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Effects of a Preschool Mathematics Curriculum:

Summary Research on the *Building Blocks*

Effects of a Preschool Mathematics Curriculum:

Summary Research on the *Building Blocks* Project

Government agencies have recently emphasized the importance of evidence-based instructional materials (e.g., Feuer, Towne, & Shavelson, 2002; Reeves, 2002). However, the ubiquity and multifariousness of publishers' claims of research-based curricula, in conjunction with the ambiguous nature of the phrase "research-based," discourages scientific approaches to curriculum development (and allows the continued dominance of non-scientific "market research") and undermines attempts to create a shared research foundation for the creation of classroom curricula (Battista & Clements, 2000; Clements, 2002; Clements & Battista, 2000). Once produced, curricula are rarely evaluated scientifically. Less than 2% of research studies concerned the effects of textbooks (Senk & Thompson, 2003), even though these books predominate mathematics curriculum materials in U.S. classrooms and to a great extent determine teaching practices (Goodlad, 1984), even in the context of reform efforts (Grant, Peterson, & Shojgreen-Downer, 1996). This study is one of several coordinated efforts to assess the efficacy of a curriculum that was designed and evaluated according to specific criteria for both the development and evaluation of a scientifically based curriculum (Clements, 2002; Clements & Battista, 2000).

Building Blocks is a NSF-funded PreK to grade 2 mathematics curriculum development project, designed to comprehensively address recent standards for early mathematics education for all children (e.g., Clements, Sarama, & DiBiase, 2004; NCTM, 2000). Previous articles describe the design principles behind a set of research-based software microworlds included in the *Building Blocks* program and the research-based design model that guided its development (Clements, 2002, 2003). This article presents initial summary research on the first set of resulting materials, a research-based, te

Battista, 2000). In contrast, we designed the *Building Blocks* approach to incorporate as many of the methods as possible. The next section describes this design.

Design of the Building Blocks *Materials*

Previous publications provide detailed descriptions of how we applied these research methods i

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correspondence, counting and using numerals to represent and generate quantities in the solution of variations of the task). At the *Non-Verbal Addition* level, the Double Trouble character might place 3 chocolate chips, then 1 more, on a cookie under a napkin. Children put the same number of chips on theoublof

individual shapes (unit

children’s mathematical activity and we determined effective prom

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research-based developmental progressions within areas of mathematics considered significant for preschoolers, as determined by a consensus of participants in a national conference on early childhood mathematics standards (Clements, Sarama et al., 2004), rather than mirroring the experimental curriculum's objectives or activities. The assessment was refined in three full pilot tests. Content validity was

includes 2 items assessing the ability to match shapes of the same shape and same size. Construction of shapes includes 2 items assessing the ability to accurately build a shape from its components (e.g., the child is given 6 straws of each of 3 different lengths and asked, “We're going to use these straws to make shapes. Can you make a *triangle* using some of the straws?”). Turns included 1 item assessing recognition of a 90° rotation and orientation included 1 item on horizontal and vertical lines. The test also includes 1 item on geometric measurement (Which of these strings is about the same length as 4 c

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Summarizing, children worked on the following number of activities, classified by their major goal (many activities addressed multiple 20

comparison children could provide a verbal response at pretest. At posttest, all experimental children did so, however 1/6 of the comparison children reproduced the set but could not give the verbal responses and between 1/5 and 1/4 gave no response. On a number comparis half on and half off computer. Both on- and off-computer activities emphasized counting on from a given number. The results of these activities is shown in the greater than double increase in correctness by the experimental group, as well as their greater use of solution strategies overall and greater use of more sophisticated strategies, such as verbal counting strategies, for most tasks. For example, on 5 + 3, a third of the experimental children, compared to a fifth of the comparison children, used objects, and a almost a fourth of the experimental children, compared to a fifteenth of the comparison children, used verbal ,

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package that is motivating for children but, unlike were efficacious, but other approaches to these topics might also be studied. In contrast, results on such topics as congruence, turn, and measurement indicate that future research should ascertain whether the small number of experiences (1-2) or the nature of of method 10, *Summative Research: Large Scale,* which we are implementing in the 2003-2005 school years. Finally, the quantitative results reported here will be complemented and extended in corresponding studies of the same classrooms involving four qualitative case studies of children learning in the context of the curriculum. The focus of these analyses was on the children's development through the learning trajectories for the various mathematical topics.

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Table 1

Categories and Methods of Curriculum Research

Categories	*Questions Asked*	*Methods*
I. *A Priori Foundations.* In variants of the research-to-practice model, extant research is reviewed and implications for the nascent curriculum development effort drawn.	What is already known that can be applied to the anticipated curriculum?	Established review procedures (e.g., Light & Pillemer, 1984) are employed to garner knowledge concerning psychology, education, and systemic change in general (method 1, Clements, 2001); the specific subject matter content, including the role it would play in students' development (method 2, Clements, Sarama et al., 2004); and pedagogy, including the effectiveness of certain types of activities (method 3, Clements et al., 1993; Clements & Swaminathan, 1995).
II. *Learning Model.* Activities are structured in accordance with empirically-based models of children's thinking and learning in the targeted subject-matter domain	How might the curriculum be constructed to be consistent with models of students' thinking and learning (which are posited to have characteristics and developmental courses that are not arbitrary, and therefore not equally amenable to various instructional approaches or curricular routes)?	In *method 4,* the nature and content of activities is based on models of children's mathematical thinking and learning (Clements, Sarama et al., 2004; Clements, Wilson et al., 2004; cf. James, 1958; Tyler, 1949). In addition, a set

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qualitative approaches continue to be useful for dealing with the complexity and indeterminateness of educational activity (Lester & Wiliam, 2002).

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Table 3

Means and Standard Deviations for Number and Geometry Subtests by Treatment Group

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Table 3 (continued)

Subtest	Building Blocks Pre	Building Blocks Post	Comparison Pre	Comparison Post	Maximum
Geometry, Measurement, Patterning					
Shape Identification	5.42 (0.92)	7.34 (1.16)	5.66 (0.93)	5.89 (1.42)	10
Composition	1.07 (1.10)	4.47 (1.92)	1.23 (1.36)	2.01 (1.65)	11
Congruence	1.02 (0.38)	1.32 (0.35)	1.05 (0.39)	1.20 (0.52)	2
Construction	0.09 (0.23)	0.61 (0.56)	0.09 (0.29)	0.38 (0.48)	2
Orientation	0.15 (0.21)	0.31 (0.28)	0.08 (0.15)	0.08 (0.14)	1
Turns	0.38 (0.49)	0.41 (0.50)	0.21 (0.42)	0.27 (0.45)	1
Measurement	0.10 (0.31)	0.19 (0.40)	0.08 (0.18)	0.08 (0.23)	1
Patterning	0.50 (0.55)	1.26 (0.78)	0.23 (0.42)	0.73 (0.67)	2
Total	8.79 (2.26)	15.91 (3.81)	8.63 (1.89)	10.64 (3.35)	30

Note. These data are from all 68 children; 7 children missed some subtests. Therefore, the average totals differ slightly from those in Table 2 in some cases.

Table 4

Percentage of Children Using Strategies by Treatment Group

	Number			
	Experimental		Comparison	
	Pre	Post	Pre	Post
[Show 2 cubes and ask] How many?				
Re				

Table 4 (con't)

	Geometry	
	Experimental	Comparison

Figure Captions

Figure 1. Hypoth[redacted]*ing trajectory for addition, i*[redacted]*evelopmental levels,*

examples of think[redacted]ocks *activities*

Figure [redacted]

Figure 1

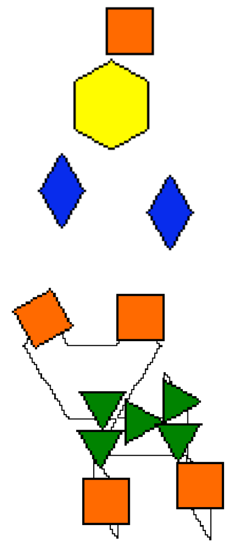
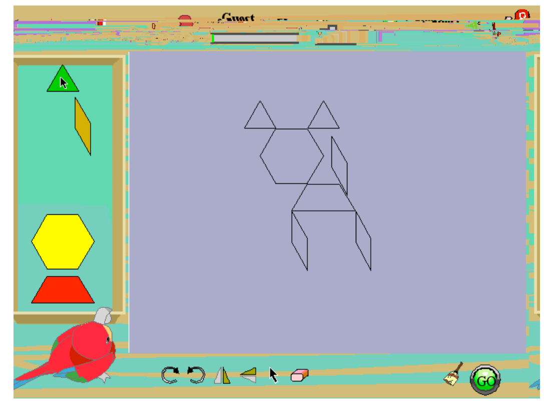
Level	*Behavioral Example*	*Instructional Task*
Non-Verbal Addition. Children reproduce small (< 5) sums when shown the addition of subtraction of groups of objects (Mix, Huttenlocher, & Levine, 2002).	After watching 2 objects, then 1 more placed under a cloth, children choose or make collections of 3 to show how many are hidden in all.	“Mrs. Double” puts 3 chips, then 1 more, on a cookie under a napkin. Children put the same number of chips on the other cookie.

Find Result. Children solve "join, result unknown" problems by direct modeling—"separating from" for subtraction or counting all for addition, with sums to 10 (Carpenter et al., 1993; Clements & Conference Working Group, 2004; Fuson, 1992a).	"You have 3 red balls and 3 blue balls. How many in all? Child counts out 3 red, then counts out 3 blue, then counts all 6.	Children play with toy dinosaurs on a background scene. For example, they might place 4 tyrannosaurus rexes and 5 apatosauruses on the paper and then count all 9 to see how many dinosaurs they have in all. 
Find Change. Children solve "change unknown" word problems by direct modeling. For example, they might "add on" to answer how many more blocks they would have to get if they had 4 blocks and needed 6 blocks in all (Clements & Conference Working Group, 2004).	"You have 5 balls and then get some more. Now you have 7 in all. How many did you get? Child counts out 5, then counts those 5 again starting at one, then adds more, counting "6, 7," then counts the balls added to find the answer, 2.	Mrs. Double tells children the cookie has 5 chips, but should have 8. She asks them to "make it 8." 

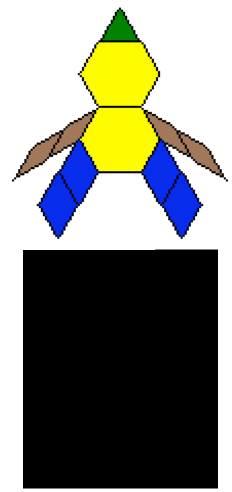
Counting On. C

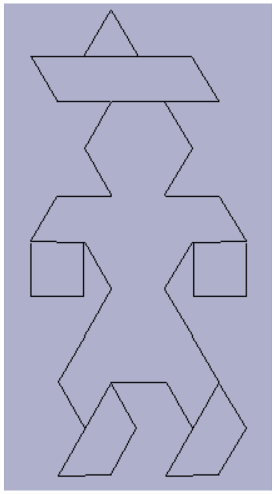
developing their counting methods even further, often using objects to keep track. Such counting requires conceptually embedding the 3 inside the total, 5 (Baroody, 2004; Carpenter & Moser, 1984; Fuson, 1992b).	"Fourrrrr…five [putting up one finger], six [putting up a second finger], seven [putting up a third finger]. Seven!"	chocolate chips. The teacher asks them to put 5 chips on their cookies, and then asks how many they would have in all if they put on 3 more. They count on to answer, then actually put the chips on to check.

Figure 2

Level	*Examples (above, free-form pictures; below, puzzles)*	*Instructional Task*
Pre-Composer. Children manipulate shapes as individuals, but are unable to combine them to compose a larger shape. In free form—"make a picture"—tasks, shapes often do not touch (upper picture in middle column). In puzzle tasks, shapes do not match simple outlines (lower picture in middle column). The instructional task (illustrated on the computer in the last column; similar tasks are presented with manipulatives and paper outlines or wooden form puzzles) uses outlines in which children can simply match shapes without turn or flip motions. (This and subsequent levels emerged from the same body of research, Clements, Wilson et al., 2004; Mansfield & Scott, 1990; Sales & Hildebrandt, 2002; Sarama et al., 1996.)		
Piece Assembler. Children can place shapes contiguously to form pictures. In free-		

Picture Maker. In free-form tasks, children can concatenate shapes to form pictures in which several shapes play a single role, but use trial and error and do not anticipate creation of new geometric shapes. For puzzle tasks, children can match by a side length and use trial-and-error (a "pick and discard" strategy). Instructional tasks have "open" areas in which shape selection is ambiguous.





Shape Composer. Children combine shapes to make new shapes or fill puzzles, with growing intentionality and anticipation. Shapes are chosen using angles as well as side lengths. Eventually, the child considers several alternative shapes with angles equal to the existing arrangement. Instructional tasks (here, solving similar problems multiple ways) encourage higher levels in the hierarchy not described here, involve substitutions (three higher levels are described in Clements, s

Figure 3

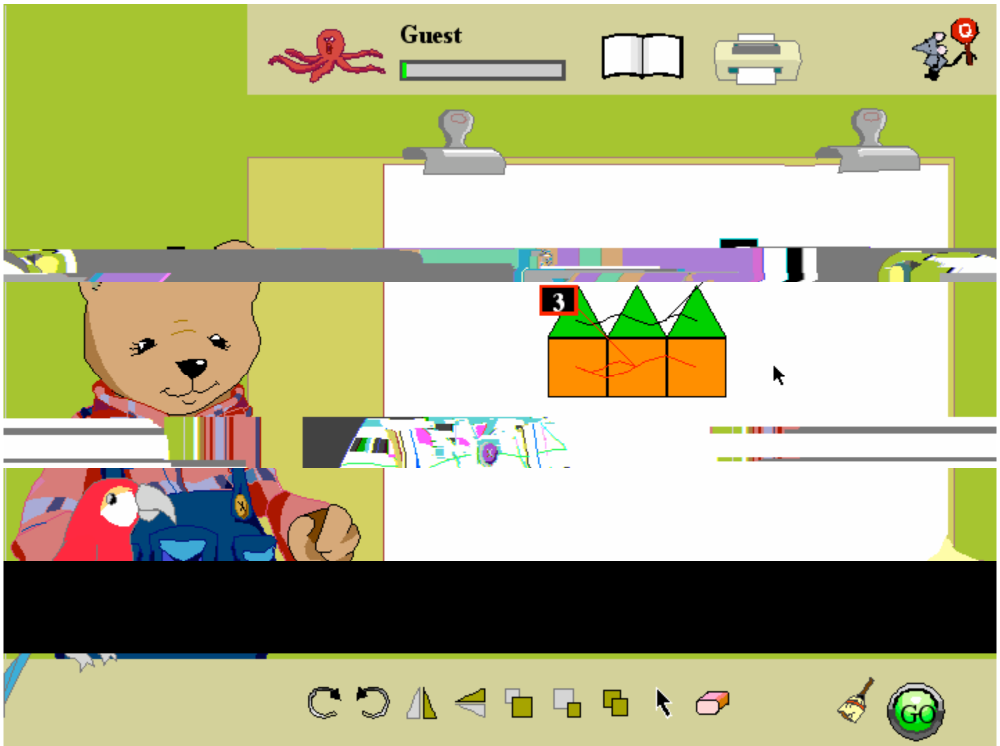
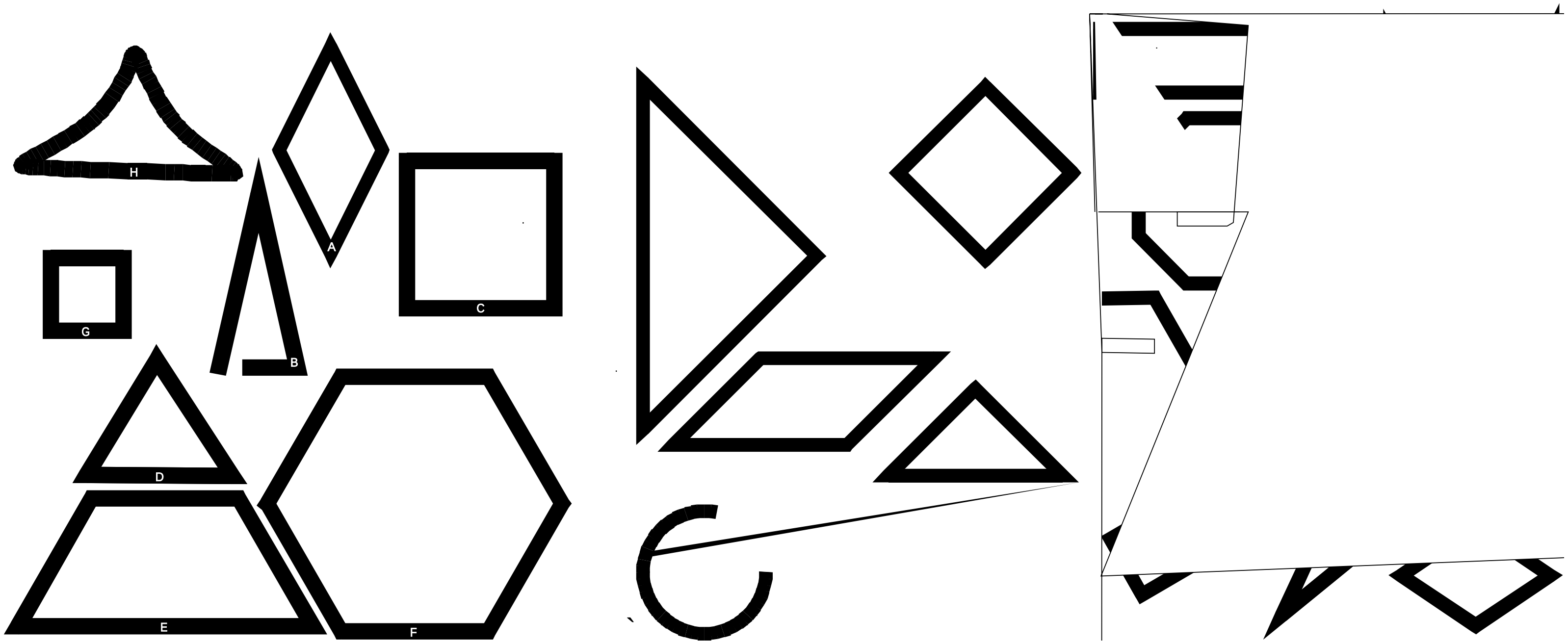


Figure 4

a.



b.