuated of air so it is a vacuum. Using a vacuum as an insulator avoids heat transfer by conduction or convection between the two walls. Radiative heat loss is reduced by applying a reflective coating to the surfaces such as silver.

Of course, the flask needs an opening to add or remove hot or cold liquids. Interestingly the most heat or cold loss happens at the stopper. Originally, the stopper would have been made of cork, with plastic being used later because it was more durable and could be formed in a shape to match the opening. A typical vacuum flask will keep liquid cool for about 24 hours, and warm for up to 8. Some vacuum flasks include a fitted cup, for convenience of use with drinks.

Building A Structure : Design a Cup

Student Name: ______________________________

CATEGORY	4	3	2	1
Function	Structure functions extraordinarily well, holding up under atypical stresses.	Structure functions well, holding up under typical stresses.	Structure functions pretty well, but deteriorates under typical stresses.	Fatal flaws in function with complete failure under typical stresses.
Presentation	Explanations by all group members indicate a clear and accurate understanding of scientific principles underlying the construction and modifications.	Explanations by all group members indicate a relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by most group members indicate relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by several members of the group do not illustrate much understanding of scientific principles underlying the construction and modifications.
Plan	Plan is neat with clear measurements and labeling for all components.	Plan is neat with clear measurements and labeling for most components.	Plan provides clear measurements and labeling for most components.	Plan does not show measurements clearly or is otherwise inadequately
Data Collection	Data taken several times in a careful, reliable manner.	Data taken twice in a careful, reliable manner.	Data taken once in a careful, reliable manner.	Data not taken carefully OR not taken in a reliable manner.
Construction -Materials	Appropriate materials were selected and creatively modified in ways that made them even better.	Appropriate materials were selected and there was an attempt at creative modification to make them even better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.
Packet Content	Journal provides a complete record of planning, construction, testing, modifications, reasons for modifications, and some reflection about the strategies used and the results.	Journal provides a complete record of planning, construction, testing, modifications, and reasons for modifications.	Journal provides quite a bit of detail about planning, construction, testing, modifications, and reasons for modifications.	Journal provides very little detail about several aspects of the planning, construction, and testing process.