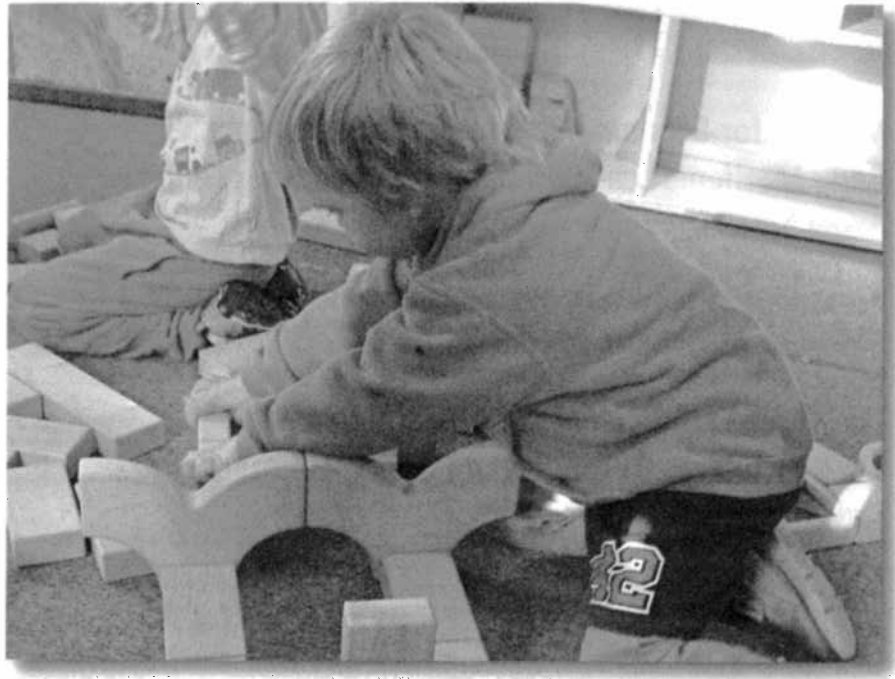


Math Is for Everyone: Strategies for Supporting Early Mathematical Competencies in Young Children



Brady and his classmates hear the teacher giving them a warning: "Five minutes until clean-up time." Next, the children settle in for circle time. Yesterday, the teacher had shown the children a huge map of the city. The map included familiar landmarks the children had identified (e.g., school, library, the movie theater, parks, the river). Today, the children have brought in photos of their homes. They watch as the teacher writes the house numbers and street names on each

of the photos and places them on the map. The children look at the map and talk about landmarks and routes from their home to the school. The children comment on who lives near school and who lives far away. Brady points out that a few people live next to the water but that most people do not. After circle time, the group heads to the playground. Before starting to play, the teacher reminds them of the rule: No more than four children in the rocking boat at a time.

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Quality instruction in early mathematics is particularly critical for children with disabilities.
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Learning about mathematics begins in the early years. Through their everyday activities, young children build important foundational knowledge and understanding of mathematics, especially when adults provide specific opportunities to learn and practice concepts and skills. In the vignette above, for example, Brady's teacher shows children how numbers can be used for a variety of purposes: to define a time period before clean-up, to identify children's houses, and to create rules for using outdoor equipment. She also guides children's discussion about the city map to teach spatial concepts of distance (*near, far away*) and location (*next to*) as well as numerical concepts such as *few* and *most*.

Recently, the National Association for the Education of Young Children (NAEYC) and National Council of Teachers of Mathematics (NCTM) brought attention to research indicating that young children are capable of understanding much more about number and spatial concepts than commonly thought possible (Baroody, 2004; NAEYC & NCTM, 2002). Young children develop early on an informal understanding of important mathematical concepts about quantity, logical relationships, number operations, shapes, and space. Children can, however, acquire much deeper and more explicit knowledge if they are provided with high-quality mathematics education during preschool that will prepare them for more formal mathematics instruction in the later grades (NAEYC & NCTM, 2002). Quality instruction in early mathematics is

particularly critical for children with disabilities, such as cognitive delays, attention problems, and listening comprehension difficulties (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Dowker, 2005), as well as for those who are at high risk for later problems in school. In response to the Good Start Grow Smart federal initiative launched in 2002, states have developed early learning guidelines that include standards and outcomes for literacy, language, and mathematics for children ages 3 to 5 years. Early childhood and early childhood special education (EC/ECSE) publications have focused much attention on early literacy and language in the past few years. Teachers have, however, received less information on early mathematics. In this article, we describe current information on the development of early mathematical knowledge and offer suggestions for how EC/ECSE teachers can support mathematical learning in preschool children.

What Are Early Mathematical Competencies for Preschoolers?

Mathematics is the study of quantities and their relationships. It includes five components: numbers and operations, geometry, measurement, algebra, and data analysis (NCTM, 2006). Skills in these areas develop simultaneously, are interrelated, and build on early cognitive, linguistic, and social foundations (Copley, 2000; NAEYC & NCTM, 2002). One of the goals for the preschool years is to build

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“Preschool block play has been found to be significantly related to math performance in junior high and high school.”

broad mathematical understanding focused primarily on numbers and operations, geometry and spatial sense, and measurement, with algebra and data analysis playing supporting roles (Clements, 2004; NAEYC & NCTM, 2002).

Numbers and Operations

Numbers and operations are used for counting, adding, and subtracting. Young children learn about numbers and operations as they help set the table and pass out one glass for each person, count how many cookies are on the plate, then eat one and count how many are left. Many preschoolers can count eight or more objects accurately, place objects in one-to-one correspondence to establish equivalent sets, and identify the result of adding or subtracting by 1 (Baroody & Wilkins, 2004; Dowker, 2005; Kamii, 1986).

Geometry and Spatial Sense

Geometry describes the shapes of objects and their relative positions in the environment. Spatial abilities and math are closely related (Clements, 1999). Interestingly, preschool block play has been found to be significantly related to math performance in junior high and high school (Wolfgang, Stannard, & Jones, 2001).

Shapes. Young children explore and manipulate 2- and 3-dimensional objects in their environment and learn that the shape of an object remains the same even though it looks different when viewed from different perspectives.

They learn about different shapes as they describe everyday objects in their environment (e.g., a round pizza, a curved line, a sharp corner), draw or cut out shapes, and build objects with blocks (Hanline, Milton, & Phelps, 2001).

Spatial sense. Spatial sense involves knowing the shape of one's environment and learning about the properties and relations of objects in space (Clements, 2004). Gross motor activities and block constructions help children learn spatial concepts about location (Where?), distance (How far?), and direction (Which way?) (Hanline et al., 2001). Preschoolers can recognize familiar landscapes, build simple maps with toys and blocks, and develop an initial understanding of how maps represent space (Clements, 1999; Golbeck, 2005).

Measurement

Measurement is the application of mathematics to real-life tasks. It involves using numbers to describe dimensions, weights, volumes, and time. Children learn to identify and compare sizes and to develop the understanding that measurement is based on using equal-size units that are repeated and counted.

Describing physical properties. Measurement concepts are used to describe physical properties of objects such as their width, length, weight, area, and volume. Adults can provide children opportunities to learn about physical properties of objects and make comparisons (Which one is taller? Which one has more?).



Using measuring tools. Children should become familiar with conventional measuring tools, how to use them, and their functions: rulers, scales, measuring cups, thermometers, and clocks. Adults should also provide experiences using unconventional units, such as blocks, Unifix cubes, paperclips, footsteps, hands, and containers to measure and compare objects (Golbeck, 2005).

Algebra

Patterns, equality, and change are important algebraic concepts that are part of children's daily lives (Taylor-Cox, 2003). Patterns are arrangements of objects, numbers, shapes, colors, sounds, and movements characterized by repetitions and sequences

(Copley, 2000). Identifying patterns on borders of placemats, for example, helps children learn to make predictions as well as generalizations. Experimenting with a pan balance scale while playing grocery store can help children develop an understanding of equality and how to make things equal. Collecting data over time, such as the height of growing plants, offers opportunities for children to observe and describe change.

Data Analysis

Data analysis is about organizing and representing information, then using it to ask and answer questions (Whitin, 1997). For preschool children, organizing information begins with learning about categories and sorting objects according to specific attributes (e.g., color, size, and shape). They can also learn different ways of representing information with drawings and simple graphs (e.g., counting and graphing children's votes on a favorite pet). Table 1 provides an overview of key preschool mathematical competencies across the five areas.

What About Children at Risk and With Disabilities?

Early mathematics intervention studies conducted with preschool children at risk (e.g., Arnold, Fisher, Doctoroff, & Dobbs, 2002; Griffin, 2004; Starkey, Klein, & Wakeley, 2004) have shown that children who participated in the interventions made significant gains

Table 1
Early Mathematical Competencies for Preschool

Component	Key Competencies for Preschool
Numbers and operations	<i>One-to-one correspondence:</i> The understanding that one can assign only one number to an object <i>Order:</i> The counting words are always said in a specific order <i>Cardinal principle:</i> The final number or last word counted represents the size of the entire set <i>Ordinal principle:</i> Numbers are determined by their relationship to each other (e.g., smaller numbers are contained in larger numbers)
Geometrical concepts	<i>Shapes:</i> Names of 2-D objects (circle, triangle, square, rectangle, diamond, star), specific features (straight lines, curves, corners, points), names of 3-D objects (cubes, pyramids, cones, cylinders) <i>Spatial reasoning:</i> Location (Where?), distance (How far?), direction (Which way?)
Measurement	<i>Describing physical properties:</i> Length, weight, area, volume, capacity <i>Using measurement tools:</i> Conventional tools, unconventional units
Algebra	<i>Patterns:</i> Visual (colors, shapes), movement, sounds, events in time <i>Equality:</i> Concepts of equal-not equal or same-different, making equal through balancing <i>Change:</i> Noticing and describing change
Data analysis	<i>Organizing information:</i> Sorting by size, color, shapes, and categories <i>Representing information:</i> Drawings, tallies, graphs

on measures of mathematical knowledge when compared to children in control groups. These interventions integrated the teaching of mathematical concepts into daily activities with books, music, games, discussions, and group projects. Some of these interventions have been developed into published curricula: *Big Math for Little Kids* (Greenes, Balfanz, & Ginsburg, 2003), *Number Worlds* (SRA/McGraw Hill, 2006), and *Pre-K Mathematics* (Klein, Starkey, & Ramirez, 2002). *Big Math for Little Kids* uses a storybook format and places heavy emphasis on the communication aspects of math. One of the unique features of *Number Worlds* is how it familiarizes children with number lines, and another is how it introduces both addition and subtraction with characters (“Plus Pup” and “Minus Mouse”). *Pre-K Mathematics* is a wrap-around curriculum with activities for small groups, a math center, and the

computer and activities for parents to do in the home. Two research studies (Aunio, Hautamaki, & Van Luit, 2005; Van Luit & Shopman, 2000) focused on 4- to 7-year-olds with disabilities. The interventions focused on teaching cognitive skills (e.g., classification, causality, spatial perception) and numeracy using both concrete objects and semiconcrete representations (pictures and symbols) during pullout small-group activities. Immediately following the intervention, participating children demonstrated better number sense than control children. This advantage, however, did not continue after the intervention ended, nor did the new skills and knowledge generalize to other contexts. These findings led the researchers to recommend that for children with disabilities, longer and more intensive interventions needed to be implemented across daily activities and environments, including the home.

Young children learn best in the context of intentionally organized learning experiences that build on their natural interest in mathematics and the physical world (Baroody, 1987; Greenes, Ginsburg, & Balfanz, 2004; NAEYC & NCTM, 2002). Teachers can support *all* children’s learning of mathematics by (a) designing environments that promote experimentation and social interaction; (b) purposefully embedding mathematical concepts into daily activities and routines; (c) intentionally using teaching strategies to address children’s individual interests, needs, and ability levels; and (d) using ongoing assessment to inform instruction. It is also important for teachers to be aware of how mathematics is used in children’s home environments. Cultural variations in children’s informal participation in activities such as counting, handling money, singing songs and reading books

with counting words, playing board games with dice, watching educational television programs, and using measuring tools may affect children’s familiarity with and learning of mathematical concepts in school (Gubermann, 1999).

Experimentation and Social Interaction

Environments and activities that involve active experimentation and social interaction help children develop important foundational skills, such as logical reasoning and problem solving, use of symbols, and social communication (NCTM, 2006). Adults can support the development of logical reasoning skills by helping children make connections among events (“What happened when you took one away?”). Adults can help children develop good problem-solving skills by providing opportunities for children to identify and apply strategies to find solutions to problems (e.g., “We need enough chairs for everyone.” “Find the lid that fits on this container box.”).

Young children need to become familiar with different ways to show symbolic representations (e.g., drawings, numbers, words, graphs, tables, and maps) for mathematical concepts and relationships (Golbeck, 2005; Greenes, 1999). Adults can show children various symbols and explain how there are different ways of saying the same thing. The quantity 2, for example, can be represented by two dots on a domino, two tally marks on paper, two fingers, and the numeric symbol 2.

The more preschool teachers talk with children about math, the more math children will learn



Table 2
Early Math Lesson Plan: Learning About Fish

Where and When	Activities and Materials	Early Math Goals	Instructional Strategies	Adaptations
Large group	<ul style="list-style-type: none">• <i>Fish Eyes</i>, by Lois Ehlert• Counting song (to the tune of "Row Your Boat"): Catch, catch, catch a fish/ Hook it on your line/ Reel it, reel it, reel it in/ This one will be mine.• Flannel board, five fish	<ul style="list-style-type: none">• Numbers and operations: counting up to 5 or 10, cardinal principle (saying last number to answer how many), adding by 1	<ul style="list-style-type: none">• Model verbal counting sequence: Explain, "The last number you said tells how many fish there are." Ask, "If we see one more fish on the next page, how many will there be?"	<ul style="list-style-type: none">• Call on some children to count smaller numbers (e.g., 3)
Dramatic play	<ul style="list-style-type: none">• Large rocking boat• Magnetic blocks ("fish")• Magnetic fishing poles• Four buckets or baskets	<ul style="list-style-type: none">• Numbers and operations: counting up to 10, cardinal principle	<ul style="list-style-type: none">• Remind children to say only one number for each fish	<ul style="list-style-type: none">• Use visuals and manipulatives (fingers, blocks)• Modify counting motion from pointing to dropping objects
Art	<ul style="list-style-type: none">• Sheets of blue paper (water)• Paper ovals and triangles• Hole reinforcement stickers (eyes), glue, glitter, markers	<ul style="list-style-type: none">• Geometry and spatial sense: recognizing and naming common shapes	<ul style="list-style-type: none">• Ask children to label and describe shapes and attributes	<ul style="list-style-type: none">• Model vocabulary of shape names and attributes• Provide models of ways to make fish with shapes
Snack	<ul style="list-style-type: none">• Colored fish crackers	<ul style="list-style-type: none">• Data analysis: sorting objects according to color• Numbers and operations: counting up to 10, comparing• Possible extension to graphing	<ul style="list-style-type: none">• Ask children to describe fish• Ask children to sort crackers• Ask questions: "How many?" "Which has more?"• If children are interested, record findings and compare findings to other snack tables	<ul style="list-style-type: none">• Model sorting by color• Model how to put crackers in rows to count and compare which has more



rulers for children to mark off the inches before counting), incorporating favorite objects and fun activities (e.g., using rhymes and caricatures to help children recall numerals, guessing shapes drawn on their backs), and simplifying a task (e.g., having children count moveable items and push each counted item aside, providing patterns to match by laying materials on top of outlines, or teaching perspective by matching photographs with viewpoints). Ms. Halpert, for example, modified the task for Alicia to make it easier for her to count by having her drop the fish into a bucket.

Naturalistic teaching. Naturalistic teaching refers to instruction of functional skills during everyday activities and routines, building on what the child is interested in, and using natural reinforcers and consequences to support the child's learning of new behaviors (Rule, Losardo, Dinnebeil, Kaiser, & Rowland, 1998). Adults use specific strategies that include following the child's lead, modeling, and using explicit prompts. For example, teachers may want to use more systematic instruction to extend the single prototype approach for teaching shapes by showing many examples of a shape during play in the table toy area, or to model the uses of maps while building a city in the block area. In the vignette, Ms. Halpert provided modeling and specific directions to help Alicia count more systematically in the context of dramatic play. Table 3 describes more examples of intentional teaching strategies for developing mathematical concepts with children who have disabilities.

count and figure out which number comes after." In the vignette, Ms. Halpert used many different types of scaffolding. She helps children better understand the cardinality principle by explicitly stating rules and connections. She asks open-ended questions to encourage children to compare quantities of red fish crackers at different snack tables. She provided language models for Jose at the art table.

Curriculum modifications. Modifications to classroom activities, routines, and learning areas allow teachers to tailor the curriculum to children's individual needs (Sandall & Schwartz, 2002). This can be done by modifying materials (e.g., using shape blocks with rubber mats so designs stay put, using paper with a grid to make graphing easier, or using paper with

child learn new skills. As the child's competence increases, the adult decreases assistance, allowing the child to work more independently. Scaffolding includes a broad variety of strategies (Notari-Syverson, O'Connor, & Vadasy, 1998). Teachers can use *open-ended questions* to help children solve measurement problems (e.g., "Who can reach this bar?" "How can we

find out if the trike will fit through the doorway?"). They can make things *more concrete* by providing visual support for counting with a number line, have children touch objects as they count, or use models of real objects to make maps. They can also provide explicit directions: "It is important to say the numbers in the same order every time." "To find out which number is bigger,

Table 3
Examples of Intentional Teaching Strategies for Teaching Early Mathematical Concepts

Instructional Strategy	Mathematical Area				
	Numbers and Operations	Geometry: Shapes and Space	Measurement	Algebra: Patterns, Equality, and Change	Data Analysis: Organizing and Representing Information
Ask guiding questions	"Do we have enough for everyone? How many more do we need?"	"How could we make a map of our block city?"	"How can we make sure your parents buy the right length of ribbon?"	"What's different? What made it change?" "How can we make the scale balance?"	"How do we know that more children like apples than pears?"
Explain rules	"You have to say the numbers in the same order every time."	"Maps usually have a special color to show the roads."	"When we use a ruler, we have to line up the zero point at the beginning of what we're measuring."	"Look for things that happen over and over again. Then think of what might happen next."	"We need to put together things that go together."
Make more concrete (Provide visuals or manipulatives)	Show the child the finger pattern when asking him or her to take a certain amount of objects.	Provide the child with sticks and show him or her how to make a triangle. Explain how it is closed and has three sides.	Cut strips of adding-machine tape for children's height instead of making a horizontal mark on the wall.	Use musical activities and games where children can experience patterns in body movements and sounds.	Use blocks to represent votes. Have children use their blocks to build a line or tower.
Simplify task/ Break skill down into parts	Teach rote counting before teaching children to count sets of objects.	Before teaching shape names, teach the terms <i>open</i> , <i>closed</i> , <i>side</i> , <i>straight</i> , <i>curved</i> .	Model vocabulary to describe pairs of things that are identical except for height or length.	Use simple alternating patterns (e.g., red, blue, red, blue) or things that come in pairs.	Have children cast yes-no votes or make a choice between two things (e.g., "Do you have a pet in your house?").
Adapt or modify materials (special equipment)	Have children slide poker chips off a piece of paper as they count.	Provide nonskid mats as a surface for making designs with shape blocks.	Measure things with 1-inch cubes rather than rulers.	Use easy to manipulate cutouts, tiles, or pattern blocks.	Make a large graph out of white vinyl with black tape lines for graphing real objects.
Use child preferences	Create a counting activity related to a child's favorite storybook.	Explore shapes through foods served at snack time.	Help children measure each other's heads before cutting paper crowns.	Make patterns out of things of interest such as dinosaurs and cars instead of colors and shapes.	Build on children's interests to encourage them to "collect data."
Model	Show a set of items, and ask children to take the same amount.	Provide many positive and negative examples of a shape. For example, do not just show equilateral triangles.	Model how to make a direct comparison. "My beads are as long as my arm."	Provide pattern models for children to copy. (Duplication is easier than pattern extension.)	Display examples of simple graphs.
Use explicit prompts	Teach the child to repeat the last number when he or she counts with a hands-out gesture. Prompt with this gesture.	Teach a song about each shape. Hum it if children need a prompt to help them recall a shape's attributes.	Provide directions for using measurement tools (e.g., "Put the first cube here at the beginning of what we're measuring.").	"Read" the pattern to the child to provide a running start, pausing at the end.	Provide visual or verbal cues to help children group objects into correct piles.

Table 4
Resources for Teachers

Copley, J. (2000). *The young child and mathematics*. Washington, DC: National Association for the Education of Young Children/National Council of Teachers of Mathematics.

Copley, J. V. (2004). *Showcasing mathematics for the young child: Activities for three-, four- and five-year-olds*. Reston, VA: National Council of Teachers of Mathematics.

Copley, J. V., Jones, C., & Dighe, J. (2007). *Mathematics: The creative curriculum approach*. Washington, DC: Teaching Strategies.

Epstein A. S., & Gainsley, S. (2005) *I'm older than you. I'm five! Math in the preschool classroom*. Ypsilanti, MI: High/Scope.

Mooma, S., & Hieronymus, B. (1999). *Much more than counting: More math activities for preschool and kindergarten*. St. Paul, MN: Redleaf.

Table 4 presents several resources for teachers.

Using Ongoing Assessment to Support Children's Learning

Assessment is an integral part of all early childhood and early intervention programs. It is important that educators conduct assessments to (a) identify children's strengths and needs across developmental areas, (b) develop Individualized Education Plans, (c) plan curriculum and instruction, and (d) monitor children's learning over time (Cook, 2004; Losardo & Notari-Syverson, 2001). Teachers can use various methods to assess children's early mathematical skills, including structured in-depth observations, checklists, anecdotal notes, children's work samples, frequency counts, and time sampling. Many curriculum-based assessments include items that address early mathematical skills. Two examples are the *Assessment, Evaluation and Programming System for Infants and Children* (Bricker, 2002) and the *Preschool Child Observation Record* (2nd ed.; High/Scope Educational Research Foundation, 2003).

Conclusion

All children, including children with disabilities, can participate in mathematical activities and learn important early mathematical concepts and skills. Recent research has shown us that young children are capable of understanding much more about mathematics than commonly thought. Keeping math fun, and increasing the number and variety of math activities (at least one to three activities completed each day), can help preschool children make significant gains in math and even helps teachers feel more enjoyment and competence in teaching math (Arnold et al., 2002). Providing children opportunities for experimentation and practice in the context of responsive adult-child interactions is also important. Preschool teachers who talk frequently with children about mathematical concepts during daily activities help children develop better mathematical knowledge (Klibanoff et al., 2006).

It is essential that all preschool children be provided a high-quality mathematics education that will prepare them for more formal mathematics instruction in the later

grades. Preschool environments and classroom activities offer many opportunities for children to learn mathematical concepts while also developing social and early literacy skills. Educators can support children's learning by using a variety of instructional strategies individualized to each child and by embedding mathematical talk and teaching across multiple activities and environments.

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