Volumize Activity 3: Playing with Scale

Exploring relationships between scale, surface area and volume of created 3D characters.

Overview

Students design their own character, determine what it would take to fill or stuff it (by volume), and using surface area as a guide, decipher the requirements to cover it with fabric, fur, clothing or another material. Students will analyze how values change as their character grows (i.e. as scale is manipulated).

Big Idea

Using the 3D modeling platform that Volumize provides, students explore the concept of changing scale and its effect on surface area and volume. Students are invited to get creative in designing a fictional character and making note of its surface area and volume. Then they are prompted to decide how much clothing their character requires based on surface area and how much food he/she/it requires based on overall volume. Using the same 3D model, students are prompted to go back and change the scale and note the effects on surface area and volume. For example, if you change a length of what was once 1 foot to 10 feet, what effect does this have on the surface area and volume of your creature? What are the food
and clothing needs for your enlarged characters?

A common misperception in growth of proportionate objects is that tripling height, for example, would result in tripling surface area and volume. However, this is not the case. As an object increases in size (e.g., a small toy car and a standard sized vehicle), its surface area and volume increases at an exponential rate. This activity will help students realize that if you triple the width of an object, its surface area gets three-squared times bigger ($3^2$), and its volume gets three-cubed ($3^3$) times bigger. Whatever factor you increase the length, width or radius by, the area increases by that factor squared, and the volume by that factor cubed.

![Image of two similar cubes]

2 similar cubes
3
Ratio of side lengths: 1: $3^1$
9
Ratio of surface areas: 1: $3^2$
Ratio of volumes: 1: $3^3$

Learning Objectives
- Students will understand the concept of scale, and how a changing scale affects surface area and volume.
- Students will understand surface area and volume across shapes.
- Students will understand how mathematical nets help you understand total surface area.

Vocabulary
- Scale
- Mathematical Nets
- Length
- Surface Area
- Volume
- Dimension, 2D and 3D
- Rectangular Prism
- Triangular Prism
- Cone
- Sphere

- Cylinder
- Pyramid

Grades
Middle School, 6-8
High School Geometry

Standards Addressed
Common Core State Standards-Math
Geometry
6.G.A.1 HSG.GMD.A.3
6.G.A.2 HSG.MG.A.1
6.G.A.4
7.G.A.3
7.G.B.4
7.G.B.6
8.G.C.9

Common Core State Standards-Math
Mathematical practices.
MP2: Reason abstractly and quantitatively. Students create a dance visually and then have to determine the quantitative moves before making it virtual.

MP4: Model with mathematics. Students outline their dance using the angles of rotation and coordinate notation for the translation.

Classroom Strategies
Single-device implementation
Invite the class to collaborate on a process that will result in designing a class mascot as the character. Project the iPad in front of the class and clothe (i.e. skin) the character together, then go through the lesson as defined herein, changing scale and exploring surface area and volume. Help to reveal the pattern and relationship between the increase in linear length with their increased surface area and volume.

Multiple-device implementation
If one iPad per student is not possible, groups of two, three or four students per iPad will suffice.
In 1:1 situations, students can simply follow the activity as defined below. For groups, be sure to facilitate students to decide on a character they would like to create and take turns scaling up the character and noting the differences in surface area and volume.

**Tips and Tricks**
Getting a handle on orienting the 3D models in the app can be tricky. The lock icon on the bottom left of the modeling screen allows you to rotate the first shape, which is referred to as the base shape. Moving your model on one axis often helps maneuver it into its desired orientation. Try swiping up or down, or right or left, and watch how your swiping affects the orientation. The more you play with Volumize, the better you’ll be able to manipulate the shapes.

Also, you can zoom in and out on models. This may help to orient the scene to your liking.

A double tap at any point will return your model to the starting position. This can be very helpful for making modifications to your construction.

**Expected Activity Time**
**Playing with Scale** (20 minutes)

**Materials and Prep**
- Playing with Scale student sheets.
- iPad with Volumize app.
- Wifi access to send work to other iPads or to the online project space.

**Activity Prompt**

**Intro:** Have you ever played with action figures, dolls, plush animals or other characters? Have you ever wondered what it would be like to make your own from scratch? What would you need to fill it or stuff it? What would be required to cover it with fabric or fur or clothing? Try to Imagine if your favorite action figure or plush animal from childhood grew in size to be as big as you? Or what if it grew to be as tall as a skyscraper? In this activity, you will use Volumize to design your own character, explore its surface area and volume, and then alter the scale of your character. When you reset the scale from 1 cm to 10 cm, 100 cm and 1000 cm, your character may grow in unexpected ways. How much more fabric will it require for clothing? How much more stuffing might you need?

As you change dimensions such as length and height of a rectangular prism, or radius of a cone, the dynamic data panel in Volumize will display the effects of those changes on surface area and volume. Note those changes each time you change your character’s scale and you will be able to explore the relationship between an increase in linear length and the resulting increase in surface area and volume.

**Playing with Scale:** Have students open the app and select “Get Building.”

Each student or group needs to start with a design of a character. Allow some time for
students to do some preliminary thinking about their character and sketch it out. The more time students have to create their own personalized models, the more invested they will be in the activity.

To Do

Playing with Scale (20 minutes)

- When each group sets about creating their character, have them start with a scale of 1 cm. The 1 cm could be the total height of their character or a part (such as leg height or face height) that will be easy to calibrate to when they are prompted to increase the scale.
- Once they have the surface area and volume of their character, (found in the data panel on the right of Volumize) have students figure out how much clothing their character needs (based on surface area) and how much it would take to fill or stuff their character (based on volume). The table in the handout is there to help keep track of these estimations. Note: The surface area and volume may be less than that of the character’s total if students determine that they don’t need the entire surface area covered and/or that the entire volume needs to be filled. For instance, the character’s head may not need to be clothed or filled with stuffing.
- Once they have the data for the first scale of 1 cm, have students go to the wrench icon and choose “Edit Scale.” What was once 1 cm, increase that same length to 10 cm.
- Students should not change their character in any way. Rather, they are simply making note of the new surface area and volume when the scale has changed. Fill in the table provided in the student sheet.
- Repeat for scale measurements of 100 cm (1 m) and 1000 cm (10 m).

Discussion

Have students share their data and discuss:

- What did you notice about your characters’ clothing requirements as scale increased?
- What did you notice about the chance in volume as scale increased?

Listen for comparisons between surface area and volume.

Extensions and Inquiring Further

Connect these investigations about fictional characters and how their surface area/volume changes as they “grow” (i.e., as scale increases) and relate it to real-life animals and plants. Are there structural reasons, metabolic reasons or evolutionary reasons why redwoods aren’t taller or blue whales aren’t longer or ants aren’t human-sized? How may those reasons relate to surface area and volume of these natural organisms?

or:

Building a 3D character on top of the 2D image is a great introduction to studying the differences between these dimensions. The book Flatland by Edwin A. Abbot is a story about a world on a two-dimensional plane and all the characters that live there. One character gets a new view of reality when it elevates off the plane and gets a view from above. This story is a classic for middle and high school math students who take an interest in concepts around dimensions.
For this activity, start off by creating a sketch of a character on paper. Your character may need clothing or fur and/or some type of filling or stuffing. Keep these things in mind as you draw. Also, try to create a character that you will be able to replicate with the basic solids in Volumize (rectangular prisms, cylinders, cones, spheres, triangular prisms and square-based pyramids). Once you have a sketch of your character, you’re ready to get started with the Volumize app.

To Do:
1. Open Volumize and tap “Get Building.” You will be prompted to take a picture of something that you would like to model. Take a picture of the sketch you made of your character.
2. You will be asked to set the scale of the scene. To do this, set the height of your character at 1 cm.
3. Using the geometric solids in Volumize, create your character on top of the sketch you made. Essentially you are giving volume to the otherwise flat drawing that you made.

4. Once you have your character built, add skins to the solids that represent its clothing, fur or other “fabric” covering.

5. Enter surface and area volume data in the table as you go. Notice that the first entry in the table asks for surface area and volume of your character when the scale is set at 1 cm.

6. Based on these surface area and volume values, estimate how much clothing (or covering) your character needs and how much filling you would need. Note: The surface area and volume may be less than that of the character’s total if you determine that they don’t need the entire surface area covered and/or that the entire volume needs to be filled. For instance, the character’s head may not need to be clothed or filled with stuffing.

7. Once you’ve used 1 cm as your scale, go to the wrench icon, and tap “Edit Scale.” Edit your scale from 1 cm to 10 cm, examine the surface area and volume data in the info panels, and enter data into the table on your student sheet.

8. Repeat step 7, changing scale to 1 meter and 10 meters and get the surface area and volume data.

9. Answer the reflection questions on your student sheet and be prepared for a class discussion about what you noticed.
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1. What is the name of your character? What sorts of clothing does he/she/it wear? Or what material is covering its body (i.e., fur, feathers, fabric)? What is your character filled with?

2. The table below is meant to help you keep track of the surface areas and volumes at each scale, as well as the clothing (or covering) and filling/stuffing as you character grows.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Total Surface Area of Your Character</th>
<th>Clothing/Covering Surface Area Required</th>
<th>Total Volume of Your Character</th>
<th>Filling/Stuffing Volume Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 m (100 cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 m (1000 cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The surface area and volume may be less than that of the character’s total if you determine that you don’t need the entire surface area covered and/or that the entire volume needs to be filled. For instance, your character’s head may not need to be clothed or filled with stuffing.

3. Do you notice any sort of pattern emerging as the height increases by a factor of 10 each time? Do the surface area and volume also increase by a factor of 10?

4. Draw the mathematical net of the character you created.