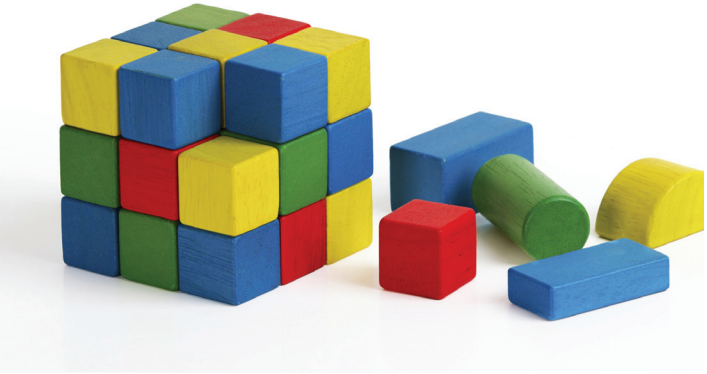
TEACHING PRESCHOOLERS ABOUT SOLID VOLUME

By Sallee Beneke

Measurement helps us determine the size of something. Volume is one of three important areas of measurement, along with length and area (National Research Council, 2009). Volume describes the size of a space. To measure something, the measurer must decide on the unit of measurement. The volume of a space is the quantity of the units it takes to fill the space. Preschoolers typically measure solid space using direct comparison (e.g., "This one holds more") or by using non-standard units (e.g., bristle blocks, unifix cubes, Legos). The National Research Council (2009, p. 204) points out that children learn a subtle but important concept as they measure volume with non-standard units—the larger the unit the child measures with, the smaller the total number of units it will take to measure the volume in a given space. Solid volume can be measured by packing a 3-D space with cubic units. Measuring the volume of a rectangular prism with cubes that can be arranged in rows and layers is perhaps the most effective way of helping young children begin to appreciate that volume can be measured. It provides a foundation for the understanding of the relationship between numbers and geometry. This microteach guide provides an overview of young children's competencies at measuring volume, the developmental continuum for learning about volume, and teaching strategies that can help young children learn about volume.

Preschoolers' Competencies at Measuring Solid Volume

Measuring solid volume rests on several underlying concepts. Prior experiences with measuring area with tiles and composing and decomposing 3-D shapes helps children to understand how those shapes fill a space and how they may fit together within that space. Mastery of cardinality allows children to measure the volume of a space by determining how many 3-D objects fit within that space. Experts in mathematics for young children typically recommend that children first experiment with solid volume using a cube as the unit of measurement to measure the volume of a rectangular box. The shape of the cubes helps children to pack them together closely



face-to-face in rows and columns, therefore providing a more accurate measure of the volume in the container. This practice builds a foundation for later understanding of the shape of a rectangular prism. However, since using cubes to determine the volume of a box requires an understanding of area, length, and height, it is a more challenging task than measuring length or area alone. In other words, children will need to think about two dimensions at once. Piaget theorized that children are not able to classify on more than one dimension until they reach the stage of concrete operations (Trawick-Smith, 2014). Lots of informal, playful, experiences constructing and deconstructing with materials such as unit blocks, magnatiles, and filling and emptying boxes with cubes provide children with a foundation that will help them understand how to truly measure solid volume in the primary years. According to Clements and Sarama (2009), "only a fifth of third graders in one study understood arrays of cubes as consisting of rows and columns in each of several layers" (p. 181).

Experts in the field of early mathematics have described developmental pathways or trajectories for children's understanding of volume that increase in difficulty. As young children learn about volume, their skills "cover a range of difficulty, including perceive, say, describe/discuss, and construct" (National Research Council, 2009). This developmental view of the understanding of volume is summarized in Table 1.

Table 1. Steps/Ages in Learning to Think About Volume*

Steps/Ages	Skill	Related Competencies
STEP 1: Two & Three Year Olds	1.1 Thinking visually/holistically	Identifies capacity or volume as an attribute.
STEP 2: Four & Five Year Olds	2.1 Thinking about parts	Places cubes into a rectangular box to fill it, eventually packs the box with cubes in an organized way.
	2.2 Relating parts and wholes	Compares objects by physically or mentally aligning; refers to at least two dimensions of objects. May be able to compare two containers using a third container and transitive reasoning (e.g., if A holds B, and B holds C, then A must hold C).
STEP 3: Five Year Olds	3.1 Thinking visually/holistically	Partially understands that cubes fill a space.
	3.2 Thinking about parts	Recognizes when a container is half full. Packs box neatly and completely with cubes; may count one cube at a time, while packing, to determine total. Compares objects by physically or mentally aligning and explicitly recognizing three dimensions.
	3.3 Relating parts and wholes	Initially, may count the *faces* of a cube building, possibly double-counting cubes at the corners and usually not counting internal cubes. Eventually counts one cube at a time in carefully structured and guided contexts, such as packing a small box with cubes.

**Adapted from Clements & Sarama (2014); Cross, Woods, & Schweingruber (2009).*

Strategies for Helping Preschoolers Learn About Solid Volume

Engaging young children in the following five mathematical processes helps them develop and communicate their thinking about all areas of mathematics, including measuring volume (National Council of Teachers of Mathematics, 2000). These mathematical processes are: (a) representing, (b) problem solving, (c) reasoning and proof, (d) connecting, and (e) communicating. Educators can teach children to use these five processes to *mathematize* or relate volume concepts to their everyday world. Tables 2 and 3 provide examples of language and materials that teachers can employ to help children use these processes.

Representing. Children may represent their understanding of solid volume in a variety of ways. For example, children might build a rectangular structure with unit blocks and then draw their construction. Or, they might tally the number of cubes it took them to fill a box.

Problem solving. "Problem solving and reasoning are the heart of mathematics" (NAEYC, 2010). Young children learn by engaging with and solving meaningful problems in their everyday environments. Teachers can support children's growing ability to solve problems of solid volume by posing questions that stretch their thinking (e.g., "Do you think you could make your block construction solid? How? Can you show me how to make

Engaging young children in five important mathematical processes helps them develop and communicate their thinking about all areas of mathematics, including geometry

another layer of blocks on top of this one? What do you think will happen if we keep adding layers?"). Meaningful questions help children solve problems related to their everyday world. Teachers who wonder out loud model the disposition to be curious and to apply new knowledge in problem solving about solid volume (e.g., "Wow! This is a big bag of cubes. I wonder how many of these cubes would fit in that box?")

Reasoning and proof. Teachers can challenge preschool children's reasoning by conversing with them about their work with solid volume and asking them to explain the decisions they make as they work with solids (e.g., "Why did you put each of these blocks on top of another? How will you remember how many cubes there are in a layer?"). Pointing to two boxes, the teacher might ask a child, "Which box would hold more cubes?" "What makes you think so?"

Connecting. At the preschool level teachers can help children see the relationship of solid volume to their everyday world. For example, while visiting a construction site, a teacher might point out a large concrete block and say, "I wonder how many of our classroom cubes it would take to make a block this size? Let's measure it and see if we can make one this size."

Communicating. Encouraging children to communicate their thinking by verbalizing, drawing, writing, gesturing, and using concrete objects or symbols can help them share their ideas about volume with other children and adults. As children learn the terminology related to solid volume they are better able to communicate their observations and theories. Useful terms might be "cube," "row," "column," "solid," and "hollow."

Early educators can help children learn to communicate about solid volume by using these terms in the course of everyday activities and by providing the terms and prompting children to use them during teachable moments. In addition, it is important for teachers to provide a risk-free environment where children feel free to share their ideas.

Strategies for Supporting Dual Language Learners

Teachers can support young DLLs in thinking about solid volume by helping them use words in their home language and in English to label volume (e.g., empty/vacío, full/complete, layer/la capa). This process is most effective when the home and English language labels are used as the young DLL plays at emptying and filling containers with solid materials (e.g., cubes, blocks). Picture displays of containers that are in various states of fullness, and are labeled in the young DLL's home language and English, can be very helpful. These visual displays also help the teacher, peers, and family members by reminding them of words to use in describing solid volume. Hand gestures and labels also can be used together to indicate varying levels of fullness (e.g., "I looked in the block box, and it was only filled with one layer of blocks."). While it may be difficult to find books about solid volume in English and another language (i.e., Spanish, French, Chinese), teachers can create their own books using digital media and incorporating the young DLL's home language and English. Additionally, songs with actions can be developed that piggyback on familiar tunes. For further information, see the microteach guide, *Supporting Mathematical Learning of Young Dual Language Learners* (Beneke, 2016).

Table 2. Examples of teacher language that supports children's mathematical processes* with solid volume

Representing
How could you line up the cubes so that there is no space left?
Why did you line the cubes up so that they are close together?
Let's take turns putting cubes in the box!
How many cubes do you think will fit inside this box? Can you draw a picture of it?
Problem-Solving
Can you show me a _____ (e.g., cube, column, row)?
How many cubes (cubes, Legos©, Bristle Blocks©) do you think would fit inside this brick? How could we find out? What if we had a box the same size?
I wonder how we could find out how many cubes (Legos©, Bristle Blocks©) can fit in this box?
How can we figure out if this box will hold more Duplo© Blocks or cubes?
Reasoning & Proof
How do you know how many _____ (cubes, Legos©, Bristle Blocks©) can fit in the box?
What makes you think that X number of _____ (cubes, Legos©, Bristle Blocks©) can fit in the box?
Do you think that the box will hold more Lego© Blocks than Duplo© Blocks? What makes you think so?
Would it make a difference if the box were _____ (longer, taller, wider)?
Connecting
See the foundation of that building? Do you think it is solid or hollow? Why?
Remember how we filled the box so that it was solid? What can you find in our building that is solid?
Let's go on a solid hunt! Can you find solid things in our room? Can you find hollow things in our room?
Communicating
How are things that are solid different from things that are hollow?
What do we need to do to make this box as solid inside as it can get?
Will you choose balls or cubes to fill your box? Why? Which one will fill the box so that it has fewer empty spaces?
I wonder how you are going to fill that box.
Why do you think this block is hollow and this one is solid?

**Mathematical processes described by the National Research Council (2009).*

Table 3. Examples of useful materials for teaching and learning about measuring solids in preschool

Blocks
Unit blocks
Brick, Blocks, and Rock Builders©
Hollow cardboard blocks
Hollow wooden blocks
Table Toys
Magnatiles©
LEGO© and DUPLO© blocks
Wooden cubes
Miscellaneous toys that can be used to fill boxes (e.g., small balls, bristle blocks)
Books
Construction by Brian Lovelock
What is Volume? by Lisa Trumbauer
Block City by Robert Louis Stevenson
When I Build With Blocks by Nikki Alling
Cube by Jennifer Boothroyd
Brick by Brick by Charles R Smith Jr.
The LEGO Ideas Book by Daniel Lipkowitz

Instructions for Doing the Microteach

1. This microteach is to take place with a group of at least 3 children, ideally of diverse abilities.

2. Assess the children in advance to determine what step they are on, on the pathway for mastery of understanding solid volume (see Table 1).

3. Select one mathematical process you will emphasize in your lesson (i.e., communicating, connecting, reasoning and proof, problem-solving, or representing).

4. Use the *Lesson Plan Template* to plan a lesson on solid volume that will support the learning of the children you will be teaching. Consider how you will individualize for the children in your small group.

5. Videotape yourself implementing the lesson with the children.

6. Follow the *Procedure for Microteach* handout.

References

Clements, D. H., & Sarama, J. (2014). *Learning and teaching early math: The learning trajectory approach, 2nd ed.* New York, NY: Routledge.

National Association for the Education of Young Children & National Council of Teachers of Mathematics (2010). *Early childhood mathematics: Promoting good beginnings*, Washington, DC: National Association for the Education of Young Children.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics.* Retson, VA: Author.

National Research CouncilCross. (2009). *Mathematics learning in early childhood: Paths toward excellence and equity.* Committee on Early Childhood Mathematics, Cristopher T. Cross, Taniesha A.Woods, & Heidi Schweingruber (Eds.).Washington, DC: The National Academies Press.

Trawick-Smith, J. (2014). *Early childhood development: A multicultural perspective, 6th edition.* Boston, MA: Pearson.