

## Teacher's Preparatory Guide

### Learning About Surface Area and Volume

**Using book: Spaghetti and Meatballs for All! by Marilyn Burns**

**Purpose:**

The purpose of this lesson is to help students extend their knowledge of area, perimeter, and volume to include surface area. The understanding of these concepts begin in the elementary grades and helps students understand events such as why a hot potato cools down quicker when it is spread out in smaller pieces and why a cell is triggered to divide. This understanding is even more important when students begin to understand the micro and nano scales in middle and high school.

**Time required:**

Several class periods or can be used as a center activity.

**Level:**

Elementary Grades 3-5

**Teacher Background:**

In the book, *Spaghetti and Meatballs for All!* by Marilyn Burns, Mr. and Mrs. Comfort decide to invite their family and neighbors over for dinner. Pretty soon, 30 people have accepted so they will be feeding 32, including themselves. Mrs. Comfort figures out that they don't have enough tables and chairs for this many people. So she rents some. She correctly figures out that 8 tables seating four people each will do the trick. She rents 8 tables and 32 chairs.

All is well, until the guests start to arrive. They don't want to sit at separate tables. They want to eat at one big table so they can be closer to everyone else. That creates a problem because as the guests begin to push tables together they realize that there is not enough sides for the chairs. Using this story the students can explore their understanding of area, perimeter, and volume.

In the book *A Framework for K-12 Science Education : Practices, Crosscutting Concepts, and Core Ideas* by the National Academy of Sciences, increasing student familiarity with the role of mathematics in science is central to developing a deeper understanding of how science works. Three of the Seven Crosscutting Concepts of the Framework include:

**Patterns-** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them;

**Scale, proportion, and quantity-** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance;

**Structure and function** – The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

The initial development of the understanding of these crosscutting concepts starts in elementary grades when students begin to look for and recognize patterns, begin to understanding scale with objects, space and time, and begin to understand how the shape of an object is related to its purpose.

The National Council of Teachers of Mathematics states that for students to apply appropriate techniques, tools, and formulas to determine measurements by the fifth grade students should:

- Develop strategies for estimating the perimeters, areas, and volumes of irregular shapes;
- Select and apply appropriate standard units and tools to measure length, area, volume, weight, time, temperature, and the size of angles;
- Select and use benchmarks to estimate measurements;
- Develop, understand, and use formulas to find the area of rectangles and related triangles and parallelograms;
- Develop strategies to determine the surface areas and volumes of rectangular solids.

In the book, *National Science Education Standards* it states that content standards for students in grades K-4 for Unifying Concepts and Processes include systems, order, and organization; change, constancy, and measurement; and form and function. Under Physical Science content standards it includes properties of objects and materials.

This lesson uses the 5 E model. The 5 E model is Engage, Explore, Explain, Elaborate and Evaluate (<http://faculty.mwsu.edu/west/maryann.coe/coe/inquire/inquiry.htm>). The purpose of the Engage stage is to capture students' attention. The Explore stage provides opportunities for students to engage in activities, giving them concrete experiences, concepts, and skills. In the Explain stage, students are given a chance to put their ideas into their own words, clarifying the concepts. This gives the teacher a checkpoint to assess student understanding. In the Elaborate stage, students are challenged to extend the concepts learned and apply them to new situations. At the Evaluate stage, the teacher is able to assess student's understanding and give opportunity for students to self-evaluate.

In the book, *The Big Ideas of Nanoscale Science and Engineering A Guidebook for Secondary Teachers* it states that every object has a size that can be defined in either one, two, or three dimensions. Doubling the size of an object affects the surface area and volume disproportionately. For instance, doubling the length of the sides of a cube increases the volume eight-fold, but the surface area of the cube is only increased four-fold. Thus, if a property depends on volume then that property will change much faster than properties dependent on area. The Big Idea of Size and Scale includes concepts related to the measure of the geometric properties of length, area, volume, and shape. This lesson helps students begin to learn the size and scale concepts that they will later use in their studies.

Nanoscale science is the understanding and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. A nanometer is one-billionth of a meter or  $1 \times 10^{-9}$  meters. Many of the special properties that matter exhibits on the nanoscale result from the effect of size on surface area to volume ratios. This is an important concept in nanoscale science and engineering. This lesson

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seeks to allow students to begin developing the knowledge of how changes in dimensions can affect surface area interactions.

This lesson can be conducted as a learning center so you will notice that in the directions the items that are included in the center are in blue.

### Materials:

- Plastic snack bags
- play dough cubes
- plastic knives
- paper plates
- small plastic cups with lids
- colored sugar
- Learning Center made out of material and PVC pipe

### Advance Preparation:

Set up the center with two of each of the following or one of each of the following for each two students if done as a class activity:

- Copies of worksheets
- Purchase or obtain book *Spaghetti and Meatballs for All!* by Marilyn Burns
- Metric ruler, combo ruler, measuring tape, or meter stick (One of each)
- Plastic bag containing at least 32 small squares for chairs and at least 50 big squares for tables made from construction paper or card stock.
- Bag containing two small sealed cups of colored sugar, small paper plate, 2 large Play Dough® balls ( about the size of a meatball 1 inch in diameter).
- Bag containing a cube (2cm x 2 cm) of Play Dough®, plastic knife, and small paper plate
- Bag containing 3 meatball (Play Dough®) cubes (2 cm x 2 cm), cup of colored sugar and paper plate.

### Safety Information:

No safety concerns in this lesson.

### Directions for Activity:

Engage (A)

1. Show students the front of the book and ask them to suggest what they think the book is about. (Allow several students to answer).
2. Read the book to the class.

Explore (A) Station 1

3. Pass out 32 chair squares, 8 table squares, and worksheet.
4. Read the book again but stop on each table arrangement. Students are to arrange their tables and chairs for each arrangement in the book. Remember the squares must touch along the whole side and each chair square must fit against a table side.
5. After arranging squares they will decide if they have room for all the chairs. Place yes or no next to sketch on worksheet.

### Explain (A) Station 2

6. Provide students with the following definitions: Area: the inside space of a shape or boundary. Formula: Area = base x height  $A = B \times H$   
Perimeter is the total lengths of all the sides of a shape  $A + B + C + D$ .
7. Have the students determine the area of one of the table squares.
8. Explain that the formula for area always gives us a unit squared. (You may want to give them other examples such as 1 ft by 1 ft square give you 1 ft<sup>2</sup>)
9. Have the students find the perimeter of one table square.
10. Have the students determine the area and perimeter of the table arrangements on their worksheet. They are to list each on their worksheet.
11. Discuss, as a class, the area and perimeter of each table arrangement.
12. Ask the students which (either area or perimeter) will give you the number of chairs that will fit at each table arrangement (Perimeter). Ask students why perimeter is the correct answer. (Allow several answers) Summarize that the chairs must fit along the perimeter, so that is why perimeter can be used.

### Elaborate (A) Station 3

13. Distribute to students several more table squares.
14. Ask the students if it would be possible to seat all 32 people at other arrangements if they had more tables but the tables were to be pushed together to make one big table. (Allow a couple of students to show you examples using their squares.) (Possible answers are 1 X 15 squares, 2 X 14 squares, 3 X 13 squares, 4 X 12 squares, 5 X 11 squares, 6 X 10 squares, 7 X 9 squares, and 8 X 8 squares)
15. Tell students that they are to find one arrangement of tables all pushed together that would seat 42 people. They are to sketch the arrangement on their worksheet and calculate the perimeter and area of each table arrangement.
16. Ask the students what arrangement(s) they came up with? (Allow several to share their arrangements and then ask others if they also came up with this arrangement?)

### Engage (B) Station 4

17. Say to the students that now that Mr. and Mrs. Comfort have solved the table and chair problem, Mr. Comfort has another problem. Go back to the book and read the page that says, "Mr. Comfort got up very early and spent all morning cooking. He baked 16 loaves of garlic bread and made eight pounds of fresh pasta. He simmered eight quarts of spaghetti sauce and rolled 96 meatballs."

Mr. Comfort's problem is he thinks that he has made too much sauce to cover the number of meatballs and thinks that he needs to go back and make his meatballs bigger. He has made 3 meatballs per person, but thinks if he puts the three meatballs together to make one big meat ball that there will be more surface on the meatball for his sauce. Ask students what they think? (Allow students to tell you what they think.)

Tell them that Mr. Comfort also decided to make all of his meatballs squares so they would not roll off the plates.

#### Explore (B) Station 4

18. Distribute Explore bags and worksheet. Both bags contain three squares of Play Dough®, one small paper plate, and one tablespoon of colored sugar.
19. Students are to follow directions on sheet. Allow students time to explore.
20. After several minutes ask students if Mr. Comfort was correct in thinking if he made his meatballs larger they would use more sauce? (Allow students to explain what they found out but make no comment)

#### Explain (B) Station 5

21. Provide students with the following definitions: Volume is the measure of the amount of space inside of a solid figure, like a cube, ball, cylinder or pyramid. Formula for the volume of a cube is length x width x height  $L \times W \times H$ .

Surface area is the total area of the outside surface of an object. Formula for the surface area of a cube is length x width x 6 sides of the cube.

22. Give the students a cube of Play Dough® and a plastic knife. Have them calculate the volume, and surface area of the block. Write on board.
23. Ask the students if you would have the same volume and surface area if you cut your Play Dough® cube into 4 equal squares? (Allow some students to provide answers)
24. Ask students to cut Play Dough® into 4 equal cubes and then calculate the total volume and surface area of the cubes. (Ask if anything changed and if anything stayed the same?) (They should tell you that the total volume stayed the same but the surface area increased)
25. Explain that the smaller something is the more surface area it has. This would be more surface area for spaghetti sauce to cover.
26. So ask students “What should Mr. Comfort do to the meatballs to have more sauce used up?”

#### Elaborate (B) Station 6

27. Pass out a bag with three Play Dough® balls, small plate, plastic knife, and one tablespoon of colored sugar. Tell students to see if they can figure out the best meatball size to use the most sauce.

#### Evaluate

28. Students will write up how many meatballs Mr. Comfort should make for each person and justify their answer with a discussion of how they arrived at this number.

**Cleanup:** All materials can be placed back into their original containers (squares, rulers) except for the play dough that has been covered with colored sugar. It will need to be disposed of in the trash.



**Student Worksheet**  
**(example answers in red)**  
**Learning about Surface Area and Volume**

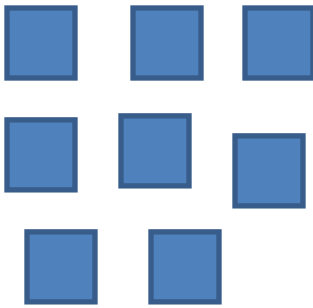


Name \_\_\_\_\_

**Explore A:**

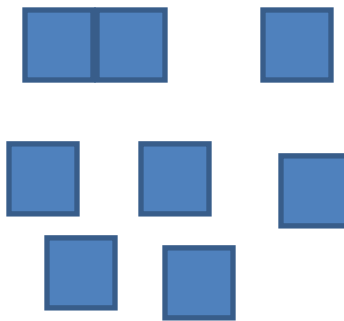
Circle yes or no under the diagram of each table arrangement to tell if it has enough room for 32 chairs.

Arrangement 1



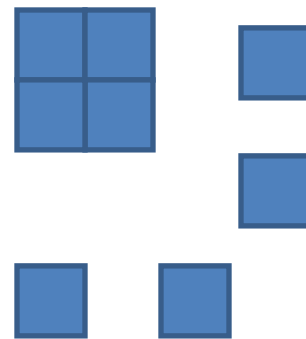
Yes or **No**

Arrangement 2



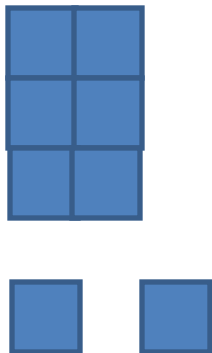
Yes or **No**

Arrangement 3



Yes or **No**

Arrangement 4



Yes or **No**

Arrangement 5



Yes or **No**



### Explain A

**Area** is the inside space of a shape or boundary. To find the area of a square or rectangle use the formula  $\text{Area} = \text{base} \times \text{height}$   
**Perimeter** is the total lengths of all sides of a shape. To find the perimeter use the formula  $\text{Perimeter} = \text{side 1 length} + \text{side 2 length} + \dots\dots\dots$

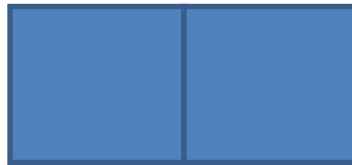
### Directions

1. Using your ruler measure the table arrangements below and write down the area and perimeter of each.

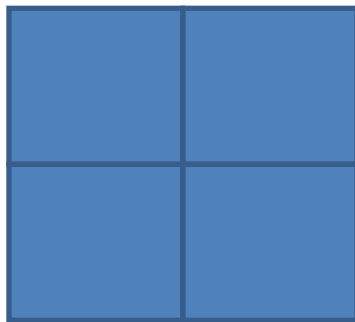


Area = 2.3 cm x 2 cm = 4.6 cm<sup>2</sup>

Perimeter = 2.3 cm + 2.3 cm + 2.3 cm + 2.3 cm = 9.2 cm Perimeter = 13.2 cm

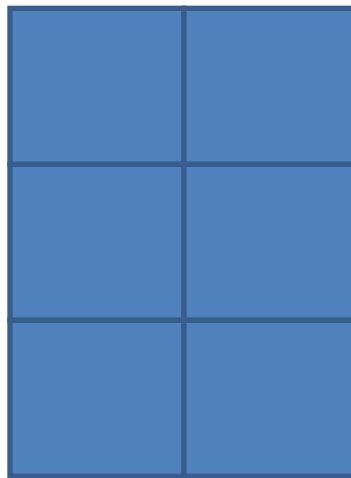


Area = 9.2 cm<sup>2</sup>



Area = 18.4 cm<sup>2</sup>

Perimeter = 17.2 cm



Area = 27.6 cm<sup>2</sup>

Perimeter = 21.2 cm

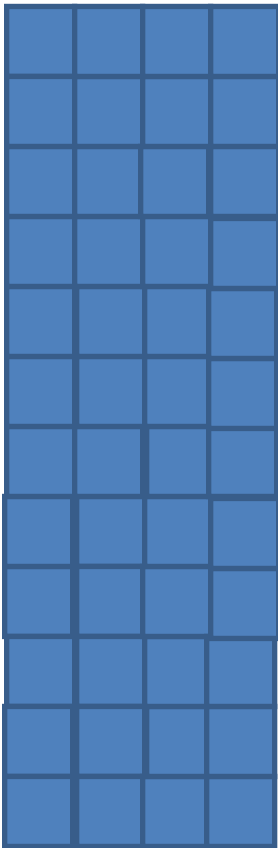


**Elaborate A**

Directions: Look at the table arrangement below:

1. Circle yes or no if it would have been able to seat all 32 people.

**Yes** No

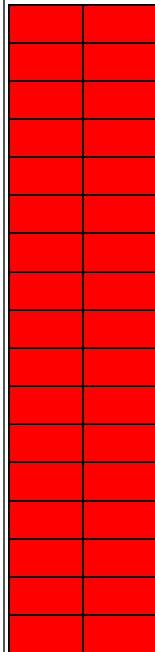


2. Determine the area and perimeter of this table arrangement.

Area 3.5 cm X 11.2 cm = 39.2 cm<sup>2</sup>

Perimeter 11.2 cm + 11.2 cm + 3.5 cm + 3.5 cm = 29.4 cm

3. Using your table squares find a single table arrangement that would seat 38 people.
4. Sketch the table arrangement below, then determine the area and perimeter.



Area 17 Blocks x 2 blocks = 34 blocks<sup>2</sup>

Perimeter 17 blocks + 17 blocks + 2 blocks + 2 blocks = 38 blocks





### **Explore (B)**

**Essential Question:** Would a big meatball or several smaller meatballs use up the most spaghetti sauce?

Directions:

1. Look at the two cups of colored sugar. Make a mark on the outside of the container to show how much sugar is in the container.
2. Open one container of sugar and pour the sugar in the paper plate. Taking one of the play dough balls roll it around the plate coating the outside with sugar. Stop rolling it around when it appears no more sugar is sticking to the outside.
3. Pour the left over sugar back into the container it came from and mark on the outside the level of the sugar.
4. Taking the other play dough ball, divide it into three smaller balls.
5. Pour the sugar from the other cup onto a paper plate. Roll the three smaller balls around on the plate until sugar stops sticking.
6. Pour the left over sugar back into the container it came from and mark on the outside the level of the sugar.
7. Looking at the two sugar containers, which size play dough ball(s) has the least amount of sugar left? Was it the container from the big play dough ball or the smaller play dough balls?

They should have less sugar left in the container that they used for the small play dough balls.

8. Why do you think one had less sugar than the other?

The smaller balls have more surface area that can be covered by sugar, so it would use up the sugar faster



### Explain (B)

**Volume** is the measure of the amount of space inside of a solid figure, like a cube, ball, cylinder or pyramid.

Formula for the volume of a cube: volume of cube = length x width x height

$$V_{\text{cube}} = l \times w \times h$$

**Surface area** is the total area of the outside surface of an object.

Formula for the surface area of a cube: Surface Area = length x width x 6 sides

$$SA = l \times w \times 6$$

Directions: These answers would depend on the size of Play Dough® given

1. Using the play dough cube you have been given, determine the volume and surface area.

Volume = \_\_\_\_\_ Surface Area = \_\_\_\_\_

2. Would you have the same total volume and surface area if you were to cut the cube into four smaller cubes? Yes or No Explain your answer

Answer will depend on what they think\_

3. Using the knife, cut your cube into four smaller cubes.

4. Determine the volume of each smaller cube and then add up all the volumes to get the total volume.

Volume of Cube 1 = \_\_\_\_\_ Volume of cube 2 = \_\_\_\_\_ Volume of cube 3 = \_\_\_\_\_

Volume of cube 4 = \_\_\_\_\_ Total volume = \_\_\_\_\_

5. Determine the surface area of each small cube and then the total surface area by adding up the SA of each of the smaller cubes.

SA of cube 1 = \_\_\_\_\_ SA of cube 2 = \_\_\_\_\_ SA of cube 3 = \_\_\_\_\_

SA of cube 4 = \_\_\_\_\_ Total SA = \_\_\_\_\_

6. Did the volume and surface area of the smaller cubes remain the same as what you had for the larger cube? Yes or no The answer would be yes and no

7. If they stayed the same, why do you think that happened? Volume stayed the same since you added no new space\_\_\_\_\_

If they changed , why do you think that happened? Surface Area increased because the smaller something becomes the more surface area it has \_\_\_\_\_



### **Elaborate (B)**

The smaller something is the more surface area it has.

Essential Question: What should Mr. Comfort do to the meatballs to have more sauce used up?

### **Directions:**

1. You have been given three Play Dough® meat balls, plate, knife, and sauce (colored sugar).  
Figure out the best size for the meatballs so that they use up the most sauce (sugar).

2. Write below how many meatballs you decided on and why.

**They should come up with a number of smaller meatballs.**

### **Assessment and rubrics**

The checking of the worksheet can be used as an assessment tool.

### **Resources:**

To learn more about nanotechnology, here are some web sites with educational resources:

[www.nnin.org](http://www.nnin.org)

<http://www.nanooze.org/main/Nanooze/English.html>

[www.molecularium.com](http://www.molecularium.com)

[http://www.nanowerk.com/n\\_neatstuff.php](http://www.nanowerk.com/n_neatstuff.php)

<http://nanozone.org/>

### **Books:**

*Spaghetti and Meatballs for All!* by Marilyn Burns 1997, Scholastic Inc. ISBN -13: 978-0-545-04445-5

*National Science Education Standards* National Research Council (1996, National Academy of Science, ISBN 0-309-05326-9)

*The Big Ideas of Nanoscale Science and Engineering : A Guidebook for Secondary Teachers* (2009, NSTA press ISBN 978-1-935155-07-2)

Additional lessons on book *Spaghetti and Meatballs for All* can be found at:

<http://www.uen.org/Lessonplan/preview.cgi?LPid=6098>

[www.mathsolutions.com](http://www.mathsolutions.com)

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<http://www.orls.org/crctt/spaghetti.pdf>  
<http://www.beaconlearningcenter.com/Lessons/183.htm>

Additional sites for learning about area, perimeter, and surface area to volume can be found at :  
<http://www.bgfl.org/custom/resources ftp/client ftp/ks2/maths/perimeter and area/index.html>  
<http://www.onlinemathlearning.com/geometry-math-games.html>  
<http://www.shodor.org/interactivate/activities/SurfaceAreaAndVolume/>

## **National Science Education Standards**

Grades K-4

Content Standard A: as a result of activities in grades K-4, all students should develop abilities necessary to do scientific inquiry.

Content Standard B: As a result of the activities in grades k-4, all students should develop an understanding of properties of objects and materials.

## **National Council of Teachers of Mathematics**

PreK-2 Expectations

- Recognize the attributes of length, volume, weight, area, and time;
- Compare and order objects according to these attributes;
- Understand how to measure using nonstandard and standard units;
- Select an appropriate unit and tool for the attribute being measured.

Grades 3-5 Expectations

- Understand such attributes as length, area, weight, volume, and size of angle and select the appropriate type of unit for measuring each attribute;
- Understand the need for measuring with standard units and become familiar with standard units in the customary and metric systems;
- Explore what happens to measurements of a two dimensional shape such as its perimeter and area when the shape is changed in some way.