Citation Information:

JOURNAL: Children of 2020 ; creating a better tomorrow /
Imprint: Washington, D.C. ; Council for Professio

VOLUME: **ISSUE:**
YEAR: 2010 **MONTH:**

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ARTICLE: The mathematical lives of young children

PAGES: 81-84

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The Mathematical Lives of Young Children

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Julie Sarama and Douglas H. Clements

Three pictures hang in front of a 4-month-old girl. The first shows two circles, the others one circle and three circles. The infant hears two sounds. Her eyes move to the picture with two circles.

At some intuitive level, this infant has recognized number and has translated number from one sensory input, sound, to another, sight. There is no age too young for mathematical thought. Children often know, or can learn, far more than most curriculum developers or teachers have believed. Babies are sensitive to number and shape. Most 2-year-olds can name the number of objects in small collections (one to three) and many can count them. Three-year-olds can do simple addition in playful contexts with objects. Preschoolers know a surprising amount about shapes and the geometry of navigation — getting around in the world. Most entering kindergartners can count, recognize some shapes, make patterns, and use nonstandard units of measurement.

The early years are a critical period for learning math. Children's knowledge of math in these years predicts their mathematics achievement for years later, even into high school, just as their early literacy predicts their later achievement in reading. That makes sense, but it is interesting that early literacy predicts later achievement in reading only. Children's early knowledge of math predicts not only later math achievement, but also later reading achievement. Thus, it appears that math is a core component of cognition. Math is knowledge of quantity, number, and space, of course, but it is also a basic way of thinking.

Therefore, learning math early is important for all children. Especially important is math for children from low-resource communities, who often have not had high-quality learning opportunities.

What can we do to change the future of young children's mathematics in positive ways? First, we could recognize that too many curricula and programs teach too much of what children already know. Many programs teach the names of basic shapes, presented only in typical ways. But many children already know these shapes. Programs seldom build upon this knowledge. When they attempt to add knowledge, it is often mathematically incorrect, such as "every time you cut a square, it makes two triangles."

Instead, programs can build on the creativity and mathematics capacities of young children. After using the Building Blocks[64] preschool curriculum, one group of 4-year-olds was trying to fill a long rectangular puzzle with triangles (Figure 1a). Cory found an elegant strategy. He put four triangles together to make squares and repeated the arrangement to fill the rectangle.

Although using a pattern to solve the problem isn't highly unusual, he understood the four triangles to be a new mathematical unit created

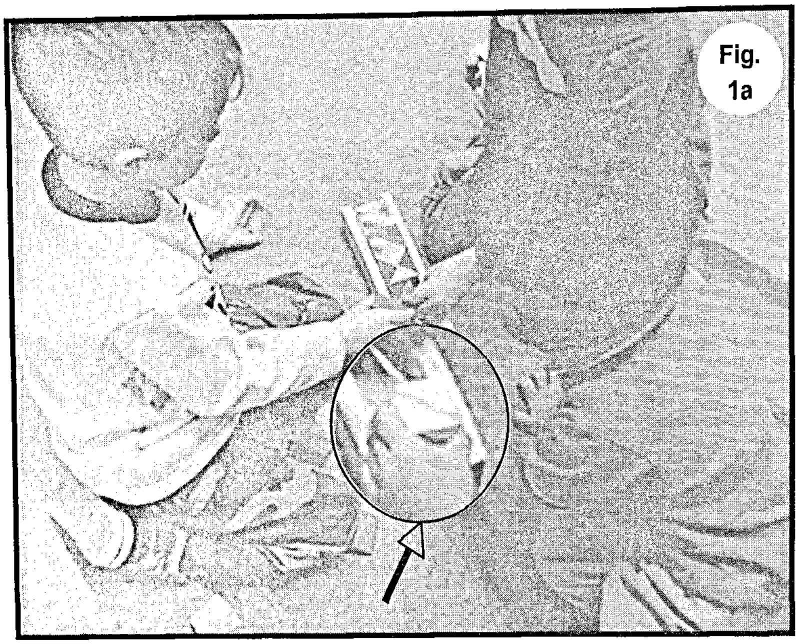

Fig. 1a

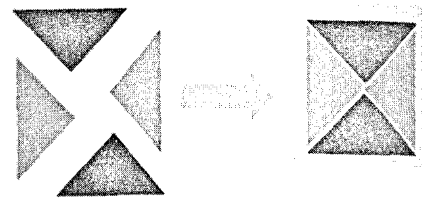

Fig. 1b

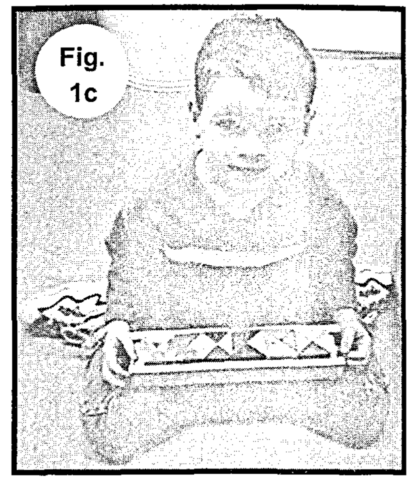

Fig. 1c

out of smaller units (Figure 1b). Another boy saw the square structure and tried to use the idea, but he built the wrong square, using only two triangles (see the two yellow triangles the boy in the lower right is holding in Figure 1a). It is commendable that he noticed Cory's structure, and more so that, when his square didn't fit, he looked again and used four triangles.

When the boys finished, they showed their teacher (Figure 1c), who asked, "How many triangles did you use?"

Cory counted them by ones: "24"

Teacher: "24 what?"

Cory: "Triangles."

Teacher: "How many squares do you have?"

One of his friends put up four fingers on the four triangles in each new unit and counted them: "6!"

The teacher provided good materials and followed up with a short but rich discussion. Unfortunately, such good instruction is limited. Preschoolers often see little or no math. Kindergartners and primary grade students engage in math far less than they do in literacy. We can and must do better. Especially for children from low-resource communities, high-quality education results in learning benefits into elementary school.

The importance of learning trajectories

Research has provided a powerful tool that educators can use to improve the learning and teaching of math: learning trajectories. Children generally follow natural developmental paths in learning mathematics. When teachers understand these paths, and sequences activities based on them, powerful mathematics learning environments can be built.

Learning trajectories have three parts: a mathematical goal, a developmental path along which children develop to reach that goal, and a set of instructional activities, or tasks, linked to each of the levels of thinking in that path that help children develop higher levels of thinking.

Goals: big ideas of math. The first part of a learning trajectory is a goal. Goals should include the big ideas of mathematics — clusters of concepts and skills that are central and coherent, consistent with children's thinking, and generative of future learning. These big ideas have been described in the National Council of Teachers of Mathematics' *Curriculum Focal Points*[65] and the National Research Council's *Mathematics Learning in Early Childhood: Paths*

Toward Excellence and Equity.[66] For example, one goal is to be able to count objects and solve problems using counting.

Development progressions: paths of learning. Developmental progressions consist of levels of thinking that lead to the mathematical goal. The developmental progression is a typical path children follow in achieving the goal. For example, we know that young children first learn the verbal number sequence, then how to keep one-to-one correspondence between counting words and objects, and then to understand the cardinality principle — that the last number word tells "how many."

Instructional tasks: paths of teaching. The third and last part of a learning trajectory is a set of instructional tasks, linked to each of the levels of thinking in the developmental progression. These tasks are designed to help children learn the ideas and skills needed to achieve that level of thinking. That is, educators can use these tasks to promote children's growth from one level to the next. For example, simple counting finger plays and songs — if children string the number words together without interruption — can help children to develop verbal counting. But more attention must be given to developing children's skills with one-to-one correspondence, such as the activity count and move, in which children count from 1 to 10 or an appropriate number, making motions with each count. For example, say "one" (touch head), "two" (touch shoulders), "three" (touch head), and so forth.

Teachers also need to carefully monitor individual children's counting, perhaps in small group lessons, making sure they adapt activities as they develop. Teachers need to check for different stages of development by altering the size of the sets being counted and emphasizing cardinality. Computers can also help (Figure 2). Activities and games can be chosen for individual students to best meet their goals. Games are important here because the goal, and how counting achieves the goal, can be clear and important to children (Figure 3).

Learning trajectories can help educators forge paths to future success in early mathematics

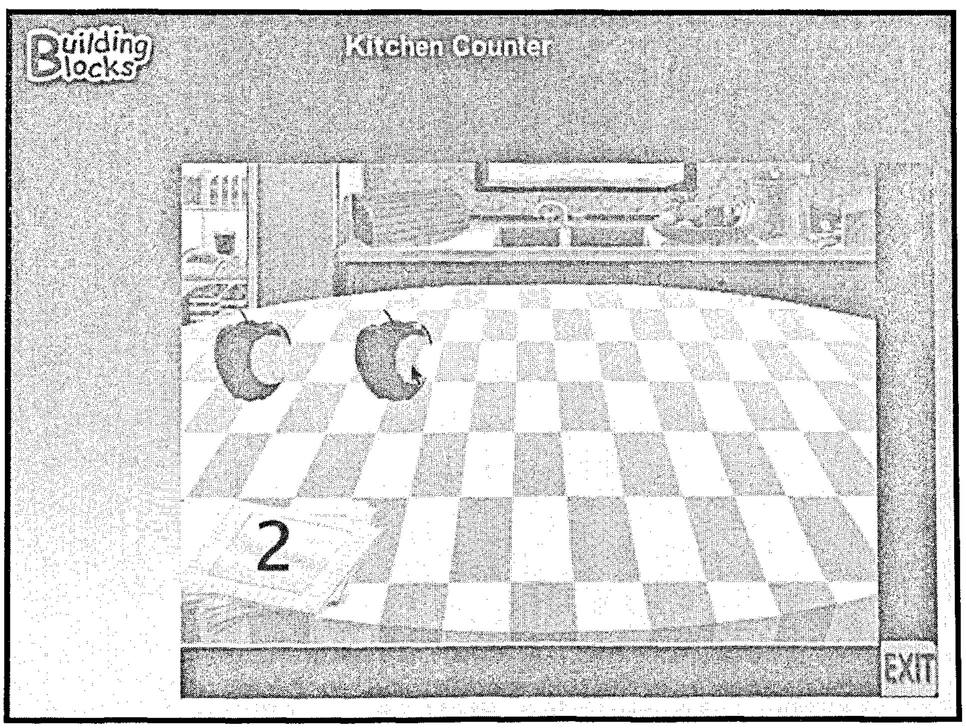

Figure 2. In the Building Blocks computer activity Kitchen Counter, children click on objects one at a time while the numbers from 1 to 10 are counted aloud. For example, they click on pieces of food, and a bite is taken out of each as it is counted.

Figure 3. Children play the Building Blocks activity Pizza Game 1 in pairs. Player one rolls a number cube and puts that many toppings (counters) on his/her plate. Player one asks player two, "Am I right?" Player two must agree that player one is correct. At that point, player one moves the counters to the circular spaces for toppings on his/her pizza. Players take turns until all the spaces on their pizzas have toppings.

education. Several randomized field trial studies have shown that curricula and professional development based on the Building Blocks learning trajectories increased children's achievement more than those that do not.

More importantly, children were able to demonstrate higher levels of mathematical reasoning in the context of developmentally appropriate activities. For example, two children were playing Pizza Game 1, with a number cube that has only 1s, 2s, and 3s on the faces. Carmen had almost filled her pretend pizzas with toppings. As she got ready to roll the number cube, she said, "I'm going to get a high number and win!" "You can't," replied her friend. "You have 4 spaces and the number cube only has 1s, 2s, and 3s on it."

Quite young children can reason logically, and mathematics is a superb context for such thinking. This is one reason why math is a core component of learning and thinking.[67] ▶

Hope for the children of 2020

That the children of 2020 are provided the chance to have rich, engaging, opportunities to learn how to make sense of their world by seeing it through mathematical lenses.

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Professional focus

Sarama and Clements conduct research on the early development of mathematical ideas and the scaling up of effective interventions.