

EARLY MATH SKILLS - BUILDING BLOCKS FOR IDAHO'S FUTURE

America's economic growth is fueled by continuing innovation in science and technology. A key challenge for Idaho is to educate a new generation with the math and science skills needed for today's economy. Idaho's governor, 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. These concerns are echoed nationwide. **NAMELY:**

- ▣ U.S. students tend to score poorly on international tests of math and science such as the TIMSS (J.A. & Kathryn Albertson Foundation, 2005).
- ▣ High school graduation rates in the U.S. trail behind most other countries (J.A. & Kathryn Albertson Foundation, 2005).
- ▣ Idaho's young people graduate from high school with fewer advanced-level math and science courses than their peers nationally (Shaklee, Brown, & Higley, 2005).
- ▣ Idaho ranks 46th in the nation in college graduates per capita (Idaho State Board of Education, 2005).

The challenge of sustaining a vital Idaho 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

Industries in Boise have engaged in noble and costly efforts to improve student ACT test results by providing their own engineers to teach classes (Idaho Statesman, 9/23/05). On the state level, the Idaho State Board of Education, in an effort to improve high school performance in math and science, may ask individual school districts to invest as much as \$2 million to increase the quantity of math and science offerings in high school.

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

"If I were asked for an area . . . that will most likely produce the breakthroughs of tomorrow, I would point to nanoscale science and engineering. Whoever becomes the most knowledgeable and skilled on these nanoscopic scales will find themselves well positioned in the . . . globalize economy of the 21st century"

--Neal Lane, National Science and Technology Council (Amato, 1999).

can predict mathematics success at the high school level (Wolfgang, Stannard and Jones, 2001). Well before children enter school they are laying the foundation for their later math skill.

Over 20 years of research shows 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. They demonstrate that children between 2 and 3 years begin to use physical models to represent actual situations and can solve non-verbal calculation problems (Huttenlocher, Jordan and Levine, 1994). By the age of three or four years, children have a good deal of mathematical competence including enumeration, number relations, subitizing (recognizing the number of briefly presented items without actually counting) and counting, informal addition, subtraction and division (Ginsberg, Klein and Starkey, 1998).

Further evidence shows that these early skills are important predictors of later achievement as demonstrated by Stevenson and Neuman (1986). Their study reported a significant relationship between pre-kindergarten math achievement scores and 10th grade math achievement.

In spite of this strong evidence for early math, there is a lack of investment in early learning which may account for the "striking disparities in what children know and can do, evident well before they enter kindergarten" (National Academy of Sciences, 2003). The National Council of Teachers of Mathematics asserts that "the foundation for children's mathematical development is established in the earliest years" (2000), yet the greatest efforts appear focused on packing more into the secondary school curricula during the final years of high school.

"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".

National Council of Teachers of Mathematics, 2000

National literature is replete with studies showing that Asian children demonstrate higher levels of achievement in school mathematics than their American peers. This difference in ability may be explained in part, by early, informal education. Ginsberg, Lin, Ness and Seo, (2003) reported that during free play American and Taiwanese children at 4 and 5 years of age exhibit similar types of mathematical activity, but Chinese children engage in considerably more mathematical activity.

Additional studies found that Taiwanese children at 3 years of age spent significantly more time in mathematical activities during play and scored significantly higher in levels of complexity of patterns and shapes than American children of the same age (Lin, 2000). Geary 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 Asian culture prioritizes mathematical learning (Geary, 1996). 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. 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.

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 were more likely to receive lessons in childcare centers than in the home.

Dr. Holly MacLean, principal of the Treasure Valley Math and Science Center, believes that a cultural shift in the way we think about mathematics holds one of the keys to addressing the problem of low math achievement. Dr. MacLean advocates starting early and working to help children and adults develop confidence, positive attitudes, and high expectations for competence in mathematics in their everyday world.

Long before children receive formal math training in patterns and sequences, they observe them in nature, at home, at play, and in stories, songs and verses.

Parents as Teachers National Center, 2002

Neuroscience, the study of how the brain develops and functions has helped us realize that there are critical periods for learning. We know from 50 years of research that an infant's experience can have permanent effects on the wiring of the brain. Research shows that early stimulating experiences activate the neural

connections and play an important role in selecting the synapses for retention (Eliot, 1999). Brain development occurs throughout life as experiences continue to enhance new brain growth and refine existing brain structures. This dynamic process develops important human capital.

The skills acquired in one stage of the life cycle affect learning at subsequent stages. Such simple tasks as manipulation of blocks helps infants and toddlers develop early skills, including math literacy - the language of numbers. Critical periods for understanding symbols and relative quantity, two significant math prerequisites, occur before the age of five years (Huttenlocher, Jordan and 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 through play, children stretch beyond their own understanding and develop new skills that support further learning. Through play, children develop an ever-growing

sense of themselves and others, knowledge of the physical world, and enhanced ability to communicate.

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 and 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

Construction 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, and 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 and 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 represent objects, places or events and to represent imaginary things

"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)

as well. 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.

Block construction 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 moving blocks in 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.

“By repeatedly playing with blocks, children exercise their brain’s motor pathways. This helps their motor skills become smooth, agile and quick”.

*Parents as Teachers National Center
2002*

Play also affords 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). 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.

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. One such context is illustrated by Popular Science News Editor Charles Hirshberg. He recalled how his mother, 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 ... 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: A LOGICAL CONCLUSION AND WISE STRATEGY

A strategic shift to intentional 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 and Grunewald, 2003)

Parents as Teachers (PAT) is one such program for parents of young children. PAT combines a curriculum, rich with stimulating, age appropriate activities for children with important lessons to coach parents to be skilled observers of their child’s learning. In each personal visit a trained parent educator helps parents learn to support their child as he or she learns new skills. This strategy reflects Vygotsky’s thesis that “every child, with assistance, can do more than he or she can by him or herself but only within the limits set by the state of his or her development” (Steffe and Lovin, 1997).

PAT helps parents understand their child’s development and anticipate what will come next. It increases parental confidence and skill in supporting their child’s learning and it underscores the importance of literacy and numeracy in everyday activities from early in a child’s life. The outcomes of PAT are children who are ready for learning at kindergarten entry and parents who are engaged and dedicated to the process. In terms of math, science and literacy success - the implications are far reaching and long lasting.

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 (Friedman, 2004). 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.

Investing in quality early childhood development programs for children during the critical developmental period of birth to 5 years will result in high public and personal returns. In addition to enhanced math competence and human capital, early learning programs strengthen our social fiber by reducing special education placements, increasing average achievement scores, and increasing rates of high school completion, reducing crime, reducing dependence on welfare benefits, and increasing wages (Friedman, 2004 and Trefler, 2005). All of these widely documented outcomes came from investing early and wisely in children.

“Studies have found that 4 year olds who have received opportunities to develop foundational mathematical concepts have the number knowledge that other children will not develop until they are 7 years of age. That three year gap in understanding continues to expand so that once the students have been in school for 9 - 10 years the gap becomes a seven-year difference”.

Dr. Holly MacLean, 2005

IN SUMMARY

Advancing math performance in Idaho's students and positioning our state for the challenges of rapidly advancing technologies will require that we think outside of the box and recognize strategic building blocks.

Research supports the following essential building blocks for success:

- ▣ 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.
- ▣ ENGAGE PARENTS AS THEIR CHILD'S FIRST TEACHER in the early years and support their engagement throughout their child's school years.
- ▣ INVEST EARLY IN THE FIRST FIVE YEARS – laying the critical foundation during the period of a child's most rapid brain development.

"Studies show that (early) differences in number knowledge increase as children progress through schooling. There is a clear tendency for low attainers in the early years to continue to be low achievers throughout their primary years and to develop negative attitudes to mathematics. There is a need therefore to give every child a positive understanding and success in early number work" (Wright, Martland, Stafford and Stanger, 2000).

When we utilize every resource available to us to find the solution to math underachievement and we think outside of the box - we expand our possibilities. Will we be ready for a nanoworld with workers and leaders who have strong math and science literacy? Our young children hold the building blocks of Idaho's future in this 'ultimate toy box of nature' and we will be ready if we invest in them and support their learning one block at a time.

"Nanotechnology is the builder's final frontier".

*Nobel laureate Richard Smalley
Rice University*

REFERENCES

- Amato, I. (1999) Nanotechnology: Shaping the world atom by atom. National Science and Technology Council. Committee on Technology. Retrieved from the world wide web at <http://itri.loyola.edu/nano/IWGN.Public.Brochure/>.
- Arnold, D., Fisher, P., Doctoroff, G. and Dobbs, J. (2002) Accelerating math development in Head Start classrooms. *Journal of Educational Psychology*. Vol. 94.
- 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.
- Eliot, L. (1999). What's going on in there? How the brain and mind develop in the first five years of life. New York: Bantam.
- Friedman, D. (2004) The new economics of preschool. New findings, methods and strategies for increasing economic investments in early care and education. Early Childhood Funders' Collaborative.

- Geary, D.C. (1996) Biology, culture, and cross-national differences in mathematical ability. In R.J. Steinberg & T. Ben-Zeev (Eds.), *The Nature of Mathematical Thinking*. Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.
- Ginsburg, H.P., Lin, C., Ness, D., and Seo, K. (2003) Young American and Chinese children's everyday mathematical activity. *Mathematical Thinking and Learning*. Vol. 5 (3).
- Ginsburg, H.P., Klein, A., and Starkey, P. (1998) The development of children's mathematical thinking: Connecting research with practice. In I.E. Sigel, K.A. Renninger (Vol Eds) and W. Doman (Series Ed) *Handbook of Child Psychology*, Vol. 4. New York: Wiley.
- Hanline, M.F., Milton, S. and Phelps, P. (2001). Young children's block construction activities: Findings from 3 years of observation. *Journal of Early Intervention*. Vol.24 (3).
- Hirsch, E. (1996). *The Block Book*. Washington, D.C.: NAEYC.
- Huttenlocher, J., Jordan, N., and Levine, S. (1994) A mental model for early arithmetic. *Journal of Experimental Psychology*. Vol. 123 (3).
- Idaho State Board of Education (2005) Redesigning Idaho's schools to reflect the worldwide economy. *Futures Now Newsletter*. August 2005.
- J.A. and Kathryn Albertson Foundation. Catalyst Newsletter, 2005.
- Lin, C. and Ness, D. (2000) Taiwanese and American preschool children's everyday mathematics. Paper presented at the Annual Conference of the American Educational Research Association. New Orleans, LA. April 24, 2000.
- Lock, R. and Gurganus, S. (2004) Promoting 'v' number. *Interventions in School and Clinic*. Vol. 40 (1).
- Lynch, R. (2004) Exceptional returns: Economic, fiscal and social benefits of investment in early childhood development. Economic Policy Institute.
- Ma, X. (1997) Reciprocal relationship between attitude toward mathematics and achievement in mathematics. *Journal of Educational Research*, 90, 221-229.
- McMahon, B.(2000). Scaffolding: A suitable teaching characteristic in one-to-one teaching in Maths Recovery. In Bana, Jack and Chapman, Anne, Eds. *Proceedings Mathematics Education Beyond 2000*, Fremantle, Western Australia.
- National Academy of Sciences (2003). Executive Summary. From neurons to neighborhoods: The science of early childhood development. Retrieved from the world wide web <http://www.nap.edu>.
- National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (NCTM) (2002) Early childhood mathematics: Promoting good beginnings. A joint position of the NAEYC and NCTM.
- Parents as Teachers National Center (2002) Born to Learn Curriculum: 3 Years to Kindergarten Entry. St. Louise, Missouri.
- Pickett, L. (1998) Literacy during block play. *Journal of Research in Childhood Education*. Vol. 12 (2).
- Rolnick, A. and Grunewald, R. (2003) Early childhood development: Economic development with high public returns. Fed Gazette, Federal Reserve Bank of Minneapolis.
- Shaklee, H., Brown, J., and Higley, R. (2005) Bridge to adulthood for Idaho youth: Learning and earning, *Idaho Kids Count*, Mountain States Group: Boise, Idaho.
- Steffe, L. and Lovin, L. (1997) Building conceptual bridges: A critique. *Issues in Education*, Vol. 3 (1).
- Stevenson, H.W. and Newman, R.S. (1986) Long-term prediction of achievement and attitudes in mathematics and reading. *Child Development*, 57, 646-659.
- Trefler, D. (2005). Looking backward: How childhood experiences impact a nation's wealth. Rotman Life-long Learning Lectures. Rotman School of Management.
- Tsao, Y. (2004) A comparison of American and Taiwanese students: Their math perception. *Journal of Instructional Psychology*. Vol.3 (3).
- Tudge, J. and Doucet, F. (2004). Early mathematics experiences: Observing young Black and White children's everyday activities. *Early Childhood Research Quarterly*. Vol 19.
- Wolfgang, C., Stannard, L., and Jones, I. (2001). Block play performance among preschoolers as a predictor of later school achievement in mathematics. *Journal of Research in Childhood Education*. Vol 15 (2).
- Wright, F.L. (1957) A Testament. New York: Harper & Rowe, Publishers.
- Wright, R.J., Martland, J., Stafford, A. and Stanger, G. (2000). Teaching Number: Advancing Children's Skills and Strategies. London: Paul Chapman Publishing/Sage.
- Wynn, K. (1992) Addition and subtraction by human infants. *Nature*, 27, 749-750.