____THE BUS PROJECT____

TODAY'S EXPLORATION: How Do We Build A Scale Model Of A School Bus?

Grade Level : 7

Overview: This unit introduces students to scale and computational thinking in order to solve real-world problems. Students will investigate the geometric concepts and measurement tools used to develop, design, and construct a scale model of a school bus.

Geometric Reasoning and Measurement (7.GM)

7.G.1. Solve problems involving scale drawings of geometric figures including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.

7.G.2. Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions.

7.G.6. Solve real-world and mathematical problems involving area, volume, and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.

8.G.2. Understand that a two-dimensional figure is congruent to another if the second can be obtained from the first by a sequence of rotations, reflections, and translations; given two congruent figures, describe a sequence that exhibits the congruence between them.

Practices

- Use Mathematics and Computational Thinking
- Develop and Use Models
- Draw, construct, and describe geometrical figures and describe the relationships between them.

Crosscutting Concepts

- Scale, Proportion, and Quantity

Materials:

- Measuring tape or rulers
- Graph paper or lined paper
- Pencil
- Laser Engraver
- Constructed Scaled model of school bus

Investigation:

Measurement in Trade and Technical Fields

1. **Systems of Measurement** - Students will:
    a. Define scale.
    b. Explain how scale allows us to understand the relationship between a representation (a drawing or model) and reality.
    c. Describe the importance of spatial design in understanding real-world problems.
    d. Understand how to scale actual dimensions.

We want to have a model of the bus's interior that fits on the worktable so we can place the elements we want in our tiny home and develop an overall design without having to move the elements in the actual bus itself. Because who wants to move something big around in a tiny home until we find its home? Better to do that on a small scale first.

Using a laser rangefinder and a measuring tape, I measured the actual dimensions of the bus's interior, including length, width, height, window size, etc. Next, I double-checked my measurements, then used them to create a true-size digital version of the bus using AutoCAD, a design app similar to TinkerCAD or Sketchup.

I needed the bus, which is 33' 4" (or 400") long, to fit on the worktable, which is 5' (or 60") long. To do so, I needed to scale the actual dimensions down. How do you do that?

2. **Measuring Scale** - Students will:
    a. Determine the scale factor of an object
    b. Communicate how scaling relates to actual dimensions and model dimensions

c. Understand how scale factor relates to a ratio or fraction

Scaling is converting something to a smaller or larger size while maintaining accurate proportions. To scale something, we want to determine the scale factor, which is essentially the number of times we will increase or decrease the object's size.

If you divide your actual dimension (400") by the known to-scale dimension (60"), you get your scale factor-- The value by which all other actual dimensions can be scaled to get the dimensions for your model. Additionally, you can use the scale factor to scale up any elements' size at the model scale to actual size.

In this case, 400" divided by 60" gives us a scale factor of 6.66 or 6 ⅔. Because we will be using our scale factor a lot, we want it to be easy to use, and 6 ⅔ is not very friendly. So even though that's the largest value we can use for the table (unless we go diagonally), we may want to find a better scale factor to make the scaling process easier.

If we scale 400" down to 50" instead of 60", we get an even scale factor of 8, instead of 6 ⅔. This means all the measurements we take from the bus can be divided by 8 or multiplied by ⅛ to get our to-scale dimensions.

It's important to indicate our scale factor on the project. When we show the scale factor, we can write it as a ratio or a fraction, 1:8 (1 to 8 ratio), or 1/8th scale.

This shows that one unit (in our case, one foot) at the model scale is one-eighth the size of the true scale.

3. **Measuring Dimensions** - Students will:
    a. Determine reference dimensions
    b. Indicate how the scale-model dimensions relate to true-scale.
    c. Create and position design elements based on the scale-model dimensions

Indicating Reference Dimensions
Now that we have our scale-factor determined and indicated on our model, we also want to find an accessible reference dimension to work with to create and position our design elements (like the kitchen, bathroom, pantry, etc.) easily.

It is common on scale models to indicate the actual size one inch represents on our model, so let's figure out how much one inch on our model equals at true-scale.

How would we do that?

Multiply it by the scale factor, which is 8. Therefore, 1” x 8 = 8” at true scale.

What if we want a specific measurement? We want to know how big one actual foot will be on our scale model. First, let's convert 1' to inches (12") because we will be using inches more than feet. Let's scale down our 12" to the model size using our scale factor. 12" divided by 8 (or multiplied by ⅛) = 1.5". So, 1.5" on our model equals 1' at true scale!

We indicate this on our project by writing 1" =8", or 1.5" =1'.

4. **Expanding Understanding of Scale Factor** - Students will:
    a. Apply knowledge to identify alternative ways to set scale factors
    b. Determine how scale factor relates to the purpose of your project
    c. Analyze the ideal scale factor to accomplish work that best meets the needs of your project

Setting The Scale Factor Another Way
Another way to choose the scale factor you use for your model is to determine how much you want 1" to represent at-scale. For example, if you want 1" to equal 1', we know there are 12" in 1', so we can easily divide 12" by a scale factor of 12 to reach 1".

With a scale factor of 12, 1" = 1', what does that make the longest dimension of our model? 400" divided by 12 (or multiplied by 1/12) = 33.3". This is about half the size of the table we have (60") and may be too small to work with.

Your ideal scale factor will be related to the purpose of your project. So if you want something to fit a particular constraint (such as table size), you'll want a specific factor of scale. And if you want a straightforward ratio to work with, like 1" equals 1' or 10' or 1mile, you will want a particular scale factor to meet your needs.

Note about scale notation with anything which may lose its scale.
Be mindful when indicating scale with digital projects because sometimes a printer can unexpectedly shrink or expand a file. If your inch all of a sudden is no longer an inch, your

project is no longer accurately to-scale.

One way to prevent this is to create your own mini-ruler associated with your project, indicating the length of one inch on one side, and the to-scale length on the other. That way, if the project loses its original scale, there's still a point of reference that can be used.

Graph Paper Project

For the graph paper you have, we're going to use a scale factor of 48. That's not a very friendly number to use for scaling, so thankfully, we can also use another measurement. Each square is ¼" wide, and at 1/48th scale, each square equals 1'. That's a bit nicer to use isn't it.

1. Collect toy buses or a smaller scale school bus model. Have enough for each group of students or each student (if they are working independently).
2. Video - Before the activity, have students watch and think about the video - [Our Brains Think About Math Visually - Youcubed].
3. After watching the video, have students work independently or in a group.
4. They will each draw a simplified, three-dimensional model (a rectangular prism) that reflects the model or toy bus. They will identify the length, width, and height of the bus. They will then work together, or independently, to measure each of the length, width, height of the buses and identify those measurements on their drawn model. Make sure the students identify the type of measurement they are taking by, in., ft., cm., or m.
5. After this, students will work together to calculate the volume of the model or toy bus. Give reminders to remember their units.
6. After collecting the measurements and calculating the volume of the model or toy bus. Share the following information with students;
    a. Average length range is 12 - 40 ft.
    b. Average height range is 9.5 - 11 ft.
    c. Average width range is ~ 8 ft.
    d. Then calculate the volume for the smallest and largest buses.
7. After finding the volume of a full size bus, small and large, compare the measurements and volume of the model or toy bus to that of a real bus. Explore the relationships. There is no right or wrong answer. The goal is to explore mathematical relationships.
    a. Can you determine a relationship?
    b. Is the real bus 2x larger, 4x larger, 16x larger, or something else?
    c. Can a ratio or fraction of size be determined if we round our two volumes to the nearest 1, 5, 10, or 100?
8. What else do you notice about the relationship between the measurements and

volumes of a small model and a real-life bus?
9. Have a class discussion, create a poster, create a slideshow, or write a reflection of the questions, measurements, and relationships discovered.

Product or Artifact Possibilities:

- Drawn mini model of bus with measurements and calculations
- Discussion, poster, slideshow or reflection.

Guiding Questions:

1. How do we measure something?
2. How do we calculate volume?
3. How can we compare the sizes of two objects?
4. Do small models have a relationship to their full size counterparts?

What Are We Discovering?

Volume of an object can be found through measuring length, width, and height and multiplying them to determine the cubed volume. Scale models exist in large and small versions. The scale models often have a relationship to one another through ratio and fractions. This relationship can be determined through mathematical investigation.

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