Early Math Skills - Building Blocks for the Future

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RESEARCH brief

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America's economic growth is fueled by continuing innovation in science and technology. A key challenge for the nation is to educate a new generation with the math and science skills needed for today's economy. Civic, business and community leaders, parents and educators share a common desire to afford our children the best opportunities and to create a promising future for our state. They also share a concern for the challenges created by a growing need for individual and collective competencies in mathematics and science.

The challenge of sustaining economic vitality in a global economy requires new strategies to keep up with the rapid pace of change in knowledge and technology. The way we approach everything from business to education to parenting must change.

RESEARCH POINTS TO EARLY LEARNING IN MATH

Recent concerns about global competitiveness have led to state initiatives to strengthen math and science skills, with a focus on the junior high and high school years. On the other hand, research suggests that children's early mathematical experiences play an enormous role in the development of their understanding of mathematics, serve as a foundation for their cognitive development, and can predict later school success at the high school level (Wolfgang, Stannard & Jones, 2001).

Over 20 years of research show that very young children understand elementary number concepts. Rigorous experimental designs demonstrate that even young infants show a differentiated response when the number of figures in a visual array is altered by adding or subtracting elements (Wynn, 1992). Research also shows that children between two and three years begin to use physical models to represent actual situations and can solve non-verbal calculation problems. (Huttenlocher, Jordan, & Levine, 1994) Between birth and five years of age, children develop mathematical concepts of space, shape, size, pattern, number, and operations (Ginsburg, Lee, & Boyd, 2008).

Further evidence shows that these early skills are important predictors of later achievement. According to the National Council of Teachers of Mathematics, "research on children's learning in the first six years of life validates the importance of early experiences in mathematics for lasting positive outcomes (2007)." In fact, a coordinated analysis of six large-scale longitudinal studies found that young children's math concepts at school entry were even better than literacy skills at predicting later school achievement (Duncan et al., 2007). Well before children enter school they are developing core skills in math on which they will build later school achievement.

> *"Mathematics is one of humankind's greatest cultural achievements. It is the 'language of science', providing a means by which the world around us can be represented and understood".*
>
> *NCTM, 2000*

In spite of strong evidence, poor investment in early learning may account for the “striking disparities in what children know and can do, evident well before they enter kindergarten” (National Academy of Sciences, 2000). Yet the greatest educational efforts at this time focus on packing more into the secondary school curricula during the final years of high school.

The research literature shows that the math superiority of Asian children has its roots in the informal play of young children. Observations during free play show that American and Taiwanese children at four and five years of age exhibit similar types of mathematical activity, but that Chinese children engage in considerably more mathematical activity and are significantly higher in levels of complexity of patterns and shapes (Ginsberg, Lin, Ness and Seo, 2003; Linn, 2004; Lin and Ness, 2000).

Geary (1996) describes many cultural differences in the valuation of mathematics. For instance, Americans place a higher value on achievement in sports than in mathematics, while the Chinese culture prioritizes mathematical learning. Tsao (2004) found in comparing American and Taiwanese students’ perception of mathematics that Chinese children held more positive attitudes and beliefs about math.

Before school age, children’s opportunities for the development of number sense or mathematical understanding, whether at home, in child care or kin care, may be largely overlooked. Research shows that age appropriate math activities promote development of stronger emergent math skills for young children (Dobbs, Doctoroff, & Arnold, 2006; Varol & Farran, 2006). However, a study of the everyday math activities of preschoolers by Tudge and Doucet (2004) found that most children were seldom or never involved in explicit mathematics activities, whether in the course of lessons or play with artifacts designed to encourage mathematical experiences**.** This study did find that parents and teachers frequently engaged children in literacy activities, perhaps reflecting a cultural norm and the impact of national and local campaigns focused on reading to children.

From birth to age 5, young children develop an everyday mathematics – including informal ideas of more and less, taking away, shape, size, location, pattern and position – that is surprisingly broad, complex, and sometimes sophisticated.

Ginsburg, Lee and Boyd, 2008

Lock and Gurganus (2004) have proposed that number sense may be the building block of mathematics, starting at the earliest ages and developing throughout a student’s mathematics education. Tudge and Doucet (2004) noted that “numbers are just as much a part of everyday activities as letters, from looking at dates on a calendar to checking the time on a clock to counting money”. Findings of an earlier study by Doucet (2000) revealed that parents were indeed more focused on helping their children learn to read than on helping their mathematical understanding. While parents may believe that preschool programs will address the area of mathematics, Tudge and Doucet (2004) found no evidence that children received more math lessons in childcare centers than in the home.

Recent decades of research show that children’s everyday experiences affect their brain development, by shaping the interconnections, or synapses, that develop between brain cells. From birth, infant’s early stimulating experiences activate the neural connections and play an important role in selecting the synapses for retention (National Academy of Science, 2000). Brain development occurs throughout life as experiences continue to enhance new brain growth and refine existing brain structures, developing important human capital.

The skills acquired in one stage of the life cycle affect learning at subsequent stages. Foundational math and science concepts develop long before high school or even kindergarten. Such simple tasks as manipulation of blocks helps infants and toddlers develop early skills, including math literacy - the language of numbers. Critical periods for symbols and relative quantity, two significant math prerequisites, occur before the age of five years (Huttenlocher, Jordan, & Levine, 1994).

Brain research shows that children reach their potential when they have the experiences needed to lay foundational skills in the early years. Making up for the learning deficits of children who have missed critical learning opportunities is more costly in time and dollars. It also denies children the chance to benefit from potential learning experiences because they lack the foundational skills to participate – a waste of human capital.

PLAY: A CHILD'S LABORATORY FOR EXPLORATION

Beginning at birth, children construct knowledge through their senses and their experiences in the world around them. Lev Vygotsky, a Russian psychologist, believed that children stretch beyond their own understanding through activities while at play, and develop new skills that support further learning. Recent research shows the investigative and problem solving skills young children show in a play environment (e.g. Schulz & Bonawitz, 2007).

Through the various stages of development, children at play begin to learn essential math skills such as counting, equality, addition and subtraction, estimation, planning, patterns, classification, volume and area, and measurement. Children's informal understanding provides a foundation on which formal mathematics can be built. Therefore, many educators advocate using play as a tool to teach young children mathematics.

> *"Play does not guarantee mathematical development, but it offers rich possibilities"*
>
> *Joint position statement of NAEYC and NCTM, 2002*

Parents and teachers can facilitate learning by offering infants, toddlers and preschoolers opportunities and materials to promote their construction of mathematical thinking. Quantity or number sense may be as important to math development as phonemic awareness (attention to word sounds) is to emergent literacy (Lock & Gurganus, 2004). Just as children need to hear language, rhymes and sounds for early literacy, they need experience to develop number sense. Children who are surrounded with interesting objects, such as blocks, are naturally led to discover relationships among them–for example, same and different, small and large, and more and less, The more frequently children make comparisons, the more complex their comparisons become. Parent, teacher or peer dialogue describing, naming and asking questions provides the words, the symbols and grasp of quantity that builds mathematical thinking.

BUILDING MATH BY BUILDING BLOCKS

Constructive play occurs when children use materials to build a structure. Empirical studies have related construction play or block abilities and mathematics learning in children. Hanlin, Milton, & Phelps (2001) found a relationship between preschool children's ability to classify, seriate and conserve in their construction play to later performance on standardized achievement tests in kindergarten and first grade.

A longitudinal study looked at the relationship between the complexities of block play in preschool children and their later math skills. Results showed that there was no relationship between block play and the student's standardized test scores or mathematics grades at the 3rd or 5th grade levels. However, block play and math performance were related in junior high and high school. Researchers found a significant relationship between preschool block performance and number of math courses taken, number of honors courses, mathematics grades achieved, and weighted mathematics 'points' scores. Even when controlling for IQ and gender, preschool block performance still accounted for significant portions of variability in later math performance (Wolfgang, Stannard & Jones, 2001).

Historically, block play has been a central activity in play-oriented preschools. Construction play with blocks requires the young child to build spatially with a large number of pieces to produce representations of objects, places or events. Construction play offers young children the opportunities to classify, measure, order, count, use fractions, and become aware of depth, width, length, symmetry, shape, and space (Hirsch, 1996). Thus, one can see a direct relationship with the skills acquired in block play as being foundational for the later cognitive structures needed for number and math skills.

> *"I sat at the little Kindergarten tabletop… and played with the cube, the sphere, and the triangle …I soon became susceptible to constructive patterns evolving in everything I saw. I learned to 'see' and when I did, I did not care to draw casual incidentals of nature. I wanted to design."*
>
> *Frank Lloyd Wright (1957)*

Block construction also offers an opportunity for wonder and exploration. What happens when we put the big block on top of the smaller one – will it balance or will it fall down? Can I make a bridge? A tower? How tall can I build them before they teeter over? Young children can investigate possible worlds as they build block constructions.

Block play engages all areas of development during one play event. As a child moves about a pile of blocks he or she uses small and large motor skills to navigate. Problem solving and planning is required in considering possible actions with the varied shapes in space. Children engage their imagination as they use a long rectangle to symbolize a telephone, then move blocks into a circle to create order. When children invite a peer to join in, they plan and communicate; exercising social and language skills. Jointly, they create a new reality. They compromise and share as the house one child created becomes the castle that another envisions. Together, they delight in the sounds and empowerment of knocking them all down. Research shows the block play setting to be a rich learning lab for children (e.g. Cohen & Uhry, 2007; Newburger & Vaughan, 2006).

Play offers opportunities to develop dispositions toward curiosity and learning - critical ingredients in academic and future success. A disposition to see work and technology as playful well into adulthood is expressed by Nobel prize-winning physicist, Horst Stormer - "Nanotechnology has given us the tools …to play with the ultimate toy box of nature - atoms and molecules. The possibilities to create new things appear limitless" (Amato, 1999, pg 2). A facility to imagine the unseen requires a certain disposition. Stormer identifies playfulness, curiosity, creativity, and thinking outside the box as advantageous to math and science success. Dispositions are habits of mind and not readily learned like facts or concepts. Research shows several personal attributes linked to math skill, including executive function and initiative (Blair and Razza, 2007; Dobbs, Doctoroff, & Arnold, 2006).

Dispositions can be nurtured by parents who understand how to give their child ample opportunity to explore and make decisions in an exciting and meaningful context (Jacobs & Bleeker, 2004; Palmquist & Crowley, 2007). One such context is illustrated by *Popular Science* News Editor Charles Hirshberg. He recalled how his mother, Joan Feynman, a distinguished physicist and the sister of one of the most famous scientists of the 20th century, introduced him to chemistry:

> *My introduction … came in 1970, on a day when my mom was baking challah bread for the Jewish New Year. I was about 10, and though I felt cooking was unmanly for a guy who played shortstop for … Little League, she had persuaded me to help. When the bread was in the oven, she gave me a plastic pill bottle and a cork. She told me to sprinkle a little baking soda into the bottle, then a little vinegar, and cork the bottle as fast as I could. There followed a violent and completely unexpected pop as the cork flew off and walloped me in the forehead. Exploding food: I was ecstatic! "That's called a chemical reaction," she said, rubbing my shirt clean. After that, I never understood what other kids meant when they said that science was boring (Hirshberg, 2002).*

Investing Early is a Wise Strategy

A strategic shift to early learning to promote optimal development, including mathematics competence, is well supported by research in education, child development and economics. The recommendation of leading economists and educators is to implement systematic, research-based early care and learning programs. Directing more resources to this effort is supported by the Federal Reserve Bank of Minneapolis assertion that "well-focused investments in early childhood development yield high public as well as private returns" (Rolnick & Grunewald, 2003). Extensively documented outcomes of quality programs for young children include increased academic attainment and employment as well as decreased public expenditures associated with crime, teen pregnancy and welfare dependency.

The return on early investment is academic success from the very beginning of a child's formal school career. The community will benefit from a growing workforce of scientists, mathematicians, architects, and engineers able to compete in a global economy. Best of all, the knowledge gained by the children in these programs, someday, will be used to enrich the lives of their children, and so on - a changing culture of parenting.

> *Early math is a more powerful predictor of later reading achievement than early reading is of later math achievement.*
> *Duncan et al., 2007*

In Summary

Advancing math performance in students and positioning the nation for the challenges of rapidly advancing technologies will require that we think outside of the box and recognize the strategic building blocks. Research supports the following essential building blocks for success:

- INVEST EARLY: In the first five years – laying the critical foundation during the period of the most rapid brain development.
- ENGAGE PARENTS: As their child's first teacher in the early years and support that engagement throughout their school years.
- RETHINK MATH EXPECTATIONS: Facilitate dispositions for math and science literacy early in life and nurture the world view of all students to ready them to operate in a world culture that includes mathematics.

By using every resource available to find the solution to math underachievement we expand our possibilities. Will we be ready with workers and leaders who have strong math and science literacy? Our young children hold the building blocks for a bright future in this 'ultimate toy box of nature' and we need to invest in them and support their learning one block at a time.

References

Amato, I. (1999) Nanotechnology-Shaping the world atom by atom. National Science and Technology Council (NSTC). Retrieved from the world wide web from http://itri.loyola.edu/nano/IWGN.Public.Brochure.

Blair, C. & Razza, R. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development,78*, 647-63.

Cohen, L. & Uhry, J. (2007). Young children's discourse during block play. *Journal of Research in Childhood Education, 21*, 302-8.

Dobbs, J., Doctoroff, P., & Arnold, D. (2006). The association between preschool children's socio-emotional functioning and their mathematical skills, *Journal of Applied Developmental Psychology, 27,* 97-108.

Doucet, F. (2000). The transition to school in middle-class and working-class African American families: A study of beliefs, values and practices. Unpublished doctoral dissertation, University of North Carolina at Greensboro.

Duncan, G., Dowsett, C., Claessens, A., Magnuson, K., Huston, A., Klebanov, P., Panani, L., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K., & Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*, 1428-46.

Geary, D. (1996). Biology, culture, and cross-national differences in mathematical ability. In R. Steinberg & T. Ben-Zeev (Eds.), *The Nature of Mathematical Thinking*. Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.

Ginsburg, H., Lee, J., & Boyd, J. (2008). Mathematics education for young children: What it is and how to promote it. *Social Policy Report, 22,* 1-23.

Ginsburg, H.P., Lin, C., Ness, D., & Seo, K. (2003). Young American and Chinese children's everyday mathematical activity. *Mathematical Thinking and Learning*, *5(30),* 235-258.

Hanlin, M.F., Milton, S. & Phelps, P. (2001). Young children's block construction activities: Findings from 3 years of observation. *Journal of Early Intervention*, *24 (3),* 341-355.

Hirsch, E. (1996). The Block Book. Washington, D.C: NAEYC.

Hirshberg, C. (2002). My mother, the scientist. Retrieved from the world wide web at http://popsci.com/article/2002-04/my-mother-scientist#

Huttenlocher, J., Jordan, N., & Levine, S. (1994). A mental model for early arithmetic. *Journal of Experimental Psychology*, *123 (3),* 284-296.

Jacobs, J. & Bleeker.N. (2004). Girls' and boys' developing interest in math and science: Do parents matter? *New Directions for Child and Adolescent Development, 106*, 5-21.

Lin, C., Ness, D. (2000). Taiwanese and American preschool children's everday mathematics. Paper presented at the Annual Conference of the American Educational Research Assn., New Orleans, LA.

Lock, R. & Gurganus, S. (2004). Promoting number sense. *Interventions in School and Clinic*, *40 (1),* 437-451.

National Academy of Sciences (2000). Executive Summary. *From Neurons to Neighborhoods: The science of early childhood development*, Washington DC: National Academy Press.

National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (2002). Promoting good beginnings. A joint position of NAEYC and NCTM. Retrieved from the world wide web at www.naeyc.org on 12/19/2007.

National Council of Teachers of Mathematics (2007). What is important in Early Childhood Mathematics? Retrieved from the worldwide web, http://www.nctm.org on 1/24/2008.

National Council of Teachers of Mathematics [NCTM] (2000). Principles and standards for school mathematics. Reston, VA. The National Council of Teachers of Mathematics.

Newburger, A. & Vaughan, E. (2006). *Teaching Numeracy, Language and Literacy with Blocks.* St. Paul, MN: Redleaf Press.

Palmquist, S. & Crowley, K. (2007). From teachers to testers: How parents talk to novice and expert children in a natural history museum, *Science Education,* 91, 783-804.

Rolnick, A. & Grunewald, R. (2003). Early childhood development: Economic development with high public returns. *Fed Gazette*, Federal Reserve Bank of Minneapolis.

Schulz, L. and Sonawitz, E. (2007). Serious fun: Preschoolers engage in more exploratory play when evidence is confounded. *Developmental Psychology, 43,* 1045-1050

Tsao, Y. (2004). A comparison of American and Taiwanese students: Their math perception. *Journal of Instructional Psychology*, *3(3),* 206-213.

Tudge, J. & Doucet, F. (2004). Early mathematics experiences: Observing young black and white children's everyday activities. *Early Childhood Research Quarterly, 19,* 21-39.

Varol, F. & Farran, D. (2006). Early mathematical growth: How to support young children's mathematical development, *Early Childhood Education Journal, 33,* 381-7.

Wolfgang, C., Stannard, L., & Jones, I. (2001). Block play performance among preschoolers as a predictor of later school achievement in mathematics. *Journal of Research in Childhood Education*, *15 (2),* 173-181.

Wright, F.L. (1957) A Testament. New York: Harper & Rowe, Publishers.

Wynn, K. (1992). Addition and subtraction by human infants. *Nature*, 27, 749-750.

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