

WHO'S THE COOLEST?

**A 5th Grade Inquiry-Based Lesson Investigating
Surface Area and the Rate of Cooling**

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PART ONE: EXPLORING SURFACE AREA

Students will work in small groups (3-4 students) to discover the concept of surface area of a rectangular solid.

Objectives:

1. Students will be able to explain the concept of surface area both in written and oral form.
2. Students will be able to construct rectangular solids using 1-inch grid paper.
3. Students will be able to find the surface area of rectangular solids using the boxes they construct using the 1-inch grid paper.

Materials for each Group:

- 1 box, 4" X 3" X 1"
- 1 piece of wrapping paper cut into a 15-inch square
- Tape
- Scissors
- 4 pieces of grid paper (for each student)
- Double Stick Tape (for teacher's use)

ACTIVITY #1 – INFORMALLY INVESTIGATING SURFACE AREA

The intent of this first activity is for students to investigate surface area of a rectangular solid or a box. The terms rectangular solid and box will be used interchangeable throughout the lesson.

Content Preparation by the Teacher Before Teaching the Lesson

Teachers should be able to fully answer each of the following questions.

1. What is the surface area of a geometric figure?
2. Explain why it is possible or impossible to have surface area of a 1-dimensional geometric figure, a 2-dimensional geometric figure, and a 3-dimensional geometric figure.
3. Explain why square units (e.g. square inches, square centimeters) are used for surface area?
4. What is the difference between area and surface area?
5. How does the surface area and volume of a rectangular solid differ?

Directions for the Teacher

At the beginning of the lesson, ask students to use their prior knowledge (if any) about what they think surface area is. Record their responses on the board or overhead transparency.

Assign students into small groups of 3-4.

Distribute Worksheet for Activity #1. Display the transparency for Worksheet for Activity #1 on the overhead, and read the directions to the class. Once you finish reading the directions orally, ask a student to summarize the directions for everyone. As you read the directions regarding the materials of the activity, show each of the items to the class.

Worksheet for Activity #1

Directions to Students: Follow each of the following steps and answer each question.

1. Make sure your group has the following materials.
 - 1 box measuring 4" X 3" X 1"
 - 1 piece of wrapping paper cut into a 15-inch square
 - Scissors (one for each student)
 - Tape
2. Cover the box with the wrapping paper using the smallest amount of wrapping paper possible.
3. Remove any of the overlapping paper if you can.
4. Once your group has finished covering your box with the wrapping paper, raise your hand and ask the teacher to check your box.

[Note to Teacher: Check to see if the groups have completely covered all sides of the box. If part of the wrapping paper overlaps, this is fine at this point in the lesson. But remember that students can remove any of the overlapping paper if they wish.]

5. After the teacher has checked your box, unwrap the wrapping paper carefully and lay it flat on the desk. Be careful not to tear the wrapping paper. Write each group member's name on the inside of the wrapping paper.
6. Raise your hand and let the teacher know you are finished and he/she will collect the flattened wrapping paper.

[Note to Teacher: With the side of the wrapping paper with the student's names facing the class, use double stick tape to post each of the flattened wrapping paper on the board. Initiate a discussion about

what students' notice about the wrapping paper by posing some or all of the questions listed below. Student responses can be expressed orally or groups can respond in written form.

Possible questions to be posed to the class include:

- ❖ What do you notice about the differing sizes of the wrapping papers?
- ❖ Are all the wrapping papers the same size? If not, why do you think they are different sizes?
- ❖ Are the wrapping papers all the same shape? If not, why do you think the shapes differ?
- ❖ Did you use all of your wrapping paper?
- ❖ Did you have any overlapping wrapping paper? If you answered YES, could you have cut away the overlapping paper?
- ❖ What are the possible ways we could go about finding the smallest amount of wrapping paper to cover the box?
- ❖ When we found the smallest amount of wrapping paper, what do you think we have found?

[Note to Teacher: Be sure that for the last question, each student writes an answer on the activity sheet. You may choose to pose these (and others) questions to the entire class orally or you may choose to have each group discuss the questions and write the answers on the activity sheet. The point of this activity is for students to articulate the definition of surface area.]

7. What is surface area? Be sure to write your answer in complete sentences.

ACTIVITY #2 – FINDING A BETTER WAY TO DETERMINE THE SURFACE AREA BY CONSTRUCTING RECTANGULAR SOLIDS USING GRID PAPER

The intent of this second activity is for students to find a more systematic way to find the surface area of a rectangular solid.

Directions for the Teacher

DESCRIBING THE LINEAR DIMENSIONS OF THE BOX

1. Using the 4" X 3" X 1" box; discuss the dimensions of a rectangular solid. Ask one person in each group to hold up the rectangular solid and point out the length of the box, then the width of the box, and then the height of the box. Even though the length of the box could be any of the sides of the rectangular solid, decide upon a uniform way of describing each of the dimensions of the rectangular solids.

For example:

The length of the box is the 4-inch side.

The width of the box is the 3-inch side.

The height of the box is the 1-inch side.

DESCRIBING THE SIDES OF THE BOX

1. The teacher needs to set up a consistent way of describing the Bottom, Top, Left, Right, Front and Back of the rectangular solid. Ask students to show you the Bottom of the box, the Top, the Left and Right sides, the Front and the Back of the box. Notice that the Bottom and Top of the box are the same size, the Left and Right are also the same size, and the Front and Back are the same size. Share this information with students.
2. Ask students to determine the dimensions of the Bottom and Top of the box. Their answers for the Bottom and Top should be 4" X 3". Ask students to determine the dimensions of Left and Right of the box. Their answers for the Left and Right should be 3" X 1" and student answers for the Front and Back should be 4" X 1".
3. You will be demonstrating how to construct a 4" X 3" X 1" rectangular solid. The students will be making their own rectangular solids as you demonstrate making yours.

DIRECTIONS FOR MAKING A 4" X 3" X 1" RECTANGULAR SOLID

[Note to Teacher: In the Figures 1-6, please note that some of the lines are solid and others are dotted. The solid lines indicate cutting lines and the dotted lines indicate folding lines.]

1. Ask students to put one piece of 1-inch grid paper on their desks. You will be using the 1-inch overhead transparency to demonstrate the strategy you will be using to construct the rectangular solid.
2. At the bottom center of the grid paper, count one square for each inch in the length of the rectangle. If you use the length of the box as 4 inches, then you will count off 4 grid squares. Using your overhead pen (and the students will be using a pencil), mark off the 4 grid squares. (See Figure 1 for Activity #2)
3. Still using the bottom part of the grid paper, you will mark off the number of squares that represent the height of the rectangular solid. Using the height of 1 inch, you want to mark off 1 grid square to the left and 1 grid square to the right of the length already marked on the grid paper. (See Figure 2 for Activity #2)
4. At the furthest left and right sides of the grid squares that you have just completed above, you will be marking off the width of the rectangle. From the furthest most left side of the marked squares, count the number of grid squares (in this case, it is 3) vertically. If you use 3 inches as the width, you will count 3 grid squares vertically from each end of the grid marks you have just completed. (See Figure 3 for Activity #2)
5. You will now make 3 rectangles; the first rectangle will represent the Bottom of the box, the second rectangle will be the Left of the box, and the third rectangle will be the Right of the box. The first rectangle will be 4" X 3" (the center rectangle), the second rectangle will be 3" X 1" (on the left of the center rectangle) and the third rectangle will be 3" X 1" (on the right of the center rectangle). The center rectangle will represent the Bottom of

the box. The left and right rectangles will represent the Left and Right of the box. (See Figure 4 for Activity #2)

6. Working vertically from the rectangle that represents the Bottom of the box (center rectangle), you will construct the Back of the box. Since the back is 4" X 1", you want to count up 1 grid square vertically. Make the rectangle (4" X 1") and this will represent the Back of the box. Now, count up 3 grid marks vertically and you will be constructing the Top of the box. The Top should be a 4" X 3" rectangle. Now to the Front of the box; the Front should be 4" X 1". You should have outlined each of the rectangles that represent the six sides of the rectangular solid. In each of the rectangles, print "Top", "Bottom", "Left", "Right", "Front", and "Back". (See Figure 5 for Activity #2)
7. Cut along the outermost lines (denoted by solid lines). Fold along each of the rectangular markings (denoted by dotted lines). You have now constructed a 4" X 3" X 1" rectangular solid.
8. Unfold the rectangular solid.
9. To find the surface area, count the number the 1-inch squares in the rectangular solid you have just constructed. Express the answers in square inches. The surface are of the 4" X 3" X 1" rectangular solid is 38 square inches.

Worksheet for Activity #2

Directions to Students: Follow each of the following steps and answer each question.

1. Make sure each person in your group has 3 pieces of grid paper.
2. Using one piece of grid paper to construct the boxes with the following dimensions:

Box #1: Length = 4"	Width = 2"	Height = 1"
Box #2: Length = 2"	Width = 2"	Height = 2"
Box #3: Length = 8"	Width = 1"	Height = 1"

[Note to Teacher: Suggest that students might want to turn their grid paper horizontally to construct Box #3.]

3. Find the surface area of each of the boxes by counting the number of squares.

Surface Area for Box #1:
Surface Area for Box #2:
Surface Area for Box #3:

[Note to Teacher: The surface area of each of the boxes is:

<i>Surface Area for Box #1:</i>	<i>26 square inches</i>
<i>Surface Area for Box #2:</i>	<i>24 square inches</i>
<i>Surface Area for Box #3:</i>	<i>34 square inches]</i>

4. Which box has the largest surface area?
5. Which box has the next largest surface area?
6. Which box has the smallest surface area?

PART TWO: THE RATE OF COOLING EXPERIMENT

Students will work in small groups (3-4 students) and perform an experiment that investigates how surface area of rectangular solids (with the same volume) impacts the rate of cooling.

Objectives:

1. Students will follow the directions for setting up and performing the cooling experiment.
2. Students will accurately record the data for the experiment
3. Students will be able to explain how the surface area of a rectangular solid impacts the rate of cooling.

Materials for each Group:

- 1 styrofoam cooler
- 3 containers, marked Box #1, Box #2, and Box #3
- 1 plastic bottle of water, colored with food coloring
- 1 measuring cup (1/2 cup)
- Newspaper
- Dry ice, cut into pieces
- Timer (for the teacher to use)
- Rubber gloves (for the teacher to use)

ACTIVITY #3 – EXPERIMENTING WITH THE RATE OF COOLING

Directions for the Teacher

The intent of the third activity is for students to set up an experiment, accurately record the data they collect, and finally determine how surface area impacts the rate of cooling of a rectangular solid with the same volume.

Content Preparation by the Teacher Before Teaching the Lesson

Teachers should be able to fully answer each of the following questions.

1. How does surface area impact the rate of cooling of water when the volume is held constant?
2. How does the volume impact the rate of cooling of water when the surface area is held constant?

3. Why is the surface area to volume ratio principle important?
4. What is dry ice?
5. How does the temperature of dry ice differ from the temperature of ice cubes?
6. What happens when dry ice warms? What happens when ice cubes warms?
7. Why is dry ice used in this experiment instead of ice cubes?
8. Describe at least 4 real world applications to the surface area to volume ratio.

Preparing the Experiment

1. Obtaining the Dry Ice

Order and pick up the dry ice at:
South Bay Fire Extinguishers
1068 Aviation Avenue
Hermosa Beach, CA 90254
310.376.6901

Call one day in advance and place the order for 10 pounds of dry ice (\$1.00 per pound). When you pick up the dry ice, take in one of coolers. Ask if they will break up the dry ice for you. They will break up the dry ice and place it in the cooler for you.

2. Preparing the Coolers:

Using the rubber gloves, evenly distribute the dry ice among the 5 coolers. Place the dry ice in such a way that the dry ice forms a flat surface. Then you can place each box on top of the dry ice. Do not touch the dry ice with your hands. You must wear the rubber gloves. During the experiment, students will fill their boxes with water, place them in the cooler, cover the boxes with newspaper and then put the lid on the cooler.

3. Preparing Other Materials

Fill the bottles with water and add couple of drops of food coloring. The food coloring will make the cooling process more visible to the students.

Directions for the Teacher

Each of the rectangular solids prepared in Activity #2 are the same size as the containers (boxes) used in this experiment. When the $\frac{1}{2}$ cup of water is poured into each container, the amount of water in the container (box) will be the same dimensions as the boxes in Activity #2. Show the class the correlation between the boxes they constructed and the containers that they will use in

the experiment. Distribute Worksheet for Activity #3. Display the Worksheet for Activity #3 transparency on the overhead, and read the directions to the class. Once you finish reading the directions orally, ask a student to summarize the directions for everyone. As you read the directions regarding the materials of the activity, show each of the items to the class.

Worksheet for Activity #3

Directions to Students: Follow each of the steps below.

1. Using the Rate of Cooling Chart on the other side of this paper, record the surface area for each box.
2. Measure 1/2 cup of water using the measuring cup and pour into Box #1.
3. Measure 1/2 cup of water using the measuring cup and pour into Box #2.
4. Measure 1/2 cup of water using the measuring cup and pour into Box #3.
5. Carefully put the boxes into the cooler. Make sure that the boxes fit flat on the dry ice. Also make sure there is room around each of the boxes. **DO NOT TOUCH THE DRY ICE!**
6. Cover the containers with the newspaper. **DO NOT TOUCH THE DRY ICE!**
7. Place the lid on the cooler.
8. The teacher will set the timer for 5 minutes. When the timer rings, remove the lid of the cooler and the newspaper. Observe the 3 boxes to determine if each of the boxes is frozen. On the Rate of Cooling chart under the heading 5 minutes, record a YES if the box is frozen and NO, if the box is not frozen. **DO NOT TOUCH THE DRY ICE!**
9. The teacher will set the timer for another 5 minutes. When the timer rings, remove the lid of the cooler and the newspaper. Observe the 3 boxes to determine if each of the boxes is frozen. On the Rate of Cooling chart under the heading 10 minutes, record a YES if the box is frozen and NO, if the box is not frozen. **DO NOT TOUCH THE DRY ICE!**
10. The teacher will set the timer for another 5 minutes. When the timer rings, remove the lid of the cooler and the newspaper. Observe the 3 boxes to determine if each of the boxes is frozen. On the Rate of Cooling chart under the heading 15 minutes, record a YES if the box is frozen and NO, if the box is not frozen. **DO NOT TOUCH THE DRY ICE!**
11. The teacher will set the timer for another 5 minutes. When the timer rings, remove the lid of the cooler and the newspaper. Observe the 3 boxes to determine if each of the boxes is frozen. On the Rate of Cooling chart under the heading 20 minutes, record a

YES if the box is frozen and NO, if the box is not frozen. DO NOT TOUCH THE DRY ICE!

12. The teacher will set the timer for another 5 minutes. When the timer rings, remove the lid of the cooler and the newspaper. Observe the 3 boxes to determine if each of the boxes is frozen. On the Rate of Cooling chart under the heading 25 minutes, record a YES if the box is frozen and NO, if the box is not frozen. DO NOT TOUCH THE DRY ICE!

13. The teacher will set the timer for another 5 minutes. When the timer rings, remove the lid of the cooler and the newspaper. Observe the 3 boxes to determine if each of the boxes is frozen. On the Rate of Cooling chart under the heading 30 minutes, record a YES if the box is frozen and NO, if the box is not frozen. DO NOT TOUCH THE DRY ICE!

Rate of Cooling Chart

	Surface Area	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.
Box #1							
Box #2							
Box #3							

ANSWER EACH OF THE FOLLOWING QUESTIONS:

1. Which box cooled the fastest? _____ What is its surface area? _____
2. Which box cooled the next fastest? _____ What is its surface area? _____
3. Which box cooled the next fastest? _____ What is its surface area? _____
4. What did you notice about the surface area of the box that cooled the fastest?
5. What did you notice about the surface area of the box that cooled the slowest?

6. Explain what you have discovered about how the surface area relates to the rate of cooling.

ACTIVITY #4: APPLICATIONS IN THE REAL WORLD

The intent of the follow-up activity is for students to discover how the surface area to volume ratio and its impact on the rate of cooling has many real world applications.

Directions for the Teacher

As you discovered during your content preparation in Part Two, there are many significant real world applications to the concepts addressed in this lesson. Present 4 real world applications with the class.

Example 1: An Application Using Temperature

1. Ask students to stand behind their chairs. Make sure that there is at least one arms distance between each of the students.
2. Ask students to put their arms by their side. Pose the question to students: “What would you do if it was 30°F outside?” Students might compress their bodies, their arms might be folded, and their heads might be down against their chests, forming something that depicts a sphere or cube. Then ask, “Why did you get in this position”?
[Note to Teacher: Students might respond that this is the way to stay warm.]
3. Next, pose the question to students: “What would you do if it was 100°F outside?” Students might expand their bodies and they may place their arms horizontally away from their bodies. Then ask, “Why did you get in this position”?
[Note to Teacher: Students might respond that this is the way to cool off.]
4. Ask one student to come up to the front of the class and ask the remainder of the class to sit in their chairs. Ask the student in front of the class to simulate what he/she would do if it were 30°F outside. Ask the class to notice the surface area of the student in this position. Now ask the student in the front of the class to simulate what he/she would do if it were 100°F outside. Ask students to notice the surface area of the student in this position.
5. Now, pose the questions: “At which temperature (30°F or 100°F) does the student’s position appear to have the larger surface area?” And “At which temperature does the student’s position appear to have the smaller surface area?”
[Note to Teacher: You might want to remind students that one way to think about surface area is like covering an item with wrapping paper. If we were to cover these students with wrapping paper, which one would need more wrapping paper, which one would need less wrapping paper? One strategy for the class to make their choices is to ask students to hold up one finger if they think the answer is “Temperature is 30°F outside” and hold two fingers up if they think the answer is “Temperature is 100°F outside”.]

6. Now, it is important for students to make the connection between the surface area and the rate of cooling in this informal example. Now pose the question, “How does the surface area formed by your body at the different temperatures connect to the rate of cooling experiment”?

[Note to Teacher: Students should be able to conclude that when the temperature is 100°F, their body positions (in Step 3 above) form a much larger area than when the temperature is 30°F. Hence, the larger the surface area, the faster the cooling process (given a constant volume); the smaller the surface area, the slower the cooling process. So if it is hot outside and you want to become cooler, you would position your body in such a way that it has a larger surface area. And if it is cold outside and you want to stay warm, position your body in such a way that it has a smaller surface area.]

Example 2: An Application Using Animals

1. Distribute a blank piece of paper to each student. Fold the paper in two pieces
2. In the one half of the paper, ask students to draw a make-believe animal with the approximate dimensions of 3 inches by 2 inches. This animal should have a large amount of surface area.
3. In the other half of the paper, ask students to draw another make-believe animal with the same approximate dimensions of 3 inches by 2 inches. This animal should have a small surface area.
4. Now pose the questions to students:
 - ❖ *Which animal would stay warmer? Why?*
 - ❖ *Which animal would you expect to find in the snowy climate? Why did you choose this animal?*
 - ❖ *Which animal would you expect to need a fur coat to stay warm? Why?*

Examples 3 and 4

Select two other applications of the surface area to volume ratio and the rate of cooling and share these applications with students.