# Effectiveness of a mathematics program for preschoolers in rural Bangladesh

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## Abstract

The purpose of the study was to examine the efficacy of a 9-month comprehensive math program for preschool children with the intention of increasing their math reasoning and skills. From 3 organizations operating preschools in Bangladesh, nine preschools were randomly selected to be in the Intervention group and 9 for the Control group. Twelve children were randomly selected from each preschool to participate in testing, though all participated in the program. A 6-unit program was adapted from an existing one, lesson plans created, and local materials developed. Teachers were trained and regularly supervised. Children in the control group participated in the regular math program offered by that organization. Children's math skills were tested before and after each unit on the skills relevant to that unit. An analysis of covariance on posttest scores, covarying pretest scores, child's age, sex, height for age, mother's education and family assets indicated that Intervention children doubled their scores on almost all tests while control children increased only slightly. The differences and effect sizes were highly significant. On a final 52-item cumulative test, intervention children obtained a mean of 82.7% while control children obtained a mean of 46.6%. The evidence from this evaluation is strong: children in the preschool years can acquire sophisticated math reasoning and operations skills given a challenging and stimulating program.

## Introduction

It is well-established that children from families who are poor and without formal education may not be acquiring an understanding of numbers and patterns at home. Consequently, most preschools offer activities and instruction in numeracy. However, this can vary from 30 minutes per week to 100 or more, with only basic competencies such as counting and shapes being taught. This instruction has been shown to benefit Bangladeshi children somewhat in their school readiness math skills and reasoning (Aboud, 2006) as has the addition of extra learning materials such as blocks (Moore, Akhter, & Aboud, 2008). However, children's math reasoning is still far below what it could be for their age (Moore et al., 2008). This is evident also in the low pass rate for mathematics competencies at the end of primary school (Bangladesh Education Sector Review Report No. 1, 2002). In view of the ongoing efforts to improve preschool programs, the current study evaluated a complete math program for 5-year-olds in preschools.

Prior evaluations of preschool programs in Bangladesh indicate that in some respects they are providing an educational environment of moderate quality. For example, one study found that 22 preschools in rural areas attained an average score of 3.5 on the ECERS with somewhat higher scores on social interaction and lower scores on Activities and Program Structure (Aboud, 2006). After implementing a number of recommendations, 10 pilot preschools reached an average of between 4 and 5 on the latter two subscales (Moore, Akhter, & Aboud, 2008). This was accomplished within a year at an extra cost of only US$1.50 per child. Of interest here is that they provided math bags with manipulatives for each child, increasing the number of games such as memory and puzzles during free play, and training the teachers in responsive talk.

Benefits were passed on to the children who attended the improved preschools in comparison to those who attended the regular program, matched for ECERS score the year before the new program was started. In particular, new-program children showed greater improvements in Block Design and Matrices, both related to visual analytic reasoning and later math skills. However, the levels were still low for children of this age -- the highest mean was 6.3 or 32% on block design. School readiness scores of the former, assessing literacy and math skills explicitly taught to children, differed by very little (*M*s = 22.9 New vs. 21.6 Regular out of 30) even though the former had their own personal math bags. Together, these findings suggested that children were benefiting from new materials but not from new instruction. They were capable of learning much more than the program offered.

Action research conducted during the 7-month implementation of the program indicated some difficulties on the part of teachers to fully use the potential of the math bags. For example, they were used mostly to count and children were required only to repeat what the teacher did and said. This simply repeated what children did in the exercise books and what the teacher did using the blackboard. When shapes were taught, the teacher showed one upright isosceles triangle, so children did not always generalize this to triangles of other orientations and shapes. They rarely applied the skills on their own to new problems. Because teachers are paraprofessionals, they cannot be expected to create new lesson plans on their own. Consequently, the programs must be fully developed prior to training the teachers.

Recently, a 6-week program of math activities was implemented with Plan Bangladesh preschools and evaluated in comparison with the regular program. The activities entailed concepts of numbers, shapes, patterns, measurement, sorting and comparing (adapted from Llewellyn, 2004). They were less didactic than the regular program in that children were required to solve problems and check them. In an intervention-control pre-post design, children who had the math activities made significantly greater gains in math skills than those in the regular program; the effect size was greater than 1 (Opel, Camellia, & Aboud, 2006). The results indicate that with appropriate training, preschool teachers can implement an activity-based math program and children will benefit.

Based on these impressive findings, we were encouraged to develop and implement a full-year program so that children would consolidate the full range of math skills and reasoning before entering primary school. We therefore examined various math programs for preschoolers, namely Big Math for Little Kids (Ginsburg, Greenes, & Balfanz, 2003; Greenes, et al., 2004) and other similar programs (e.g. Sophian, 2004; Starkey et al., 2004). Most provide activities to enhance math concepts related to enumeration, shapes, patterns and their rules, measurement, sorting and classifying, and comparison. There was also some introduction to operations such as addition, subtraction, and concepts underlying multiplication and division. From these programs, we developed activities and materials for rural Bangladeshi children. The objective of the study was to create a math program (Bangladesh Math for Preschoolers) and evaluate its effectiveness.

## Ethical Considerations

Scientific and ethical approval of the protocol was provided by a review committee of academics and researchers in this field convened by BRAC University's Institute of Educational Development. Permission was obtained from the organizations (Save the Children US, BRAC pre-primary, Plan Bangladesh,) who implemented the preschool programs, from the teachers who implemented the math activities, and from the mothers of children who contributed data to the evaluation. Data were kept confidential, names removed at the end, and outcomes did not have a bearing on the child's school records.

## Method

### *Design and sample size estimation*

The design of the study was a pre-post assessment of intervention and control groups to evaluate the outcome of the math program. Using an alpha of .05 and power of .80, the sample size should be 80 per group to find a difference of .5 SD (standard deviation based on prior studies was set at 7, and Mean of 20 on a 30-item test). To allow for attrition due to the drop out of students and the temporary closure of schools due to flooding, we aimed to recruit 100 students from 9 preschools in each group.

This design has some limitations as it was randomized by preschool rather than by student. The other potential problem was that the regular preschools came from three organizations and so had different programs. They were therefore expected to yield high variance in outcomes, but this was not the case as described in the analysis section.

### *Setting*

Intervention children were recruited from 9 randomly selected preschools run by 3 organizations in three different rural settings of Bangladesh. Three preschools were randomly selected from BRAC's 22 Dhamrai preschools; three schools were selected from Grameen Shikkha's 78 preschools in Gazipur; and three more from Pubail where

Village Education Resource Centre (VERC) has 18 preschools. Likewise, 3 preschools were randomly selected from each of the locations to be controls. BRAC pre-primary schools have their own math program, Grameen Shikkha offers the program developed by Plan Bangladesh, and VERC offers the SUCCEED program of Save the Children US.

The educational attainment of the teachers ranged from Grade 8 to 11. Intervention teachers had on average 9.33 years of education and the control teachers had 9.67 years. Most teachers had been in this position for a reasonable length: intervention teachers had on average 3.11 years of experience with this age group, and the control teachers had 1.63 years.

In terms of training, all provided basic training in early childhood learning and classroom management to teachers at the start of the academic year (though BRAC provided this only to newly recruited teacher). All organizations provided a monthly one-day refresher training on how to implement the lesson plans for the coming month.

### *Participants*

Twelve children each from the 9 intervention and 9 control preschools were randomly selected from a class list of 25-30 children to participate in this study. The remaining children attended classes as usual but were not tested. Thus, 108 children were enrolled for each group. The final numbers differed due to absenteeism. Children from 3 preschools missed one full unit (Unit 5) because flooding forced the closure of their schools for three weeks. The number of children tested for different units are mentioned in the results section.

### *Measures and testing procedure*

*Math skills*. Tests were created for each of the six different units to assess the skills taught in that unit. The number of items in each test ranged from 16 for Patterns to 37 for Numbers. There was also a Final test with 52 items (alpha .95) to assess a selection from each of the six separate tests. Items required the child to answer orally or in writing or by pointing to the correct alternative. Children took the same test for that unit before and after the unit was implemented in their preschool. The tests for Units 1 and 2 were administered together because we planned for a shorter implementation time than was required. Subsequently units were tested one at a time. The final test was given shortly after the final unit was implemented to determine whether skills from earlier units were retained. Tests were administered by trained research assistants with university degrees and several years of experience. They interviewed each child individually in a quiet location near the school. On average, each test took approximately 30-40 minutes. The Principal Investigator retested 10% of the children and found very negligible differences.

*Socio-Demographic and Nutritional Status*. The mothers were interviewed before the intervention to collect information about the child's age, mother's and father's educational status, 11 family assets. The child's height was taken and height for age was used as an indicator of nutritional status.

### *Intervention*

Adapted versions of selected activities from the Big Math for Little Kids (Ginsburg et al., 2003) were created and written in Bangla on Lesson Plan cards. They were implemented during the usual 30-minute math class six days a week in the months of April to December 2007. Most of the activities for a particular skill were conducted in one day and repeated on the next day. Thus, altogether 1 hour was spent on each of the skill-sets. Teachers conducted one activity from the previous skill-set as a review before introducing the activities for the next skill-set.

Activities on 58 different types of skills were done in 97 school days. One criterion for adapting and creating activities was the need to have low-cost and easily accessible materials for the children to manipulate. Materials such as the following were created: number cards, dot cards, shape cards, shape puzzle, storybooks on number and shape. Materials such as wooden blocks and foam shapes were already available. Most activities were run in large or small groups so that individual exercise books or copied sheets would not be necessary.

The skills for each unit are outlined below:

**Unit 1: Properties of Numbers** (17 activities conducted in 20 days during April-May)

1. Counting (by ones to 50, by tens to 100, by fives to 50)
2. Counting to tell how many (up to 15 objects)
3. Match numbers to sets of objects
4. Comparing sets (identify same, more, fewer, more than, less than, use a graph to compare numbers)
5. Reading, writing, representing numbers (represent numbers in different ways, write numerals 0 to 10)
6. Numbers and position (before, after, between, front, back, next, last, identify first to tenth, identify position of events in a sequence)

**Unit 2. Shapes Around You** (10 activities conducted in 15 days during May-June)

1. Two-dimensional shapes (recognize circles, squares, triangles, rectangles, hexagons, pentagons; use shape vocabulary & match shapes and names; count sides and corners, recognize common attributes)
2. Symmetry (match halves at line of symmetry, identify lines of symmetry)
3. Three-dimensional shapes (recognize cubes, rectangular prisms, cylinder, spheres, pyramids, triangular prisms, identify faces of three-dimensional shapes

**Unit 3. Patterns to Create** (6 activities conducted in 12 days during July)

1. Patterns (identify, create, copy, and extend, sound patterns, color patterns, shape patterns, number patterns, identify patterns with color and shape)
2. Logic (reason logically)

**Unit 4: Measure your World** (11 activities conducted in 22 days during November and December)

1. Length (compare and order height and length, nonstandard & standard units of measurement
2. Weight (use a pan balance to compare weight, order objects by weight, use of nonstandard units)
3. Capacity (identify more and less, order by capacity, use nonstandard units, recognize relationship between size & capacity)
4. Temperature (compare temperatures)
5. Time (use a calendar, order events, use temporal vocabulary: first, second)
6. Money (identify and name currency notes)

**Unit 5: Operating with Numbers** (8 activities conducted in 16 days during August)

1. Comparing numbers (compare sets to identify more & fewer, use bar graph to compare numbers)
2. Operating with numbers (add to 12 with concrete objects, use repeated addition, subtract with concrete objects, separate a set into two equal groups, share objects equally among more than two groups)
3. Representing numbers & operations (use tokens to represent objects, identify and use + & – symbols, write addition & subtraction sentences, identify ones and tens)

**Unit 6: Space – Where are you going?** (6 activities conducted in 12 days during September)

1. Positions and locations (right and left, forward and backward; inside, next, behind, in front, bottom, middle, top, over, under.
2. Directions (follow and identify directions)

***Teacher training and supervision***

Teachers of the 9 intervention schools received 96 hours of training on five different occasions conducted by three Bangladeshi investigators. Training for Units 1 and 2 was given together over 4 days; training for each of the other units was given for approximately 4 days before its implementation. All the participating teachers from one organization received their training at the same time. Each preschool teacher was given a Manual consisting of the lesson plans and materials for each unit. It described each activity – what the teacher should do and say, what the children should be asked to do, and how the teacher was to question and respond to their answers. A training manual with different sub-sections for each Unit was created describing different activities and games and lesson plans. Modifications were made to the Manual during training to incorporate the suggestions of teachers.

On-the-job supervision was provided to the teachers during the implementation. Three trained supervisors visited each school twice a week to coach the teachers as they implemented the math activities. One teacher who replaced another mid-year was visited almost regularly by one supervisor to help her learn the method. The Bangladeshi investigators also visited to observe and give advice.

**Method of analysis**

T-tests were conducted on the demographic variables to determine if the random assignment to control and intervention groups yielded children with similar backgrounds. Post-test gains in the two groups were compared separately for each unit with an analysis of covariance (ANCOVA), covarying baseline scores, child's age, sex and height-for-age, mother's education and family assets. The Final test had no baseline so only the socio-demographic variables were covaried.

## Results

### *Characteristic of the sample*

The children in the two groups were very similar on demographic variables as shows in Table 1. The two groups did not differ significantly in terms of child age or sex , height-for-age, mother's education and socioeconomic status (11 household assets).

**Table 1**
**Mean (SD) and t-values comparing Regular and Intervention preschoolers**

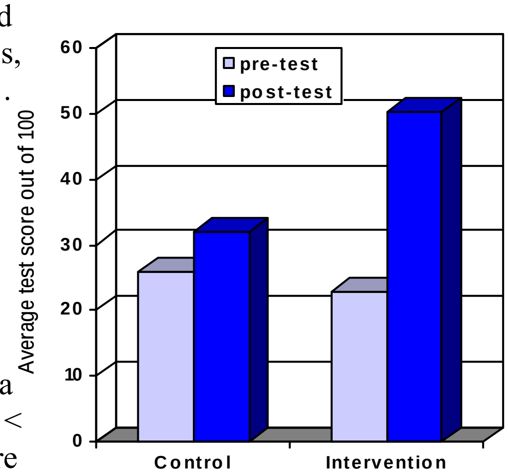
| Variable | Control (n = 104 ) | Intervention (n = 100 ) | t | p |
|---|---|---|---|---|
| Age (months) | 66.06 (6.09) | 65.30 (7.13) | .85 | ns |
| Height for age | - 1.28 (.96) | - 1.41 (1.08) | .92 | ns |
| Mother's education (yr) | 4.29 (3.71) | 4.51 (4.22) | .41 | ns |
| Family Assets (11) | 7.97 (2.31) | 7.58 (2.66) | 1.14 | ns |
| Income/month | 6984.26 (5581.41) | 5807.18 (3990.98) | 1.78 | ns |
| % Girls | 55% | 58% | | ns |

### Math skills

The scores for each Math unit are presented separately as they cover different skills. The pre- and post-test items for each test were same. They were scored either correct (1) or incorrect (0). Consequently, each child's score for a particular unit was the sum of points across all items for the test of that unit. A final test was taken at the end to see the retention of skills, which had 52 items covering the basic skills of different units. Pretest scores from the Regular and Intervention children were not significantly different on 5 of the tests (*t*s ranged from 0.05 to 1.51, *ns*); however, they were different on the Unit 3 test (Patterns) where Intervention children scored higher, $t$ (202) = 3.01, $p$ = .003.

**Unit 1. Properties of Numbers?**

Chart 1: Properties of numbers

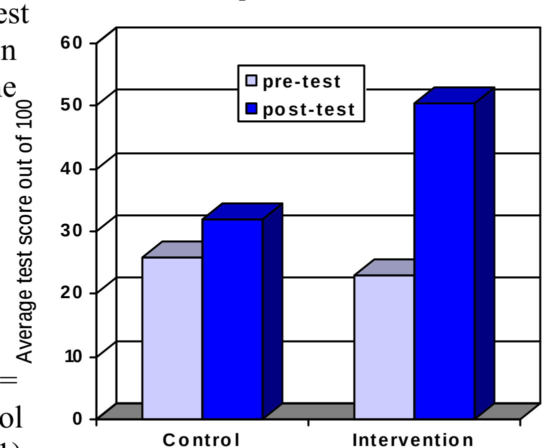



The pre- and post-test of unit 1 had 37 items and alpha coefficient was .88. An example of a test question is that "the child was given a handful of buttons and asked to take 7 buttons". The pretest and posttest scores, transformed into percentage, are presented in Chart 1. The analysis included 104 Control and 100 Intervention children.

The posttest scores were subjected to an analysis of covariance, covarying first the pretest score, the child's age, height for age, mother's education, and family assets. The pretest covariate was significant ($p < .0001$), as expected. The posttest score yielded a significant effect for group, $F(1, 195) = 89.03$, $p < .0001$, partial $\eta^2 = .31$. The control students had pre and post means of 9.60 (SD 5.56) and 11.79 (SD 5.54), respectively, while the intervention students had pre and post means of 8.71 (SD 5.84) and 18.60 (SD 8.86), respectively. Adjusting for covariates, the number of standard deviations that separate the two groups at posttest, i.e. the effect size, was d = 1.09. The improvement as a result of the math intervention for the first unit was very strong.

**Unit 2. Shapes Around You**

Chart 2: Shapes Around You



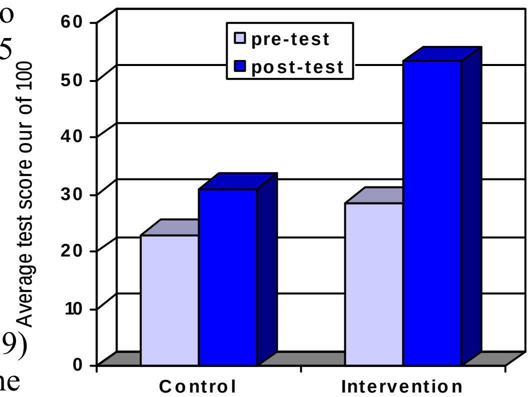

The pre- and post-test of unit 2 had 24 items and alpha coefficient for the 24 items was .45 at pretest and .92 at posttest. One test item required children to find all the triangles in a complex design. The pretest and posttest scores, transformed into percentages, are presented in Chart 2. The analysis included 104 Control and 100 Intervention children.

The analysis showed that the pretest covariate was significant ($p < .0001$). The posttest score yielded a significant effect for group, $F(1, 195) = 267.79$, $p < .0001$, partial $\eta^2 = .57$. The control students had pre and post means of 2.23 (SD 1.41) and 2.86 (SD 1.61), respectively, while the intervention students had pre and post means of 2.23 (SD 1.41) and 12.25 (SD 5.69), respectively. Adjusting for covariates, the effect size was d = 2.6. The improvement was very large.

### Unit 3. Patterns to Create

The pre- and post-test of unit 3 had 15 items and alpha coefficient for the 15 items was .49 on the pretest. One test item required children to complete the following pattern: 1 3 5 1 ? ? The pretest and posttest scores, transformed into percentage, are presented in Chart 3. Only 75 Control and 70 Intervention students were analyzed, though 106 and 100 took the pretest.

Chart 3: Patterns to Create

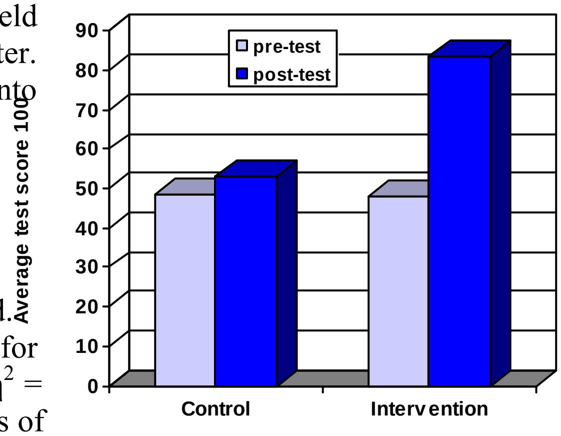



The analysis showed that the pretest covariate was significant (p < .0001). The posttest score yielded a significant effect for group, $F(1, 137) = 38.65$, $p < .0001$, partial $\eta^2 = .22$. The control students had pre and post means of 3.53 (SD 1.89) and 4.65 (SD 2.52), respectively, while the intervention students had pre and post means of 4.53 (SD 2.20) and 8.00 (SD 3.12), respectively. Adjusting for covariates, the effect size was d = 1.07. The improvement was significantly strong.

### Unit 4. Measure your World

The pre- and post-test of unit 4 had 35 items and alpha coefficient was .74. One item from the test asked children which of three differently sized pots held more water and then to fill it half full with water. The pretest and posttest scores, transformed into percentages, are presented in Chart 4. 89 Control and 89 Intervention children were analyzed.

Chart 4: Measure your World



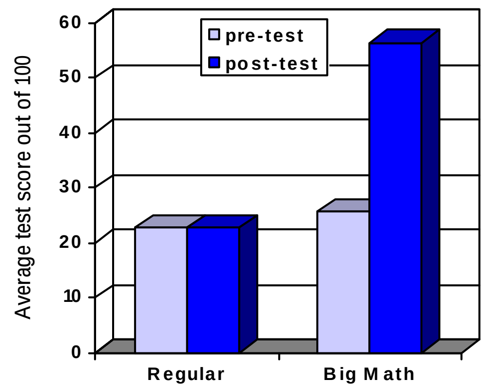

The ANCOVA shows that the pretest covariate was significant (p < .0001), as expected. The posttest score yielded a significant effect for group, $F(1, 171) = 234.93$, $p < .0001$, partial $\eta^2 = .58$. The control students had pre and post means of 16.92 (SD 4.08) and 18.6 (SD 4.29), respectively, while the intervention students had pre and post means of 16.90 (SD 3.952) and 29.19 (SD 5.59), respectively. Adjusting for covariates, the effect size was d = 2.17. The improvement was very large.

### Unit 5. Operating with numbers

The pre- and post-test of unit 5 had 23 items and alpha coefficient was .81. One item was: Iqbal has 8 balls and he gives 3 to his sister. How many balls does he have left? Write the story in numbers. Another asked children how many tens and how many units are in the number 47. The pretest and posttest scores, transformed into percentage, are presented in Chart 5. 72 Control and 75 Intervention children were analyzed.

The ANCOVA showed that the pretest covariate was significant (p < .0001), as expected. The posttest score yielded a significant effect for group, $F(1, 139) = 106.48$, $p < .0001$, partial $\eta^2 = .43$. The control students had pre and post means of 5.35 (SD 2.67) and 6.19 (SD 3.30), respectively, while the intervention students had pre and post means of 5.96 (SD 3.44) and 12.97 (SD 5.53), respectively. Adjusting for covariates, the effect size was d = 1.45. The improvement as a result of the intervention was very strong.

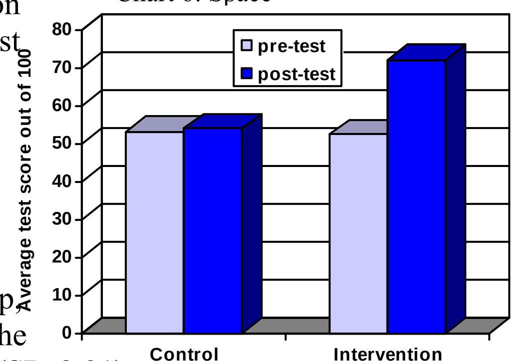
Chart 5: Operating with numbers




**Unit 6. –Space – Where are you going?**

The pre- and post-test of unit 6 had 26 items and alpha coefficient for the 26 items was .73. One item provided children with a tower of 4 differently coloured blocks and asked which is on top? How do you know? The pretest and posttest scores, transformed into percentages, are presented in Chart 6. Control and Intervention groups each consisted of $n = 69$.

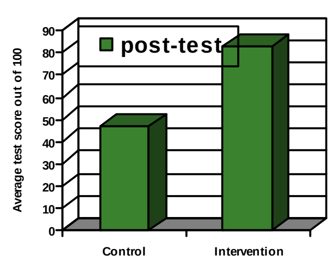
Chart 6: Space




The ANCOVA showed that the pretest covariate was significant (p < .0001), as expected. The posttest score yielded a significant effect for group, $F(1, 130) = 67.00$, $p < .0001$, partial $\eta^2 = .34$. The control students had pre and post means of 13.61 (SD 2.91) and 14.09 (SD 3.43), respectively, while the intervention students had pre and post means of 13.75 (SD 3.70) and 18.70 (SD 4.02), respectively. Adjusting for covariates, the effect size was d = 1.23. The improvement as a result of the intervention was very strong.

**Final Cumulative test**

Chart 7: Cumulative test




A combined test was created picking selected items from each of the units to measure the retention of skills at the end of the year. This combined test had 52 items with an alpha coefficient of .95. The total scores transformed into percentages are presented in Chart 7. Only 59 Control and 54 Intervention children were analyzed, approximately 60% of our initial sample.

The ANCOVA showed that the posttest score yielded a significant effect for group, $F$(1,

106) = 203.94, $p < .0001$, partial $\eta^2 = .66$. The control students had a mean of 24.25 (SD 5.96), while the intervention students had a mean of 43.02 (SD 8.15). Adjusting for covariates, the effect size was d = 1.23. The improvement as a result of the intervention was very strong. The Math Intervention children had retained most of their newly acquired math skills by the end of the year.

**Discussion**

The findings demonstrate very clearly that children benefited immensely from this 9-month Bangladesh Math for Preschoolers program. After each unit, Intervention students generally doubled their test score, while Control children remained at the pretest level. This was seen in the Units on Properties of Numbers, Shapes, Patterns, Measurement and Operating with Numbers. Only the Unit on spatial concepts showed less dramatic gains because children had half of these skills at the pretest. In sum, these rural children were capable of learning sophisticated mathematics during their preschool year.

Children's performance on the final cumulative test provided striking evidence that the math children had retained the skills they acquired over the previous 9 months. Their average of 82.7% compared with 46.6% for Control children. It was very likely that the Intervention children mastered during later units some of the earlier skills that they missed because math skills are used cumulatively. In other words, if a child did not master an earlier skill with regard to numbers, there would be another chance to acquire it while solving problems relating to patterns, measurement or operating on numbers.

Some of the Control schools had math programs with lesson plans for the teachers to follow. This was true of both BRAC and Plan preschools. By the end of the year, they had mastered only half of what the Intervention children did, mainly with respect to counting, shapes, and spatial concepts for which they received instruction. They did not receive instruction in patterns but might have acquired this understanding through play or through their natural ability to reason and observe. Playing with different coloured and shaped blocks is important, but early childhood experts are realizing that that a play-oriented math curriculum directed toward specific math skills is appropriate for preschoolers.

It is also clear that the currently used programs are not sufficiently comprehensive, stimulating or challenging for the flexible young brains of children. Most teach counting up to 10 or 20 and operations up to 10, whereas the Math program had children counting by 1's, 5's and 10's to 50 and 100, and writing numbers to 10. Most teach three 2-dimensional shapes such as circles, squares and triangles, but not the others, no 3-dimensional shapes and no combination of shapes to create new shapes. The form of instruction in most programs entails repeating after the teacher or repeating the same activity such as counting. However, the Bangladesh Math program requires children to solve problems and then check their answer, or generalize from one problem to another and express the answer in words. Children applied their new skills to what they saw in their school and home environment. Because they had developed math reasoning skills, they were able to master items on the test that they had never seen before.

The materials required for the program could be largely found in most preschool play corners. However, these were not sufficient for a comprehensive and challenging program. Rather than create an exercise book which children are not able to manipulate, we developed materials that children could use in pairs or in small groups, such as dot cards, number cards, and shape designs. The cost was similar to what might be spent by most organizations on the control math program, namely $4.00 per child. The cost-effectiveness is evident.

Finally, there is the question of teacher training. Most teachers had to be trained in how to provide many different problems for children, and ask them to solve the problems. Rather than provide the answer, teachers were required to coach the children as they worked toward the solution. This took 96 hours or 16 hours for each unit, along with many hours of in-class support. However, once this becomes part of the preschool program, it can be fit into the regular training and refresher course. Despite their lack of professional training, the participating preschool teachers mastered the teaching technique and were able to use the Manual of lesson plans to guide them.

In conclusion, we can now say that a comprehensive preschool math program exists for Bangladesh children – one that is sufficiently stimulating and challenging to meet their needs. The evidence is clear and dramatic that children were able to learn how to reason and perform the operations with numbers, shapes, patterns, space and measures. The teachers accomplished the successful implementation of this program and the cost of materials was low. Early childhood organizations now need to take responsibility to pass on these benefits to the children, with a view to improving math competencies in primary school.

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