Math in the early years

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Math in the Early Years

A Strong Predictor for Later School Success

The earliest years of a child's education—from birth through 3rd grade—set the foundation upon which future learning is built. In recent years, state policymakers have emphasized the need to improve children's reading skills early on because a lack in this essential skill is a strong predictor of low student performance and increased high school dropout rates. By 2012, a total of 32 states plus the District of Columbia had policies in statute aimed at improving 3rd-grade literacy, with 14 of those states requiring retention of students on the basis of reading proficiency. While the emphasis on reading proficiency is critical, research shows that the development of mathematics skills early on may be an even greater predictor of later school success. Early knowledge of math not only predicts later success in math, but also predicts later reading achievement even better than early reading skills.

Young children have a surprising capacity to learn substantial mathematics, but most children in the U.S. have a discouraging lack of opportunities to do so. Too many children not only start behind, but they also begin a negative and immutable trajectory in mathematics, with insidious long-term effects. These negative effects are in one of the most important subjects of academic life and also affect children's overall life course.

What's Inside

The good news is that programs and curricula designed to facilitate mathematical learning from the earlier years, continued through elementary school, have a strong positive effect on these children's lives for many years thereafter. Starting early—in preschool—with high-quality mathematics education, creates an opportunity for substantial mathematical learning in the primary years that builds on these foundational competencies.

This issue of *The Progress of Education Reform* reveals five surprising findings about the importance of early math learning, and provides implications and recommendations for state policy.

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Surprising Research Findings

Surprise 1: There is predictive power in early mathematics

Mathematical thinking is cognitively foundational[1], and children's early knowledge of math strongly predicts their later success in math.[2] More surprising is that preschool mathematics knowledge predicts achievement even into high school.[3] Most surprising is that it also predicts later reading achievement even better than early reading skills.[4] In fact, research shows that doing more mathematics increases oral language abilities, even when measured during the following school year. These include vocabulary, inference, independence, and grammatical complexity.[5] Given the importance of mathematics to academic success in all subjects[6], all children need a robust knowledge of mathematics in their earliest years.

> *Before her 4th birthday, Abby was given five train engines. She walked in one day with three of them. Her father said, "Where's the other ones?" "I lost them," she admitted. "How many are missing?" he asked. "I have one, two, three. So [pointing in the air] fooooour, fiiiive ... two are missing, four and five. [pause] No! I want these to be [pointing at the three engines] one, three, and five. So, two and four are missing. Still two missing, but they're numbers two and four." Abby thought about counting and numbers—at least small numbers—abstractly. She could assign one, two, and three to the three engines, or one, three, and five! Moreover, she could count the numbers. That is, she applied counting ... to counting numbers!*

Surprise 2: Given opportunities to learn, young children possess an informal knowledge of mathematics that is amazingly broad, complex, and sophisticated[7]

When children 'play,' they are often doing much more than that. Preschoolers can learn to invent solutions to solve simple arithmetic problems, and almost all of them engage in substantial amounts of pre-mathematical activity in their free play.[8] In fact, early childhood programs that include more mathematics have increased higher-level free play, all of which promotes self-regulation and executive function. Through higher-level play, children explore patterns, shapes, and spatial relations; compare magnitudes; and count objects. Importantly, this is shown to be true regardless of the children's income level or gender.[9] These explorations through play are pre-mathimatical. It is high-quality education that can help all children utilize their inherent skills in order to truly mathematize.[10] However, if high-quality mathematics education does not start in preschool and continue through the early years, most children are trapped in a trajectory of failure.[11]

Surprise 3: Teachers vastly underestimate what their children know and can learn[12]

In numerous countries, professionals in multiple educational roles vastly underestimate beginning students' abilities.[13] One study showed that groups of teachers, teacher trainers, and counselors who worked with preschoolers underestimated the mathematical competencies of these very same students when they entered kindergarten.[14] For example, more than 80% of the students could count out nine marbles, but the adults' estimates were from 20% to 50%. More than 40% of the students could subtract 10 – 8 without objects, but all adults estimated less than 10%. If teachers and those who work with teachers underestimate what students already know and can learn, they will not present appropriate, challenging mathematics activities.

Surprise 4: All students need a math intervention

Most children benefit from a math intervention.[15] As W. Steven Barnett and others' research has shown, it is not just the poorest children who need interventions.[16] When they enter kindergarten, most children are behind their peers from the best-funded communities. That is, there is a significant gap between every "quintile" and the highest 20% (see Figure 1 on following page). Still, those in poverty need mathematics interventions the most.[17] There is a three-year difference in mathematics developmental level for students from low-resource versus high-resource communities.[18]

POLL RESULTS

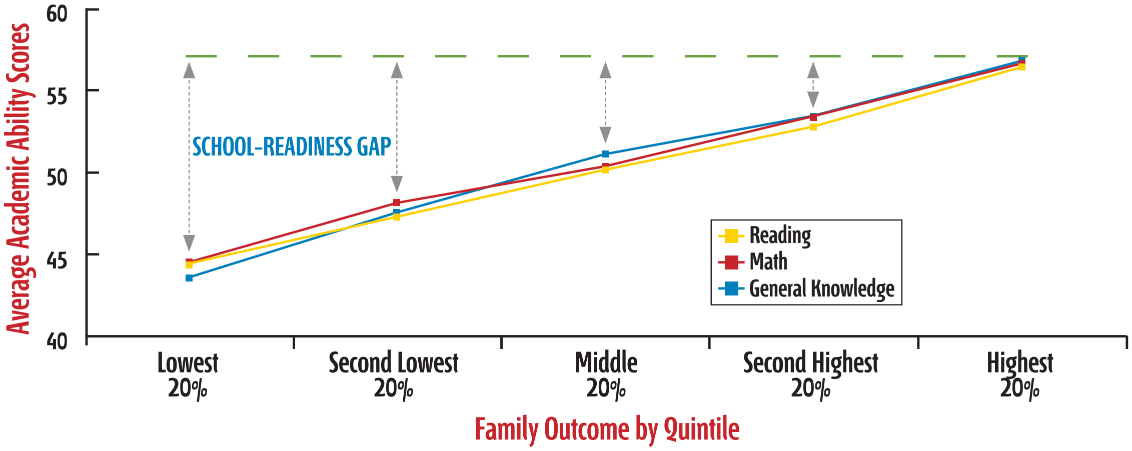
What do parents and children say about math?

98%	Math is very important *(parents)*
89%	Math is very important *(children)*
55%	I am good at math *(children)*
91%	Schools need to help the brightest learn math *(parents)*
55%	Children who like math before middle school

Source: Harrison Group, PROMISE research, Phase 2, June 2010, Michigan State University.

Figure 1: Closing the school-readiness gap

When they enter kindergarten, children from lower- and middle-income families are, on average, far behind their wealthier peers in reading, mathematics, and general knowledge. High-quality preschool could help close this gap in school readiness.

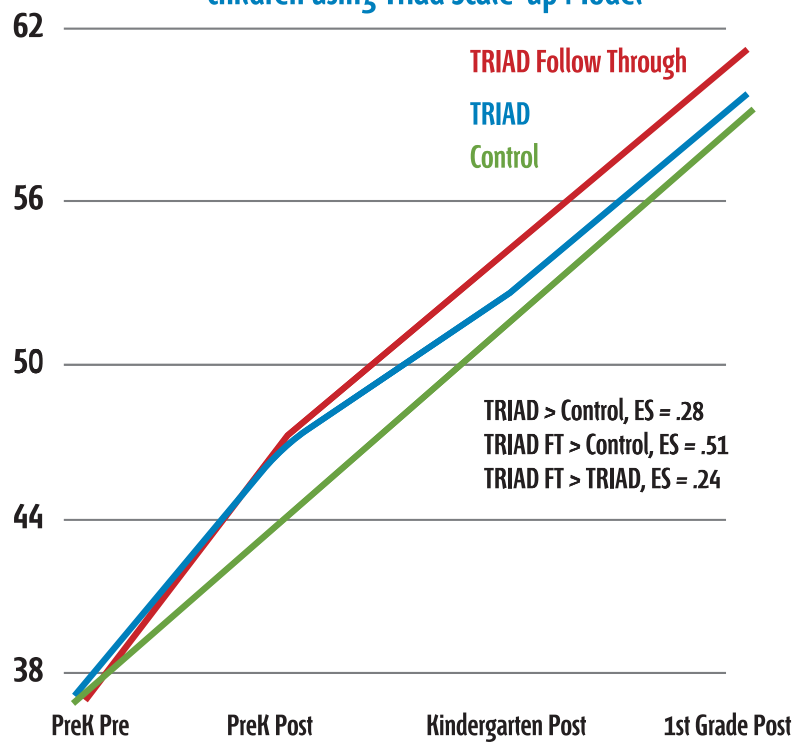


Source: Analysis of data from the *Early Childhood Longitudinal Study, Kindergarten Class of 1998–99* (See nces.ed.gov/ecls/kindergarten.asp) by W. Steven Barnett and Milagros Nores for the National Institute for Early Childhood Education Research.

Surprise 5: We know a lot

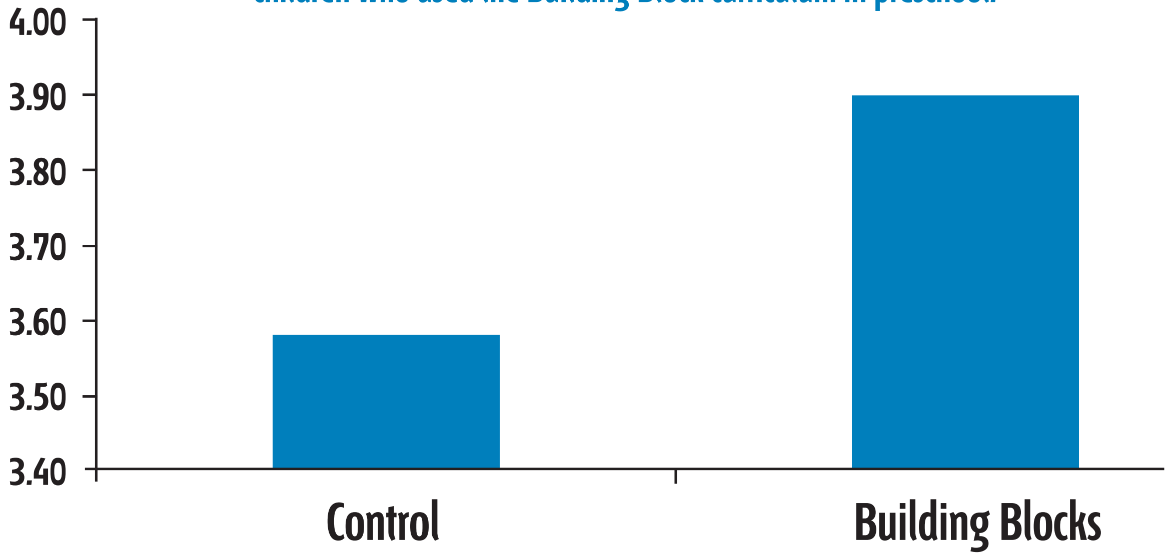
A lot is known about how children think about and learn math, and teachers can use learning trajectories to synthesize this knowledge into effective interventions for children. There are books and research available to districts that detail the learning trajectories that can help underlie scientific approaches to standards, assessment, curricula, and professional development and provide teachers with curricula that show effect sizes that are large and significant.[19] Two such models are the Building Blocks curriculum and TRIAD scale-up model (see figures 2 and 3). High-quality instruction has meaningful effects on children's mathematics knowledge.[20]

Figure 2: Mathematics achievement scores for children using Triad Scale-up Model



Source: D.H. Clements, J. Sarama, C.B. Wolfe, and M.E. Spitler, "Longitudinal Evaluation of a Scale-up Model for Teaching Mathematics with Trajectories and Technologies: Persistence of Effects in the Third Year," *American Educational Research Journal*, 50(4), (2013): 812–850, doi: 10.3102/0002831212469270.

Figure 3: Expressive oral language scores at the beginning of kindergarten for children who used the Building Block curriculum in preschool.



Source: J. Sarama, A. Lange, D.H. Clements, and C.B. Wolfe, "The Impacts of an Early Mathematics Curriculum on Emerging Literacy and Language," *Early Childhood Research Quarterly*, 27, (2012): 489–502, doi: 10.1016/j.ecresq.2011.12.002.

Policy Implications and Recommendations

The Importance of High-Quality Curriculum and Instruction

The quality of mathematics education varies across settings but is generally disappointing, especially in the earliest years. For example, 60% of 3-year-olds had no mathematical experience of any kind across 180 observations.[21] Even if a program adapts an ostensibly "complete" curriculum, mathematics is often inadequate, with the most commonly used engendering no more math instruction than a control group.[22] It is little surprise, then, that evaluations show little or no learning of mathematics in these schools.[23] As an example, observations of Opening the World of Learning (OWL), which includes mathematics in its curriculum, found that out of a 360-minute school day, only 58 *seconds* were devoted to mathematics. Most children made no gains in math skills, and some lost mathematics competence over the school year.[24] Teachers often believe that they are "doing mathematics" when they provide puzzles, blocks, and songs. Even when they teach mathematics, that content is usually not the main focus, but is "embedded" in a fine-motor or reading activity.[25] Unfortunately, evidence suggests such an approach is ineffective.[26] To ensure a program is truly effective, policymakers and school leaders must prioritize investing in high-quality math curricula and instruction that meet the needs of all students.

58% Percent of adults who cannot compute a 10% tip

71% Percent who cannot compute the interest paid on a loan

78% Percent who cannnot calculate miles per gallon on a trip

Source: G.W. Phillips, *Chance Favors the Prepared Mind: Mathematics and Science Indicators for Comparing States and Nations* (Washington, DC: American Institutes for Research, 2007).

Qualified Instructors

Teacher certification for pre-K through 3rd-grade teachers should emphasize both knowledge of the subject (specifically, a profound knowledge of the math taught in early and elementary years) and strengths in pedagogy. It is only recently that some states are requiring teachers to be evaluated on fluency in literacy instruction. What we now know is that math instruction is far more effective coming from a specialist who understands both the subject matter and the most effective ways in which young children learn math. A successful program will be one that ensures that early math instructors specialize in these areas. One solution may be for a school to designate a teacher in each grade who is responsible for teaching only math to all students.

Seamless Learning Trajectories

The most common argument offered for limiting investments in preschool is that the gains made are soon lost as a child matriculates through the early primary grades. The losses primarily signify a siloed approach to education, where each grade level and teacher holds different expectations for students, creating a learning trajectory that is not seamless. Therefore, in order for students to benefit from math instruction in the early years, primary grade teachers must build on early math interventions and engage students in more interesting, challenging, and substantial math lessons as students progress through competency levels. If there are follow-through interventions in kindergarten and the primary grades, students maintain their preschool advantages.[27] This effect is highlighted in Figure 2 (page 3), which presents a significant, positive effect on student math scores when the Triad Model is used on an ongoing basis.

Professional Development

Early math is not often emphasized in teacher preparation programs. As a result, pre-service and in-service teachers alike lack content knowledge, such as understanding of mathematical concepts and procedures. More importantly, they lack mathematics knowledge for teaching—how mathematical knowledge is interconnected and connected to the real world, how a student's thinking about mathematical content develops, and how mathematical content can be taught in a meaningful manner.[28] They suffer from negative effects, including math anxiety and a lack of confidence in their own mathematical ability and ability to teach mathematics—beliefs that lead to undervaluing the teaching of mathematics or prevent effective teaching.[29] Therefore, professional development for early childhood mathematics needs to address content (mathematical) knowledge, particularly mathematics knowledge for teaching, as well as pedagogical knowledge, and affective issues.[30]

Conclusion

It is time to begin shifting the mindset of teachers, district leaders, and policymakers from a 'reading only' early intervention strategy to one that incorporates and even emphasizes mathematical thinking and reasoning. To do so, stakeholders should take a deep look into the current state of early math instruction beginning in preschool and creating a seamless trajectory for math learning through the early grades. Education leaders should find ways to maximize children's abilities to learn by evaluating the current state of mathematics instruction within schools, based not only on the current curricula, but also the time committed to instruction, as well as who is doing that instructing. Most children can master the required skills early if given the chance.

Dr. Clements engages in math activites with two kindergarteners in order to help them understand the core unit of patterns.

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ECS Resources

Recent State Policies/Activities: Preschool Policies

Summaries and links to newly enrolled or enacted legislation and recently approved state board rules from across the states. Updated weekly.

http://www.ecs.org/ecs/ecscat.nsf/WebTopicViewAll?OpenView&Start=1&Count=1000&Expand=204#204

Third Grade Reading Policies

This paper outlines state policies relating to 3rd-grade reading proficiency, including identification of, intervention for, and retention of struggling readers in the P-3 grades. The paper provides a state-by-state policy summary, sample statutory language, and highlights from bills enacted this year.

http://www.ecs.org/clearinghouse/01/03/47/10347.pdf

ECS Research Studies Database:

Find research studies that provide features that define high-quality learning environments for PreK-3 students: http://www.ecs.org/rs/SearchEngine/SearchResults.aspx?faq_id=a0870000004rrIvAAI
or on what mathematics practices impact student achievement:
http://www.ecs.org/rs/SearchEngine/SearchResults.aspx?faq_id=a0870000006yt5BAAQ.

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GE Foundation

The Education Commission of the States is a nationwide nonprofit organization formed in 1965 to help governors, state legislators, state education officials, and others to develop policies to improve the quality of education. ECS is the only nationwide, nonpartisan interstate compact devoted to education at all levels.

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