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Accelerating Math Development in Head Start Classrooms

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Teachers implemented a 6-week classroom intervention designed to promote emergent math skills and math interest in preschool-aged children. Teachers in experimental classrooms incorporated math-relevant activities into their daily routine during circle time, transitions, mealtime, and small-group activities. Control classrooms engaged in their typical activities. After the program, experimental children scored significantly higher than control children on a standardized test of math ability and enjoyed math activities more than the control children, as measured by both teacher and self-report. Teachers rated the program as highly satisfactory and reported that they increased their own enjoyment and skill in implementing math activities in their classrooms. The intervention effects were largely accounted for by substantial gains by boys, whereas girls showed much smaller program response.

Math skills are critical to many science and technology careers (Clark, 1988), and math deficiencies limit students' career options (Eccles, 1997). General worry has been expressed about poor performance among U.S. children (e.g., Geary, 1996), with particular concern about math development in girls and low-SES (socioeconomic status) children (e.g., Eccles, 1997; National Science Foundation, 1996). Women compose only 8% of engineers and 20% of physical scientists (National Science Foundation, 1996), and low-SES groups are even more vulnerable to poor math attainment (Rech & Stevens, 1996). Because math-oriented jobs tend to be well paid, these patterns contribute to the gender gap in salaries and to chronic cycles of poverty. In addition to the economic consequences of poor math achievement, poor school performance puts children at risk for mental health problems (Caspi, Elder, & Bem, 1987; S. S. Feldman & Wentzel, 1990; Hinshaw, 1992; Kazdin, 1985; Tremblay et al., 1992). Thus, it is important to understand factors that influence math success and underachievement. It is thought that such factors are malleable but begin to operate from an early age: Potentially changeable parent, school, and community variables have been linked to young children's math development, and early skills are predictive of later math achievement.

Both general parent attitudes, such as expectations for math success, as well as specific parent behaviors, such as monitoring and scaffolding, predict children's math development (e.g., J. R. Campbell & Mandel, 1990; Entwisle & Alexander, 1992; Halle, Kurtz-Costes, & Mahoney, 1997; Huntsinger & Jose, 1995; Jacobs, 1991; Jimerson, Egeland, & Teo, 1999; Parsons, Adler, & Kaczala, 1982; Pratt, Green, MacVicar, & Bountrogianni, 1992). Time spent in quality day care, measured in terms of a low child–teacher ratio, teacher training, physical characteristics, and general atmosphere, is associated with differential math outcomes (Field, 1991). Structural family and community factors, such as single-parent status, availability of math materials, and school segregation, are also associated with math achievement (e.g., Entwisle & Alexander, 1992, 1997; Pong, 1997; Young-Loveridge, 1989). Because all of these variables are potentially changeable, these literatures suggest that math achievement may also be malleable (Lytton, 2000).

The early stages of math development appear to be important, as early skills predict later achievement (e.g., Jimerson et al., 1999; Stevenson & Newman, 1986). For example, Stevenson and Newman (1986) found that prekindergarten math achievement scores correlated .46 with 10th-grade math achievement. SES differences in math skills emerge at an early age (e.g., Jordan, Huttenlocher, & Levine, 1992; Secada, 1992), and recent studies suggest that preschoolers are more able to learn mathematics than previously believed (e.g., Greenes, 1999). The National Council of Teachers of Mathematics (NCTM, 2000) recently summarized this literature by concluding that "the foundation for children's mathematical development is established in the earliest years" (p. 73) and recommending that math instruction begin in preschool. Others have also called for improved math instruction support and training for child-care providers, particularly in low-SES communities (e.g., McDill & Natriello, 1999).

Despite this increasing focus on early math skills, much remains to be learned about young children's math development. Studies have overemphasized Anglo samples, and little is known about preschool teachers' role in promoting math skills. All of the previously noted research is correlational; there exists little experimental evidence documenting a causal connection between early experiences and math development, and to our knowledge, only one empirical evaluation of a math intervention for preschool-aged children has been published (Clements, 1984). Several studies of comprehensive early intervention programs did include later math outcomes, demonstrating that improved math skills accompanied other gains. For example, F. A. Campbell, Pungello, Miller-

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Johnson, Burchinal, and Ramey (2001) found that children who participated in a full-time, high-quality preschool program (with no noted math emphasis) at Age 3 had greater math achievement at Age 21, compared with children who received no extra intervention. Reynolds and Temple (1998) found that participants in an extended early-childhood intervention program had higher math achievement in Grade 7. Such studies support the notion that math outcomes are malleable and that early intervention can have lasting effects. At the same time, these interventions were comprehensive and very broadly targeted, so it is difficult to determine processes through which math skills were affected. In fact, these gains might be accounted for by general changes in overall cognitive abilities rather than specific math learning (e.g., F. A. Campbell et al., 2001). Further, such comprehensive interventions may be of limited value to existing programs looking to specifically target emergent math skills within the context of an established curriculum.

In addition to the need for an empirically tested program to promote preschoolers' math skills, motivational factors warrant greater recognition in models of general academic achievement and specific math achievement (Reynolds, 1989; Wigfield et al., 1997). The educational community believes academic interest to be critical: In a poll of 350 educators, creating academic interest was rated as the most important problem in all of education (O'Flahavan et al., 1992). Academic interest has been understudied among early intervention researchers, though extant research is consistent with its importance. In studies of older children, attitudes toward math are related to math success (Lester, Garofalo, & Kroll, 1989; Ma, 1997; Renninger, 1991). Interest predicts later grades and course level (Schiefele & Csikszentmihalyi, 1995), and children's cognitive skills in kindergarten predict later math interest (Stevenson & Newman, 1986). With preschool children, there is no research to date on the relationship between math interest and achievement, but early interest is an important predictor of later skills (Crain-Thoreson & Dale, 1992; Manning & Manning, 1984; Scarborough, Dobrich, & Hager, 1991; Stipek & Ryan, 1997; Thomas, 1984; Wells, 1985). This interest might be fostered (Ortiz, Stowe, & Arnold, 2001). In sum, the relationship between interest and ability has not been examined extensively enough to understand causality or the mechanisms through which these variables interact (Efklides, Papadaki, Papantonious, & Kiosseoglou, 1997; Ma, 1997; McLeod, 1994). However, a variety of sources have called for increased investigation of the contribution of interest to academic success (e.g., O'Flahavan et al., 1992; Scarborough & Dobrich, 1994; Schiefele, 1991; Skinner, Wellborn, & Connell, 1990; Wentzel, Weinberger, Ford, & Feldman, 1990).

Thus, an experimental means of increasing interest would serve as an invaluable research tool to increase understanding of the processes and causal paths associated with academic interest. An early math intervention program that promoted interest as well as skills might also be more likely to have a long-term practical impact (Ruble & Flett, 1988), because subject interests may not yet be entrenched (Wigfield et al., 1997) and individual differences in numerical ability not yet magnified (Morrison, McMahon, & Williamson, 1993). Additionally, though there is little research on the role of motivational variables with low-income children, Stipek and Ryan (1997) did find that interest variables affected economically disadvantaged children more strongly than economically advantaged children, and girls seem to show a stronger relationship than boys between interest in math and career choice (Post, Stewart, & Smith, 1991). Interest may be a key leverage point in addressing the SES gaps and gender gaps described previously. Because interest measures at this age have less established validity than assessments of skills and are likely more prone to error variance and bias, a multimethod approach to assessing interest is critical.

In the present study, we focus on preschool as a potential mechanism for promoting early math skills and interest. Preschools provide a means of reaching large numbers of children, with enrollment rapidly increasing. In particular, Head Start serves great numbers of disadvantaged children who are at increased risk for math failure, and so we focused our math intervention on this setting. The goal of the study was to promote children's emergent math development by incorporating math-relevant activities into classrooms' daily routines. We designed our math intervention to be easily incorporated into existing programs and to be practical and not overly time consuming. Even brief, well-targeted interventions can have substantial effects (e.g., Arnold, Lonigan, Whitehurst, & Epstein, 1994; Whitehurst et al., 1994). Another goal was to foster teachers' enjoyment and confidence in math teaching to promote continued program use. If successful, such an intervention would provide the first experimental evidence that preschool teachers can affect math development and could be an important step toward promoting children's math development and facilitating study of the processes and causal mechanisms of emergent math learning.

Method

Participants

One-hundred twelve children (64 girls) from eight classrooms in two Head Start centers participated. Six of these classrooms were half-day classrooms, the other two were full-day classrooms. Basic demographic and attendance information was obtained from children's files. Children averaged 53.18 months of age at pretest (range = 37 to 64, $SD = 7.32$). Forty-five of the children are Puerto Rican, 44 are African American, 11 are Anglo American, 6 are Asian (3 Chinese and 3 Vietnamese), and 6 are biracial (5 African–Anglo American, 1 African American–Puerto Rican). Head Start income eligibility requirements are made by reference to the official federal poverty line (e.g., $14,150 for a family of three for the year 2000; Administration for Children and Families, 2000). The actual median family income reported for this sample was $13,229. The 16 teachers from these classrooms, all female, participated. Six of these teachers are Puerto Rican, six are Anglo American, two are African American, and the ethnicity of two is unknown. Teachers were paid $15 per hour for completing assessment questionnaires; they volunteered their time to be trained in the intervention program.

Procedure

Children were individually administered a standardized test of emergent math skills and an interest in math activities assessment by doctoral psychology students. Teachers completed two surveys about children's interest in math activities and a survey about their own attitudes toward teaching math. Classrooms were then matched on full- versus half-day status and on morning-versus-afternoon hours, within centers, and one of each matched pair was randomly assigned to the intervention condition. After teachers were trained in the intervention, they implemented the program for 6 weeks, during which time they tracked and rated their use of the various math activities. Each assessment was repeated after the intervention ended, and experimental teachers also completed a questionnaire about program satisfaction and feasibility.

Measures

Test of Early Mathematics Ability (Second Edition; TEMA-2). Children's emergent math ability was assessed with the TEMA-2 (Ginsburg & Baroody, 1990), which took approximately 20 min per child to administer. This test includes, at the preschool age, items measuring concepts of relative magnitude, counting, calculation, and number facts. This measure was chosen because it has good psychometric properties and covers a wide range of items at the early stages of math development, appropriate for children as young as Age 3. The TEMA-2 is reliable, with internal consistency and test–retest estimates of .94. The test relates to other standardized measures of math achievement and differentiates children who are struggling in math (Ginsburg & Baroody, 1990). In our own sample, pretest TEMA-2 scores correlated .95 with posttest TEMA-2 scores for the control children, suggesting that the assessments provided a reliable measure of children's math abilities in the present study. One departure from standard administration was made to facilitate item analyses: All children were administered Items 4–12 of the test and Item 17 (how high children can count), even if they reached ceiling before these items were administered, to ensure all children would have these items in common. However, scores were calculated in the typical, standardized fashion. One-hundred three of the 112 children had TEMA-2 data at pre- and posttest and so were included in the TEMA-2 analyses (the other 9 children were missed because of attendance problems).

Child interest: Teacher report. Teachers completed the Level of Interest Survey (LIS), on which they rated from 1–7 how interested each child in their class was in sorting toys, counting activities, number–manipulative activities, and math activities overall. Also, in an attempt to lessen demand characteristics, teachers completed the Relative Interest Survey (RIS), on which they rank ordered, for each child, the child's relative preference for 10 different common activities such as balls, circle time, and pretend play. Included in the 10 activities were sorting objects and number–manipulative activities, designed to serve as measures of math-relevant interest. Although relative interest may be difficult to influence, previous research suggests that this method of assessment may serve as a valid, less obvious measure of child interest (Ortiz et al., 2001). We considered each measure separately, but also created an aggregate measure of teacher-reported child interest, called the Overall Teacher Interest Survey (OTIS), because aggregated measures reduce error variance (e.g., Schwarz, Barton-Henry, & Pruzinsky, 1985) and should provide the most accurate assessment of interest. The LIS sorting item was omitted because it was related to neither other items nor TEMA-2 scores. Thus, the OTIS was created by standardizing and summing across the other 5 teacher-interest items. The OTIS had acceptable reliability, with a pretest coefficient alpha of .72 and test–retest reliability of .62. In addition, teacher agreement on the OTIS was reasonable (intraclass correlation = .70), providing some evidence both for the reliability and validity of the measure. Finally, the measure correlated .64 with TEMA-2 scores at pretest, providing evidence for construct validity.

Child interest: Child report. Children reported on their own interest in specific math toys and in numbers more generally with the Children's Math Interest Self-Report (CMIS). This assessment was based closely on the Feelings about School assessment that was developed by Stipek and colleagues, who have demonstrated adequate reliability and validity (Stipek, Feiler, Daniels, & Milburn, 1995; Stipek & Ryan, 1997). Prior to the assessment, children were trained to indicate how much they like different activities with two practice items: "How fun is playing outside?" and "How fun is falling down and getting hurt?" Children pointed at one of five faces that ranged from having big frowns to big smiles. Children supplemented their pointing with verbal reports, to help the experimenter assess children's understanding of the scale. In 13 pretest cases, even after training, children did not understand the procedure. The experimenter noted this fact, and these children were not included in the CMIS analyses. After training, children were given three math toys to play with for up to 10 min each: sorting animals of different types and colors, felt numbers and shapes with a felt board, and a matching card game with numbers and corresponding objects. After playing with the toys, children were asked to indicate how fun each activity was. Then they were asked more generally how fun numbers are. Responses were scored from 1–5 and summed across the 4 items to create an index of children's interest in math-relevant activities. Coefficient alpha was .62 for this measure, and test–retest reliability was .33. CMIS scores were not related to TEMA-2 scores at pretest ($r = .06$).

Teacher attitudes about math. Teachers were asked to rate the extent to which: (a) "Math readiness has been the most fun part of my teaching" (from 1 [*not that fun*] to 10 [*most fun*]) and (b) "Math readiness has been the thing I am best at teaching" (from 1 [*not my best*] to 10 [*my best*]).

Intervention tracking. Teachers in the intervention group charted the activities they tried with daily tracking forms, which were designed to take less than a minute per activity to complete. Teachers indicated the specific activity or activities they tried each day and whether they found each activity *extremely good*, *good*, *ok*, or *not good*. In addition to providing an index of how much teachers liked the activities, these forms allowed for a measure of intervention exposure to be created for each child by multiplying the percentage of days each child attended school by the number of activities implemented per day by their teacher.

Program satisfaction and feasibility. After the intervention, experimental teachers were asked to rate from 1 (*not at all satisfied*) to 10 (*completely satisfied*) their "overall satisfaction with this program." They were also asked to rate the program's practicality with the question, "Given all of the other responsibilities that you have, how able were you to implement the intervention activities?" (from 1 [*not able to do anything*] to 10 [*was able to do everything*]).

Intervention

The intervention strove to incorporate math into the regular classroom routine. The activities were designed to be fun for the children and to provide choices and flexibility for the teachers. Teachers chose from a wide variety of suggested math-relevant activities, adapted these, or created their own. This design enabled teachers to match the program to their own styles and their children's abilities and interests. The programs were structured around specific times of the day, with an initial 3-week unit for circle time, and then a second unit with 3 weeks of activities for small groups and for transitions and meal times (circle-time activities were continued as desired). Teachers were asked to implement at least one activity each day during the first unit, and two transition and mealtime activities and one small-group activity per day during the second unit. The teachers used their discretion in adjusting the length of activities depending on children's interest. Teachers were encouraged to repeat activities that seemed beneficial and enjoyable. Teachers attempted to have all children participate in the small-group activities.

The program content was presented in an activity book with a total of 85 choices. This large number was provided because pilot work in other classrooms suggested that children and teachers differ widely in their interests and that children vary in their developmental levels. The activities used a range of approaches (e.g., books, music, games, discussions, and group projects) designed to be interesting and relevant to target the following skills that the literature suggests are important (e.g., Baroody, 1987; Donlan, 1999; Shane, 1999): counting, recognizing and writing numbers, one-to-one correspondence, comparison, change operations, and understanding numbers and quantity. Some of the activities were based on previously published curriculum (Althouse, 1994; Copley, 1999, 2000; Croft & Hess, 1980; Cryer, Harms, & Bourland, 1988; J. Feldman, 1995; Kurth, 1996; Larson, Henthorne, & Plum, 1994; Rogers, 1983; Trencher, 1976; University of Chicago School Mathematics Project, 1998; Waite-Stupiansky & Stupiansky, 1992). Other activities were generated by brainstorming sessions of our research group. Examples for circle time include finding objects that are bigger and smaller than the children, creating bar graphs with pictures of each child (e.g., of eye color), adding circles to a caterpillar based on dice rolls, and partner-matching based on paired paper-strip lengths or dot numbers. Examples for transitions include lining up by numbered footprints or counting the number of steps it takes to get outside. Small-group examples include baking pretzels in the shape of numbers, number scavenger hunts, and estimation guessing games. Mealtime examples include choosing seats by identifying numbers and counting quantities of food while being served. The Appendix provides two example activities to give a sense of the format of the activity suggestions.

Teacher training involved one 2-hr meeting prior to the start of the intervention. The meeting primarily emphasized process information in terms of implementing activities with four overriding principles: (a) encouraging–praising, (b) keeping it fun, (c) following the children's lead and adjusting the activities to you and your kids, and (d) labeling what children do to provide feedback and scaffolding. The meeting emphasized practical plans for implementing these principles, with specific examples and strategies. Teachers were also taught to help children learn the process of problem solving, with examples and discussions of specific ways to encourage this, in the context of an example activity. Once each week, a member of the research team briefly checked in with teachers to address any aspect of the program that was not progressing smoothly. In most cases, these check-ins lasted only a minute or two, but occasionally teachers asked for more guidance choosing activities, preparing materials, or generating ideas for improving activities. Teachers monitored and rated their use of the activities with daily tracking sheets. Following the intervention, experimental teachers gathered as a group to provide feedback on the program.

Results

Descriptive Information at Pretest

Table 1 presents descriptive information about the primary study variables for the experimental and control groups. Average TEMA-2 raw scores at pretest were 7.82 (*SD* = 6.12), or in standard scores, 89.07 (*SD* = 11.92). This corresponds to approximately the 23rd percentile compared with national norms. This slight delay is consistent with the disadvantages associated with poverty. Scores were similar for girls and boys (p = .62) and almost identical for children in the control and experimental groups (p = .85). Test scores for Puerto Rican children were somewhat lower than for African American or Anglo American children (*M* = 5.68, 8.28, and 8.30, respectively), $F(2, 88) = 2.44$, p = .09, which is not surprising given that the tests were administered in English. Because this sample included only 6 Asian and 6 biracial children, they were not included in this formal ethnicity analysis. However, consistent with previous studies suggesting an emphasis on math in many Asian cultures (J. R. Campbell & Mandel, 1990; Geary, Bow-Thomas, Liu, & Siegler, 1996; Huang & Waxman, 1995; Stevenson, Chen, & Lee, 1993), the Asian children's scores were higher (*M* = 14.50) than the other groups' scores.

With respect to child interest in math at pretest, teacher's reports on the LIS indicated moderate levels of interest in number activities (*M* = 4.53 of 7, *SD* = 1.44), counting activities (*M* = 4.67, *SD* = 1.21), and overall math-activity interest (*M* = 4.39, *SD* = 1.21). In terms of interest relative to other activities, teachers reported on the RIS that both sorting and number–manipulative activities were, on average, approximately children's 5th favorite activity from the list of 10 choices (*M* sorting choice = 4.74, *SD* = 1.79; *M* number–manipulative choice = 5.04, *SD* = 1.90). Children reported high liking of the math toys at pretest, with an average pretest score of 4.18 (*SD* = .89) of 5 on the CMIS. No significant differences between experimental and control children's interest were observed on the OTIS (p = .37) or on the CMIS (p = .21).

Teachers reported moderate levels of enjoyment (*M* = 5.33 of 10, *SD* = 2.64) and skill (*M* = 4.75, *SD* = 2.22) on the teacher math-attitude survey; pretest differences between control and experimental teachers' ratings of enjoyment and skill in teaching math were not significant.

Intervention Tracking, Satisfaction, and Feasibility

The daily tracking forms suggest that teachers used the math program on a regular basis, with an average of 1.7 activities per

Table 1
Means and Standard Deviations of the Central Variables of the Study by Experimental Condition

	Experimental group				Control group			
	Pre		Post		Pre		Post	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Child skills and interest								
TEMA-2 scores	7.93	5.72	11.59	6.33	7.69	6.60	8.53	7.56
OTIS scores	−0.36	2.83	0.15	3.78	0.43	4.11	−0.13	3.55
CMIS scores[a]	4.08	1.03	4.26	0.93	4.32	0.68	4.16	0.80
Teacher attitudes[b]								
Math is fun.	4.00	1.26	7.75	2.27	7.60	2.30	5.80	1.79
I'm good at teaching math.	3.83	0.98	6.33	1.21	6.60	1.82	5.80	2.17
Attendance and implementation								
Percentage of days at school			85.20	13.50			89.60	11.90
Intervention activities done per day			1.70	0.23				
Overall program satisfaction[c]			9.50	2.27				
Practicality of intervention[c]			8.00	1.51				

Note. TEMA-2 = Test of Early Mathematics Ability (Second Edition); OTIS = Overall Teacher Interest Survey; CMIS = Child Math Interest Self-Report; Pre = pretest; Post = posttest.
[a] Scale ranged from 1 to 5. [b] Scale ranged from 1 to 10. [c] Scale ranged from 1 to 10. Score given is the median.

day. Teachers reported that 80% of the activities were either excellent or very good. Eighteen percent were good, and only 2% were either mediocre or poor. Consistent with this daily tracking, teachers reported a median overall satisfaction rating with the program of 9.5 of 10, indicating very high levels of satisfaction. Informally, the teachers reported that the children were quite excited about the activities and that children's interest in math had generalized to other situations. For example, one teacher reported that "the children used to just put the counting bears in a cup and pretend they were coffee—now they love to sort and count them." With respect to the question, "How able were you to implement the program?," the median response was 8 of 10, suggesting that teachers found the program practical to use, consistent with their reports and plans to continue using the activities.

Intervention Effects

TEMA-2. Scores for children in the intervention group improved substantially compared with the scores for children in the control group. Effects were highly statistically significant regardless of whether raw or standard scores were analyzed, using change scores or an analysis of covariance (ANCOVA) with pretest scores as a covariate (all ps $< .01$). We prefer to present changes in raw scores, because they most directly represent the amount learned. The experimental group improved their TEMA-2 scores by 3.67 points, compared with an improvement of 0.84 points in the control group, $t(101) = 4.64$, $p < .01$. The change is substantively large as well as statistically significant; the experimental group learned more than four times the amount of the control group, with the effect size of 1.21 (with respect to change scores) corresponding to a large effect under Cohen's (1977) rules of thumb for evaluating effect sizes. The standard deviation of change was larger for the experimental than for the control group (3.64 vs. 2.34, $p < .01$), suggesting variability in response to the intervention. Within the experimental group, our exposure to the intervention variable did not significantly predict changes in TEMA-2 scores ($r = .09$, $p = .53$).

Response to the intervention significantly varied as a function of gender. Boys in the experimental group exhibited greater TEMA-2 change than did girls (4.79 vs. 2.77), $t(52) = 2.10$, $p = .04$. In terms of standard scores, boys gained 7.71 standard score points, whereas girls' math quotients remained unchanged, $t(52) = 3.01$, $p < .01$. Girls in the experimental group did improve more on the TEMA-2 than girls in the control group (2.77 vs. 0.81), $t(59) = 2.88$, $p < .01$. There was no difference between control girls' and control boys' change on the TEMA-2 ($p = .90$).

Response also varied as a function of ethnicity (on the basis of an analysis of variance comparing African American, Puerto Rican, and Anglo American children), $F(2, 42) = 3.33$, $p < .05$. This was accounted for by Anglo American children showing less improvement (M change $= 0.57$) than Puerto Rican ($M = 4.14$) or African American ($M = 3.19$) children. Although the 3 Asian children from the experimental group were not included in this analysis of variance for reasons of power, they improved more than children in the other groups ($M = 8.33$) despite already being above the mean at pretest. Response did not vary as a function of age ($r = -.05$, $p = .70$), and response differences across intervention classrooms were not significant, $F(3, 50) = .52$, $p = .67$.

To provide a preliminary picture of specific areas that the intervention influenced, the intervention and control groups were compared on individual TEMA-2 items. Such an item analysis should be interpreted cautiously and is intended only to give a general sense of the areas of change. One item (Number 17) involves asking children to count as high as they can, so change on this item was analyzed using all children, with a t test, $t(101) = 2.09$, $p = .04$. For the other, right–wrong items, learning was compared across groups with a chi-square for children who did not correctly answer the item at pretest. Table 2 presents the items on which the treatment group learned significantly more than the control group. Children in the experimental group learned significantly more on items that include the following areas specifically targeted by the intervention: counting, being able to identify "more," reading numbers, and writing numbers.

Child interest: Teacher report. Changes in children's level of interest were compared in experimental-versus-control children using ANCOVAs that controlled for children's attendance record and their gender, because these variables were expected to account for variance in interest. Children in the experimental group showed changes in OTIS scores compared with the control group, $F(1, 107) = 3.82$, $p = .05$. With respect to specific items, experimental children showed higher LIS scores on number activities, $F(1,$

Table 2
TEMA-2 Items That Experimental Children Were More Likely to Learn Than the Control Group

Item	Description	Control	Experimental	p
5	Counting stars	4/18 (.22)	14/26 (.54)	.03
6	Remembering number counted	3/33 (.09)	17/37 (.46)	< .01
7	Number stays constant when blocks shuffled	7/42 (.17)	16/44 (.36)	.04
9	Displaying 3, 5, and 4 fingers	7/33 (.21)	17/37 (.46)	.03
10	Counting 10 blocks	5/15 (.33)	10/14 (.71)	.04
12	Reading numbers	7/43 (.16)	18/44 (.41)	.01
17	Counting out loud			.04
18	What number is next (e.g., after "23, 24")	1/44 (.02)	8/54 (.15)	.03

Note. Numbers represent the number of children who got the item correct divided by the number of children who got the item incorrect, at posttest. Only children who missed the item at pretest are included. Numbers in parentheses represent the percentage of children who learned the item. Because Item 17 asked children to count as high as they could, this was evaluated with a t test. Children in the experimental group counted to 18.13, on average, at posttest, compared with 15.51 in the control group, compared with 12.72 and 13.14, respectively, at pretest.

107) = 7.20, $p < .01$, whereas differences on counting activities, $F(1, 107) = 3.44$, $p = .07$, and overall math interest, $F(1, 107) = 2.82$, $p = .09$, approached significance. With respect to relative interest, experimental children showed increased RIS scores on sorting activities compared with control children, $F(1, 108) = 5.76$, $p = .02$, although differences on number–manipulative toys were not significant ($p = .44$). Experimental response on OTIS scores was not significantly predicted by gender, ethnicity, or age. Exposure to the intervention did predict the amount of change in OTIS scores ($r = .39$, $p < .01$).

Child interest: Child report. Significant changes were observed on child-reported interest in the toys, $F(1, 86) = 4.54$, $p = .04$, with experimental children increasing their interest by an average of .20 on the CMIS and control children decreasing their interest by the same amount. Experimental response in child-reported interest was not significantly predicted by gender, ethnicity, or age. The relationship between CMIS response to the intervention and exposure was not statistically significant ($r = .18$, $p = .20$).

Teacher attitudes. Teachers in the experimental group reported significant changes in their feelings of liking and competence about math at posttest, compared with pretest (both ps $< .02$) and compared with the control teachers (both ps $< .09$). They described math as more fun to teach (4.00 of 10 at pretest vs. 7.75 at posttest) and reported that they felt they had improved their teaching of math (3.83 vs. 6.33).

Discussion

Children receiving the intervention improved their emergent math skills compared with the control group, consistent with recent work suggesting that preschoolers are developmentally ready to learn math (Greenes, 1999; NCTM, 2000). Experimental children also showed increased interest in math compared with control children on both teacher and child reports.

The finding that the intervention benefited boys much more than girls was not predicted and so should be repeated. Assuming replication, at least three possible explanations may account for these results. It might be that teachers differentially implemented the program with boys. Boys receive more general attention from preschool teachers than girls (Fagot, Hagan, Leinback, & Kronsberg, 1985; Serbin, O'Leary, Kent, & Tonick, 1973; Stipek & Sanborn, 1985), and this "invisible girl" phenomenon (Morgan & Dunn, 1988) could lead girls to get less program attention. Math-specific gender differences in teacher instruction have been demonstrated as young as second grade (Leinhardt, Seewald, & Engel, 1979) but have not been examined in preschoolers. Second, perhaps some aspect of the program appealed more to boys than to girls. Girls tend to prefer math strategies that involve manipulatives compared with boys, whereas boys tend to prefer using memory and spatial representation to solve math problems (Carr & Davis, 2001; Carr & Jessup, 1997; Fennema, Carpenter, Jacobs, Franke, & Levi, 1998). Perhaps the group activities required cognitive strategies that better matched boys' preferences. Finally, it is possible that child characteristics drove the differential response. For example, boys may have been more assertive in participating in the activities. Consistent with possible child effects, older boys' different beliefs about teachers are associated with math development (Carr, Jessup, & Fuller, 1999).

These possibilities are not mutually exclusive. We examined the teacher tracking sheets to look for patterns in the activities chosen that might help distinguish between these possibilities. No clear pattern of individual-versus-group or of manipulative-based-versus-mental activities was found, leaving the reason for this gender difference unclear. Gender performance differences in children this young have not been reported previously and were not present in the present sample prior to the intervention. These findings point to the importance of not inadvertently creating such differences as earlier math interventions are developed. Understanding the role of gender will be critical toward ensuring that interventions ameliorate rather than exacerbate the gender gap in math achievement. Process studies should elucidate the reasons for the gender differences.

Puerto Rican and African American children demonstrated larger treatment gains than Anglo American children. The larger gains of Puerto Rican children might be a function of the extensive English learning that is likely occurring. It is less clear why African American children showed greater gains than Anglo American children. African American children tend to learn especially well in cooperative learning situations (Dill & Boykin, 2000; Haynes & Gebreyesus, 1992; Lucker, Rosenfield, Sikes, & Aronson, 1976) and in activities that use music and/or movement (Allen & Boykin, 1991; Allen & Butler, 1996). Our intervention included some emphasis on these factors, so this could account for the differential response, but this explanation is speculative, so replication and process studies are needed.

Experimental effects were found on teacher and child reports of child interest in math activities. The reliability and validity data for the child-report data are less impressive than for the teacher-report measure, so future studies should try to improve child-reported measures of interest. Nonetheless, poor reliability does not increase Type 1 error, and we found significant treatment effects on children's reports. These findings provide converging evidence that the program fostered interest. Further, the child-report findings lessen the chance that interest changes were due to responding bias, because the children were unaware of our hypotheses.

The relationship between intervention exposure and outcome was in the predicted positive direction for TEMA-2 scores, teacher-reported interested, and child-reported interest, but this relationship was only statistically significant for teacher-reported interest. Given the teachers' uniform enthusiasm, it is possible that amount of exposure has a larger impact on interest than skills, whereas teacher skill in implementation, which we did not measure, might be most critical to skill learning. Alternatively, our measure of exposure was fairly crude, so more carefully measured exposure might predict both skill and interest, particularly if a greater range of exposure were present. We could not examine the relationship between intervention satisfaction and outcomes because of uniform program satisfaction, but if more variability in satisfaction were present this might become important.

This study only included Head Start children, so results cannot be generalized to centers with fewer resources or more advantaged children. Also, the control condition did not equate level of teacher attention. We believe it is unlikely that attention differences account for the intervention effects, because the math activities were incorporated into the usual classroom routine, and the skills assessed are so specific that they seem unlikely to respond to nontargeted attention. Nonetheless, future studies should verify this point. Similarly, the possibility that the program-satisfaction ratings are an artifact of demand characteristics cannot be ruled out. More generally, this study was not designed to examine the processes of change, but such process studies will be critical toward understanding and promoting math development.

Future studies should evaluate longer-term effects of this program. If the effects hold across time, the combined changes in skills and interest might help reverse negative cycles of poor achievement and disengagement. Also, the program could easily be lengthened or adapted as a parallel parent program, which might enhance effects and maintenance.

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Appendix

Two Examples of Activity Choices

Circle Time: Caterpillar

Activity type: Visual representation, discussion, tactile.

Skill targeted: Counting objects, matching number word with quantity, comparison.

Brief description: Make a lot of felt circles that can be used on a flannel board. Two of the circles should have faces on them, as the circles will be used to build two caterpillars. Children are divided into two teams and take turns rolling a die. The number on the die is the number of circles the child adds to their caterpillar (each caterpillar starts with just the face circle placed on the flannel board). After every child has had a turn, children count the number of circles making up each caterpillar to determine which one is longer.

Extension. Talk about the life cycle of the caterpillar. Split the circles into equal groups (talk about counting and concepts of equivalence). Each group of circles can be rearranged into a wing shape so that they look a little like a butterfly, and you can talk about how the number of circles stays the same when you rearrange them.

Small Group: Ice Cream Cone Book

Mealtime: Seating by numbers.

Activity type: Visual representation, auditory.

Skill targeted: Recognizing numerals.

Brief description: Label the tables with numbers. After each child washes his or her hands, give the child a card with a number and have the child match the card to the numbered table setting (you could even just say the number for kids that can understand it without matching).

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