Staying Cool Design Challenge:

How Do You Keep Things From Getting Too Hot?

Grade Level
2-4

Duration
3-4 days
of 30-45 minute periods

Essential Question

How does the amount of sunlight and heat change in areas that are shaded?

Lesson Overview

Introduction to Design Challenges

Design Challenges are intended to focus on real-life situations that give students the chance to deal with many of the same issues with which scientists, engineers, and researchers are confronted in their laboratories and at their computers every day. Using the "Staying Cool" theme addressed in the MESSENGER Education Modules, we challenge you students to work as a team to design and build an effective sunshade for a model MESSENGER craft.

This challenge provides a motivating experience for children using a scientific approach, problem solving and cooperative teamwork. Students will discover their own and others' strengths as they take on different roles on a team, and they will witness first hand the importance of both successes and failures, for they can learn from both.

Each Design Challenge team member is responsible for his or her part of the final project, whether it be research, drawing, building, analyzing, testing, or whatever. There must also be a team commitment to ensuring the success of each member, by providing the necessary support and back-up required. The value of this type of a cooperative arrangement is in its ability to allow for creativity and independence within a supportive environment, to teach responsibility, and to keep all students engaged in learning. Yet we do not lose sight of the value in healthy competition, and encourage teachers to use our criteria for judging each team's work, awarding the most successful in age- and grade-appropriate ways.

A Design Challenge is provided at the culmination of each MESSENGER unit focused on The Scientific Process in Action. A challenge may used to prompt theoretical discussions in the classroom and further research only, or may be used in its entirety, including the actual building of a working model. We recommend that at least one Design Challenge per year be assigned to the students, to give them the unparalleled experience of working together on applying both creativity and the scientific process in their daily lives; it is sure to change their way of thinking in the years to come.

Note: This particular challenge is not a competition. The design standards are set as a challenge for each team or individual to meet. Since every product will be different, each will be evaluated on whether or not it meets the design standards.

The Design Challenge: How do you keep things from getting too hot?

In this Design Challenge, using the "Staying Cool" theme, which is addressed in the MESSENGER mission to Mercury, your students will work as a team to:

- Draw and build a scale model of the MESSENGER spacecraft with design elements as specified
- Design and test a sunshade to protect sensitive on board tools and instruments from excessive heat of the Sun. The sunshade must keep the instrument deck at least 10 degrees Celcius cooler than the temperature of the craft without the sunshade.

Standards & Benchmarks

National Science Education Standards

<u>K-4 Standard E 1-5</u> Abilities of Technological Design

- Identify a problem. In problem identification, children should develop the ability to explain a problem in their own words and identify a specific task and solution related to the problem. [See Content Standard A (grades K-4)]

- Propose a solution. Students should make proposals to build something or get something to work better; they should be able to describe and communicate their ideas. Students should recognize that designing a solution might have constraints, such as cost, materials, time, space, or safety.

- Implementing proposed solution. Children should develop abilities to work individually and collaboratively and to use suitable tools, techniques, and quantitative measurements when appropriate. Students should demonstrate the ability to balance simple constraints in problem solving.

- Evaluate a product or design. Students should evaluate their own results or solutions to problems, as well as those of other children, by considering how well a product or design met the challenge to solve a problem. When possible, students should use measurements and include constraints and other criteria in their evaluations. They should modify designs based on the results of evaluations.

- Communicate a problem, design and solution. Student abilities should include oral, written, and pictorial communication of the design process and product. The communication might be show and tell, group discussions, short written reports, or pictures, depending on the students' abilities and the design project.

National Science Education Standards

K-4 Standard E 6-10 Understanding About Science and Technology

- People have always had questions about their world. Science is one way of answering questions and explaining the natural world.

- People have always had problems and invented tools and techniques (ways of doing something) to solve problems. Trying to determine the effects of solutions helps people avoid some new problems.

- Scientists and engineers often work in teams with different individuals doing different things that contribute to the results. This understanding focuses primarily on teams working together and secondarily, on the combination of scientist and engineer teams.

- Women and men of all ages, backgrounds, and groups engage in a variety of scientific and technological work.

- Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

AAAS Project 2061 Benchmarks for Science Literacy Grades 3-5

3B1

There is no perfect design. Designs that are best in one respect (safety or ease of use, for example) may be inferior in other ways (cost or appearance). Usually some features must be sacrificed to get others. How such trade-offs are received depends upon which features are emphasized and which are down-played.

3B2

Even a good design may fail. Sometimes steps can be taken ahead of time to reduce the likelihood of failure, but it cannot be entirely eliminated.

3B3

The solution to one problem may create other problems.

11B1

Seeing how a model works after changes are made to it suggest how the real thing would work if the same were done to it.

Concepts

- Light is a form of energy.

- Tools help scientists make observations, measurements, and discoveries of things that they could not otherwise see, calculate, and do.

- Spacecraft traveling near the Sun must be designed so that sensitive instruments are protected from being overheated by the Sun.

- People have always had problems and invented tools and techniques (ways of doing something) to solve problems. Trying to determine the effects of solutions helps people avoid some new problems. Scientists and engineers often work in teams with different individuals doing different things that contribute to the results. This understanding focuses primarily on teams working together and secondarily, on the combination of scientist and engineer teams.

Science Overview

Modeling

The task of building a spacecraft and sending it to distant planets can be overwhelming, so models are necessary to try out every piece of equipment, including cameras and other valuable instruments on board, to see if there are any problems. After students have sufficiently studied lessons related to launching a spacecraft such as MESSENGER and sending it through space to do research on the planet Mercury, they should use a model of the craft to discuss potential problems with flying so far from Earth, and so close to the Sun.

Definitions of a Model

A model may be defined as a physical (three-dimensional with surface and mass, or two-dimensional "flat") representation, sharing one or more characteristics of the object under study. The purpose of a model is to:

- represent an object or a phenomenon in a manageable way,
- help us learn about the object or phenomenon that the model represents by altering certain characteristics (such as size) that make the real thing otherwise difficult or impossible to study.

Some ways to make physical models more accessible include making the model larger or smaller, colder or hotter than the real object. For example, three-dimensional and flat models may be smaller copies of their counter-parts, (e.g. model train, toy car, plastic dinosaur). Models may also be bigger versions of the real thing to illustrate objects usually too small for study (e.g. an enlarged chart of letters or handwriting, a three-foot long toothbrush).

Other versions of models may help us explore things too hot for study (e.g. a play kitchen unit built to simulate an oven, colored paper cut to the shape of a flame), or too cold for study (a snowman rebuilt in styrofoam, an igloo made in plastic).

Proportion in scale models

A physical model is particularly useful if it is a scale model. This means that all parts of the model are scaled up or down by the same factor. If you have a 1/50 scale model of an airplane, then the length of the model wing is 1/50 the length of the real wing, the height of the tail is 1/50 the height of the real tail, etc. Caution: Areas and volumes will not scale the same way. For example, the real airplane will contain much more than 50 times the volume of the 1/50 scale model. NOTE: The idea of scale modeling may be too advanced for some early elementary school children.

Professional Need of Models

Models are not just toys. Scientists, engineers, architects, and other professionals use them to see how parts fit together, how something will look from different angles, how much bigger some parts are than others, or whether a new kind of product will actually work.

Certain model characteristics are essential to represent an object, but the characteristics chosen depend upon the model's purpose. For any kind of model, its purpose is to show one or more characteristics of the actual object, though it does not usually portray them all.

However, some mode ls are perfect replicas, and may be used in simulations and re-enactments, historical films, safety tests, or in museum exhibits. Many details may be omitted from models, since their inclusion could make the model unnecessarily complicated. Often, the characteristic not accurately conveyed is size, though on a scale model, at least the relative size of parts is correct. Another characteristic you would not want to accurately represent is the temperature of a very hot object, such as the Sun. Other model characteristics might be: color, shape, density, texture, weight, smell, taste, sound, and physical state (solid, liquid or gas).

A Few Generalizations About Models

- A model is often bigger or smaller than the real object. We typically make models at a size that we can comfortable manipulate, so that we may better study the real object.
- A model may be a perfect replica, the same size as the real object with all the same characteristics.
- A model doesn't a ways work like the real thing.
- A model is not a ways made of the same materials as the real object.
- A model can be flat (2-D picture) or have the complete physical shape (3-D) of the actual object.
- A model can be a mathematical or graphic representation of something, such as a chart or an equation.
- A model may represent an object, a phenomenon or a concept.

Teaching Tip

Do not require students to memorize all the generalizations, but just to gather the general understanding of the differences between models and the objects they represent.

The MESSENGER Mission Connection

The MESSENGER Craft

Scientists and engineers building the MESSENGER craft conduct research to answer questions such as, "How can the MESSENGER spacecraft be kept cool so close to the Sun?" To test their ideas, scientists and engineers may test materials and construct models. The scientists learn what will happen to different materials under certain conditions. These tests help determine the structure and the materials of the model.

The real MESSENGER spacecraft (without the sunshade or solar panels), is about the size of a small car (182 cm X 127 cm X 137 cm) With the solar panels (see exploded image of MESSENGER) the spacecraft measures almost 20 feet across and weighs about 1100 kilograms (2,420 pounds) with fuel. The spacecraft will carry 600 kilograms (1320 pounds) of fuel and a host of very sensitive instruments. On the MESSENEGER spacecraft, a white sunshade will keep the operating environment of the instruments at room temperature.

The materials used to construct the sunshade are ceramic- based materials named Nextel capable of withstanding temperatures in excess of 1,000o C. (The temperatures at Mercury are expected to be about 350oC). When layered with an aluminized blanketing material, the materials form an effective thermal barrier. The sunshade materials are stretched over a titanium frame to produce the desired shape and provide support. A model of the sunshade using real materials, has been tested to ensure that the shade resists the maximum conditions expected at Mercury. A sun sensor located on the sunshade, keeps the sunshade facing the Sun at all times.

The MESSENGER Payload

There are 8 major instruments on board MESSENGER, and each one has a special purpose. Some of the instruments, such as the camera, take black and white or color images of Mercury's surface. Other instruments measure the materials in the crust and atmosphere of Mercury.

These instruments are very sensitive and must be shielded from the Sun. We have to make sure that the instruments work perfectly before they leave Earth, and we must try to keep them in good working order, under the hostile conditions of space.

WARM-UP AND PRE-ASSESSMENT

Describe the idea of a design challenge to the students. Define or review the design process. Be sure to explain that this design challenge has two parts. First, students will construct a scale model of the MESSENGER spacecraft. Second, they will design and test solar shades to protect sensitive instruments aboard the spacecraft.

The Design Process

a. Define the problem: What is the problem that needs to be solved? What materials will best protect sensitive instruments aboard the MESSENGER spacecraft as it orbits the planet Mercury?

b. Develop a Context: Have students research the conditions of the planet Mercury. Discuss some of the striking features of the planet and its environment in space. Use the images provided to discuss the design of MESSENGER and other spacecraft.

c. Consider a number of solutions: As a class, in small groups, or individually, brainstorm some possible solutions to the design challenge. At the end of this exercise, there will be many ideas for the types of materials that will best protect the sensitive instruments aboard MESSENGER.

d. Choose a Solution: Small groups of students need to discuss and reach consensus on a single design for the sunshade.

e. Design and draw the solution and plan the work: Using the measurements provided, draw a scale diagram of the sunshade with the materials and features identified clearly. This will be the blueprint from which the actual sunshade will be constructed.

f. Build the solution: Remember to keep in mind the design constraints. Size, weight, durability, and materials, are all factors you may have to consider when making your sunshade.

g. Test and evaluate the solution: After attaching the sunshade to the scale model of the MESSENGER craft, each team will gather temperature data from inside the film canister.

h. Record the results: Each student will be responsible for taking, recording and analyzing the temperature data.

i. Evaluate, Modify, redesign: Evaluate the success of the sunshade and use the data gathered to modify and improve on the design. Go back to step f. if necessary.

j. Re-test and record the results: After attaching the modified sunshade to the scale model of the MESSENGER craft, each team will gather temperature data from inside the film canister.

k. Report, share, reflect, and celebrate: Talk about the real materials used in the construction of MESSENGER's sunshade.

Individual Roles and Responsibilities

As in any collaborative effort, it is useful to consider assigning roles and responsibilities to the students in advance of starting the activity. Each student within a team is responsible for researching, collaborating and helping with the creation of the team's product. At the elementary level, a group of 3-4 students is optimal.

Here are some possible roles for students within a group to choose or be assigned.

Scientist- Collects, maintains and organizes all team member's research information.

Design Engineer- Coordinates the design of the spacecraft

Drafts Person- Creates the scale drawing of the model

Writer- Incorporates the member's ideas into words

Mission Specialist- Oversees team. Creates a schedule and keeps the team on task

Teaching Tip

You may want to create binders or folders for each member of the group to organize each student's work.

Design Challenge Overview

Day 1: Building a Scale Model of MESSENGER Spacecraft

Day 2-3: Creating a sunshade for the MESSENGER Spacecraft

Day 4: Testing the sunshade

Day 1 Preparation

If you have teacher aides or parent volunteers, ask them to help with this activity. Divide the students into groups of three or four. These groups will build their MESSENEGER model and test their solar shades together.

Teaching Tip

Consider asking your class to collect items on the list of materials. A letter to parents would be useful

Warm-Up and Pre-Assessment

Begin this lesson by having students focus on the warming effects of sunlight by asking them to cite examples from their own experiences. Students might mention touching a car on a sunny day, sitting on a chair in the sun, or walking barefoot across hot sand. Reinforce the concepts of earlier experiences. Review or introduce the idea that when sunlight hits a surface, such as a car or sand, the light energy changes to heat and warms not only the surface but also the air around the surface. Bring them to the understanding that the light of the sun warms the surface of the Earth.

Materials
for Spacecraft- Day 1.

- A variety of materials for building a model. (Suggested materials include cardboard tubes and boxes of different sizes and shapes, foil, meat trays, foil pans, pipe cleaners, plastic lids and containers), cardstock)
- Tape
- Glue
- Glue gun if available
- Stapler and staples
- Grid paper for drawing the model

Day 1 Procedures

1. Distribute to each group a diagram of the MESSENGER spacecraft. Talk about the materials that are available for building a scale model of the MESSENEGER spacecraft. Tell students that they can add other materials if they choose.
2. Tell the students that, using the materials provided, each team of students will create a simple model of the MESSENGER spacecraft. While some parts can easily be created from small cardboard boxes and tubes, others may need to be created out of cardstock paper, cans, lids or other materials.

Design Restraints and Requirements

Each team of students will construct a scale model of the MESSENGER spacecraft. The model should contain the following parts. The approximate scaled size of each part of the spacecraft is listed in the chart below. The position of each feature is pictured in the image below.

MESSENGER Model 1:10 Scale

Part	Width (cm)	Height (cm)	Depth (cm)
Primary structure (main instrument box)	11	13	19
Solar panel (x2)	16	18	0.2
Sunshade	25	18	
Main tank assembly (3 tanks side by side)	17	6	10
Auxiliary tank	4		4
Helium tank	4		6
LVA Thruster	2	2	7
Magnetometer & Boom	36		

Materials
for Sunshade- Days 2-3

- An assortment of materials for constructing the sunshade:
  Various colors of construction paper;
  Various reflective materials like foil;
  Remnants of different colored fabrics

Materials
for Sunshade- Days 2-3

- Materials for testing sunshade- Day 4.
- Lamp with 100-200 watt bulb
- 2 black film canisters per group with hole in the lid for inserting a thermometer
- Thermometer

3. Give students ample time to assemble the basic MESSENGER model. Remind them that the point of this design challenge is to build the model of the craft itself, not to make the best and most effective sunshade that protects the spacecraft!

4. When complete, store the models in a safe but accessible place. Students will need constant access to the spacecraft as they design their sunshades.

Teaching Tip

Children in Grades 2 and 3 may have difficulty with the concept of a scaled model. Show them the picture of the craft and ask them to build a structure that has all of the main parts beginning with a large facial tissue box as the primary structure.

Days 2 & 3: Designing and Constructing Sunshades

If you have teacher aides or parent volunteers, ask them to help with this activity. Divide the students into groups of three or four. These groups will build their MESSENEGER model and test their solar shades together.

Teaching Tip

Be resourceful, and see what materials can be donated from local fabric, hardware, or dollar stores, etc. Ask the custodian and art teacher for any unusual packing materials, too. Tell students to check with their parents to see if there's anything safe in the garage or storage closets they may use.

DAY 2-3 PROCEDURES

1. Distribute student worksheet "The Design Process."

2. Tell the students that they are now going to follow procedures described in the "Design Process" to help them get started on their Solar Shade designs. Explain that the Sun's rays light and heat the Earth. When sunlight strikes a surface – such as the instruments aboard the MESSENGER spacecraft – the light changes to heat energy. This extreme heat would damage delicate instruments if they were left unprotected.

3. Remind students that challenge is build an effective sunshade to protect all the important, sensitive mission-related instruments. You will then test all the groups' solar shields and see whose sunshade keeps the temperature the coolest. To measure the temperature, a black film canister, fitted with a thermometer through the lid, will be positioned on the simulated equipment deck of the model MESSENGER spacecraft. The whole set up will then be exposed to full sunlight or to the heat of a 100-200W lamp.

4. Give the students ample time to design and build their shields from the available materials.

Teaching Tip

With beginning design students, take them through the design process methodically, step by step. They should be working only in pencil at first. Although the students will be anxious to begin work on the actual model or sunshade, students first need an accurately drawn plan. For students who may struggle with the concept of a scale drawing, the student could be allowed to draw a full scale drawing on poster grid paper available at many teacher stores.

For students working in groups, remind students that each member of the group must participate in creating the model, setting up the tests, recording and analyzing the data. It may be useful to assign roles to group members.

Inaccurate measurement often causes problems. Make sure that students learn from the start how to use a ruler. Metric measurements are preferred.

Using quick drying "tacky glues" helps students immensely. Teachers may want to consider using parent volunteers to work with students using low heat glue guns.

DAY 4: PROCEDURES FOR TESTING THE SOLAR SHIELDS

1. Place the MESSENGER model in full sunlight or position a 100-200 watt light bulb 6 inches from the instrument deck of the spacecraft to simulate the sun. (Safety note: Caution the students that the lightbulb will become very hot. Position the lamp to that there is access only from the front to avoid accidental burns.)

2. Place a thermometer through a small hole in the lid of a film canister that is positioned on the instrument deck of the model that you built in Activity 1.

3. The spacecraft should stay exposed to the sunlight or light bulb for 10 minutes.

4. Record the temperature inside the film canister. Repeat the process two more times. Calculate and record an average temperature.

5. Allow the film canister to cool by removing the lid from the film canister and moving the model out of the light for 5 minutes in order to cool.

6. Attach the sunshade that has been designed to each model. Again place the MESSENGER model in full sunlight or position a 100-watt light bulb 6 inches from the instrument deck of the spacecraft to simulate the sun's light and heat.

7. Record the temperature inside the film canister. Repeat the process two more times. Calculate and record an average temperature for the sunshade test.

8. Calculate and record the temperature difference (the difference between the model in Step 4., without a sunshade and the model in Step 7., with a sunshade).

Discussion & Reflection

Reassemble the class. Ask a representative from each group to share the group's findings. Encourage students to use findings from the tests to support their ideas.

Cirriculum Connections

Take advantage of this design project to embed measurement and other mathematical skills. This project provides frequent opportunities for measurement, the creation of scaled drawings, graphing and the calculation of area.

Lesson Adaptations

Construction of the model poses some issues for students. Provide students with clamps and work surfaces that secure parts of the spacecraft while they are working on other parts.

Assessing Design Projects

Student Work	What Elements You Might Access	How You Might Assess
A Design Drawing	Accuracy of Measurement Spatial relationships Completeness of Drawing Units of Measurement	Create a rubric with a range of 1-5 to evaluate each component of the design drawing.
Complete Model	Constructed Properly Does the model meet the requirements of the design challenge?	Have each student complete a self-assessment followed by a conference with the teacher to consider the following: Did the model make creative use of materials? How did the model solve the design challenge? What were the roles of each student? What care was taken for the appearance? How did the students overcome construction problems?
Data Discussion and Display	Accuracy of data Appropriate graphs, charts and representations of data.	Create a rubric that assesses the following types of information: Do the students use the data displayed to make a convincing case? Do the graphs and charts help explain information? Is there a complete record of data?

Design Process Worksheet

The Design Process

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