



Effects of a Preschool Mathematics Curriculum: Research on the NSF-funded *Building Blocks* Project¹

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Building Blocks is a NSF-funded PreK to grade 2 software-based mathematics curriculum development project, designed to comprehensively address the most recent mathematics standards. *Building Blocks* materials were created upon explicit design principles and a nine-phase formative model—they are truly *research-based* (details are provided in Clements, 2002a; Clements, 2002b; Sarama & Clements, in press). This summary presents initial summary research on the first *Building Blocks* product, a preschool mathematics curriculum.

Design of the *Building Blocks* Materials

Based on theory and research on early childhood learning and teaching (Bowman, Donovan, & Burns, 2001; Clements, 2001), we determined that *Building Blocks*' basic approach would be *finding the mathematics in, and developing mathematics from, children's activity*. The materials are designed to help children extend and mathematize their everyday activities, from building blocks to art to songs and stories to puzzles. Activities are designed based on children's experiences and interests, with an emphasis on supporting the development of *mathematical* activity. So, the materials do not rely on technology alone, but integrate three types of media: computers, manipulatives (and everyday objects), and print.

Many claim a research basis for their materials, but these claims are often vacuous, citing vague theories without specifics. *Building Blocks* is research-based in several fundamental ways. Our design process is based on the assumption that curriculum and software design can and should have an explicit theoretical and empirical foundation, beyond its genesis in someone's intuitive grasp of children's learning. It also should interact with the ongoing development of theory and research—reaching toward the ideal of testing a theory by testing the software and the curriculum in which it is embedded. Our model includes specification of mathematical ideas (computer objects) and processes/skills (computer tools) and extensive field-testing from the first inception through to large summative evaluation studies (Clements, 2002a; Clements & Battista, 2000; Sarama & Clements, in press). Phases of this design process model are: drafting curriculum goals, building an explicit model of children's knowledge and learning in the goal domain, creating an initial design, investigating components of the software design, assessing prototypes and curriculum (with one-on-one interviews with students and teachers), conducting pilot tests (in a few classrooms), conducting field tests in numerous classrooms, and publishing the materials. All the while, feedback from the field results in further refinement of to the design of the software and activities, which then results in further testing. In this way, we continually loop through the earlier phases of the model.

Several steps deserve more elaboration. The step of “building an explicit model of children's knowledge and learning in the goal domain” involves the adaptation, creation, and use of learning trajectories. *Building Blocks* is structured on empirically-based learning trajectories through the big ideas and skill areas of mathematics (Clements & Battista, 1992; Clements, Sarama, & DiBiase, in press; Fuson, 1997). The step of “creating an initial design” is based largely on these learning trajectories, but also on other bodies of research. For example, mathematics goals are based on research on what topics are developmentally appropriate for, generative for, and interesting to young children (Clements et al., in press, *Building Blocks* organizes mathematics content into two areas: number/operations and geometric/spatial, with three subthemes woven throughout: patterns, data, and classifying/sequencing). As another example, the design

¹ This material is based in part upon work supported by the National Science Foundation Research Grant ESI-9730804, “Building Blocks—Foundations for Mathematical Thinking, Pre-Kindergarten to Grade 2: Research-based Materials Development.” Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation.

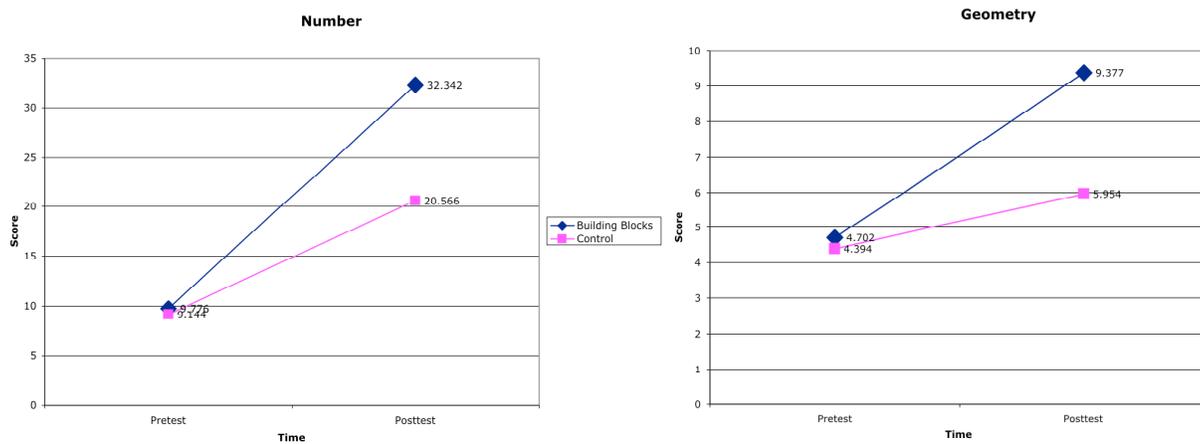
directly applies research on making computer software for young children motivating and educationally effective (Clements, 1993; Clements & Swaminathan, 1995). Previous publications provide detailed descriptions of how we applied these research corpora in our design process model (Clements, 2002a, 2002b; Sarama, in press; Sarama & Clements, 2002, in press).

Summative Research Evaluation

Summative research was conducted at two sites, involving the two principal types of public preschool programs serving low-income families, Head Start and state-funded pre-kindergarten programs. At each site, one classroom was assigned as experimental, one control. Mathematics knowledge of all children was assessed at the beginning and end of the school year with two tests, number (counting, number sense, and arithmetic) and geometry (shapes, composing shapes, spatial sense, measurement, and patterning). The *Building Blocks* preschool curriculum was implemented in the experimental classes following the pretesting. This curriculum, a component of the *DLM Early Childhood Express* (Schiller, Clements, Sarama, & Lara-Alecio, 2003), consists of daily activities in four teacher’s editions, and a *DLM Express Math Resource Package* (Clements & Sarama, 2003) including computer software, correlated games, activities, and centers, and ideas for integrating mathematics throughout the school day. The software includes 11 activities, each with up to 6 sublevels, and a management system that guides children through research-based learning trajectories.

Results

The results are illustrated in two graphs. We computed effect sizes using the accepted benchmarks of .25 as indicating practical significance (i.e., educationally meaningful), .5 as indicating moderate strength, and .8 as indicating a large effect (Cohen, 1977). The effect sizes comparing *BB* children’s posttest to the control children’s posttest were .85 and 1.44 for number and geometry, respectively, and the effect sizes comparing *BB* children’s posttest to their pretest (measuring achievement gains) were 1.71 and 2.12. Therefore, *all effects were positive and large. Achievement gains were comparable to the coveted “2-sigma” effect of excellent individual tutoring* (Bloom, 1984).



In summary, we designed the *Building Blocks* materials upon research in a well-defined, rigorous, and complete fashion. We contend that such research-based curriculum development efforts can contribute to (a) more effective curriculum materials because the research reveals critical issues for instruction, (b) better understanding of students' mathematical thinking, and (c) research-based change in mathematics curriculum (Clements, Battista, Sarama, & Swaminathan, 1997; Clements et al., in press; Schoenfeld, 1999). The summative evaluation study reported here provides strong evidence that materials created according to that model are effective in developing the mathematical knowledge of disadvantaged 4-year-old children.

Conclusions and Implications

Results indicate strong positive effects of the *Building Blocks* materials, with achievement gains near or exceeding those recorded for individual tutoring. We believe this is the result of implementing a curriculum built on *comprehensive research-based principles*. The materials include research-based computer tools, providing software analogs to critical mathematical ideas and processes. These are used, or implemented, with activities and a management system that guides children through research-based learning trajectories. These activities-through-trajectories connect children's informal knowledge to more formal school mathematics. In addition, such synthesis of curriculum/technology development as a scientific enterprise and mathematics education research reduces the separation of research and practice in mathematics and technology education. Funding from agencies such as the NSF is necessary to carry out such comprehensive research and development projects. We are presently evaluating a large-scale implementation of *Building Blocks*.

References

- Bloom, B. S. (1984). The 2-sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher*, 13, 4-16.
- Bowman, B. T., Donovan, M. S., & Burns, M. S. (Eds.). (2001). *Eager to learn: Educating our preschoolers*. Washington, DC: National Academy Press.
- Clements, D. H., Nastasi, B. K., & Swaminathan, S. (1993). Young children and computers: Crossroads and directions from research. *Young Children*, 48(2), 56-64.
- Clements, D. H. (2001). Mathematics in the preschool. *Teaching Children Mathematics*, 7, 270-275.
- Clements, D. H. (2002a). Curriculum research: Toward a framework for "research-based curricula". *Submitted for publication*.
- Clements, D. H. (2002b). Linking research and curriculum development. In L. D. English (Ed.), *Handbook of International Research in Mathematics Education* (pp. 599-630). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Clements, D. H., & Battista, M. T. (1992). Geometry and spatial reasoning. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 420-464). New York: Macmillan.
- Clements, D. H., & Battista, M. T. (2000). Designing effective software. In A. E. Kelly & R. A. Lesh (Eds.), *Handbook of research design in mathematics and science education* (pp. 761-776). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Clements, D. H., Battista, M. T., Sarama, J., & Swaminathan, S. (1997). Development of students' spatial thinking in a unit on geometric motions and area. *The Elementary School Journal*, 98(2), 171-186.
- Clements, D. H., & Sarama, J. (2003). *DLM Express Math Resource Package*. Colum., OH: SRA/McGraw-Hill.
- Clements, D. H., Sarama, J., & DiBiase, A.-M. (in press). *Engaging young children in mathematics: Findings of the 2000 national conference on standards for preschool and kindergarten mathematics education*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Clements, D. H., & Swaminathan, S. (1995). Technology and school change: New lamps for old? *Childhood Education*, 71, 275-281.
- Cohen, J. (1977). *Statistical power analysis for the behavioral sciences (rev. ed.)*. New York: Academic Press.
- Fuson, K. C. (1997). Research-based mathematics curricula: New educational goals require programs of four interacting levels of research. *Issues in Education*, 3(1), 67-79.
- Sarama, J. (in press). Technology in early childhood mathematics: *Building Blocks*TM as an innovative technology-based curriculum. In D. H. Clements & J. Sarama & A.-M. DiBiase (Eds.), *Engaging young children in mathematics: Findings of the 2000 national conference on standards for preschool and kindergarten mathematics education*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Sarama, J., & Clements, D. H. (2002). *Building Blocks* for young children's mathematical development. *Journal of Educational Computing Research*, 27(1&2), 93-109.
- Sarama, J., & Clements, D. H. (in press). Linking research and software development. In K. Heid & G. Blume (Eds.), *Technology in the learning and teaching of mathematics: Syntheses and perspectives*. New York: Information Age Publishing, Inc.
- Schiller, P., Clements, D. H., Sarama, J., & Lara-Alecio, R. (2003). *DLM Early Childhood Express*. Columbus, OH: SRA/McGraw-Hill.
- Schoenfeld, A. H. (1999). Looking toward the 21st century: Challenge of educational theory and practice. *Educational Researcher*, 28, 4-14.

