Effects of Number-Way Curriculum on Pre-Schoolers' Mathematical Learning for Low Socioeconomic Status Children

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Abstract: The objective of this research is to test the effectiveness of a game-based mathematical curriculum Number-Way in preschools for low socioeconomic status (SES) children. This curriculum contains fifteen interesting number games representing four main principles. The result indicated that this curriculum promoted early mathematical competence for preschoolers significantly.

The greatest German mathematician and physical scientist Karl Friedrich Gauss described math as "the queen of science" (as cited in Waltershausen, 1856, p. 79). Math is so important because it serves as the basis of modern science and engineering fields. In addition, math is an essential part of our daily life because we are confronted with math-related problems ubiquitously. The report from the Program for International Student Assessment (PISA) showed that U.S. students continually lag behind their international competitors in mathematics (PISA, 2006, 2009). A study also revealed that the mathematic skill level of children in the United States was less advanced than their international peers even before elementary school (Siegler & Mu, 2008).

Most preschool teachers in the United States ignore children's potential in mathematics and mistakenly assume that they are too young to learn abstract concepts (Lee & Ginsburg, 2009). Therefore, no adequate and appropriate mathematics instruction has been offered to young children in preschool. However, numerous studies indicate that young children of preschool age have the capability of learning formal knowledge of mathematics. In Seo and Ginsburg's study (2004), it was shown that young children could develop strong interest in mathematically related activities and they were eager to explore mathematical ideas with appropriate encouragement. In addition, Duncan et al. (2007) reported that early math skill is more powerful than early reading and literacy and it is the strongest predictor of later academic achievements.

An increasing number of educators are starting to realize the current situation of early mathematics education and have begun to pay more attention to early mathematical research. Starkey, Klein, and Wakeley (2004) proved that mathematics intervention for young children significantly promoted young kids' mathematical knowledge. There are growing research-based mathematic programs such as *Big Math for Little Kids* (Greens & Ginsburg, 2004), *Building Blocks* (Clements & Sarama, 2007), *Number Worlds* (Griffin, 2004), and *Storytelling Sagas* (Casey, Kersh, & Young, 2004). Although the mathematics performance of U.S. children is improving, no sufficient progress has been obtained by all children. Research data showed that achievement varies between different socioeconomic statuses (SES) groups of children: children from low-income families had very limited opportunities and resources for early mathematics

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instruction; consequently, they fall behind their middle-income peers on early mathematic skills (Denton & West, 2002; Jordan, Kaplan, Olah, & Locuniak, 2006).

Therefore, it is essential to provide appropriate and effective mathematical instruction for low SES children. However, the lack of appropriate resources and family support limits efforts for improving low SES children's math skills. Currently, research-based mathematics programs are not available for kids from low-income families. The reality is that low-income parents are unable to spend hundreds of dollars purchasing materials, supplements and a curriculum. The purpose of this study is to introduce inexpensive resource based number games to low SES kids and test the effectiveness of the Number-Way curriculum.

Research Hypotheses

The research was planned to examine mathematical development of preschoolers who came from low income families. Specifically, the study was planned to explore two research questions: (a) Can the intervention group of children who received Number-Way curriculum significantly increase mathematics achievement scores? (b) Is there a difference between the intervention group with number games participation and control group in a normal classroom setting without any number games practice? Accordingly, it was hypothesized that an inexpensive resource-based number games curriculum would help the intervention group of children increase their math competence. In addition, children from the intervention group would achieve more advanced levels of mathematical competency compared to the control group children.

Method

Participants

Twenty preschool children from a church-affiliated preschool were chosen for this study. The children aged from 4 years 1 month to 4 years 11 months (M = 4 years 6 months). Nine were girls and eleven were boys. These children were in the free Voluntary Prekindergarten Education Program (VPK) class. All participants came from families whose incomes were under the poverty line. The preschool was located in a neighborhood with lower than average income families, so this preschool was typical among a large number of preschools serving children from low-income families. Ten children were randomly assigned to the intervention group, and the other ten children were in the comparison group. The children in the intervention group and comparison group were similar in respect to ethnicity, gender, and SES status. Their dominant language was Spanish.

Procedure and Materials

The 20 participants were randomly selected from the school with a total of 31 four-year-old preschoolers. VPK assessment was administrated by the school in the beginning of the school year in September. After the pretest, we conducted 15-minute sessions of game-based curriculum twice a week for ten children in the intervention group. We played number games with children individually with a one-on-one approach in a separate room beside the classroom. Meanwhile, we observed each child and wrote journals to record changes. The process of intervention lasted four months. In the end, each child in the experimental group received a total of 30 sessions of professional tutoring. The study adopted pretest and posttest design to examine the effectiveness of the game-based curriculum by comparing scores of the intervention and control group.

The curriculum focuses on the development of early number sense, because number theory is the most important component of mathematics that is considered to be the strongest touchstone of mathematical problem-solving capability (Jordan, Glutting, & Ramineni, 2010). Number-Way curriculum contains 15 number games representing 4 main principles of early number knowledge.

Four Main Principles

Number writing and identification. Numbers can be presented in different ways such as Arabic number "1." the English word "One" and the dot-quantity "**.**". At the very beginning, young kids were not able to realize the different expressions. Number writing and identification activities can help children build up their number sense gradually. Previous research also discovered a strong correlation between numeral writing skills and mathematical problem-solving ability (Johansson, 2005).

One-to-one correspondence. One-to-one correspondence is a foundation for early numerical understanding. It is very important to help young kids connect abstract numbers with concrete objects. When children count the number with a corresponding amount of cookies, it's meaningful for them to acquire the concept behind simple rote-counting.

Number comparison and sequence. Children start making very small number comparisons by visually perception, which is believed to be a natural capability. To obtain a higher level of number comparison, they need to understand that the number to be counted later in the sequence means a larger quantity. After plentiful practice of counting forwards and backwards, children will be able to tell which number is bigger or smaller easily and accurately.

Number-bonds. Number bonds, coming from Singapore mathematics, refer to small parts of a number. For example: 1+9=10 and 2+8=10, so 1, 9 and 2, 8 are number bonds to make 10. The significance of number-bonds is the support setting learning trajectory for simple addition and subtraction.

Measures

The VPK assessment is a statewide measure developed by the Florida Department of Education to check four-year-olds children's learning progress in the VPK Program classroom. It is in accord with early learning and developmental standards for four-year-old preschoolers, including four principle aspects: Print Knowledge, Phonological Awareness, Mathematics, and Oral Language and Vocabulary. The VPK mathematics measure contains a total of 13 assessment items and 18 highest possible points in three numeracy skills: counting skills, numerical relation skills, and arithmetic reasoning skills. It is appropriate to measure the children's early numeracy skills. The VPK assessment was conducted by the school instructor in September and January.

Results

A test with a highest possible score of 18 was designed for this study. The intervention group did the pretest with a mean score of 4.5. After four months, the average score improved to 11. The control group started with a mean of 4.4 and ended with 8.3. Figure 1 shows that intervention group had a significantly higher VPK assessment score in the post-test than in the pre-test (* $p<0.01$). Figure 2 showed there was no significant difference between the intervention group (M=4.5) and the control group (M=4.4) in VPK assessment, which showed that the two groups of children's mathematical capability were at the same level before implementation of the game-based number curriculum, while the intervention group (M=11)

shows a difference with the control group (M=8.3) in post-test. Results of independent t-tests' post scores of two groups show that there were significant differences between the intervention and control groups in mathematics achievement ($p<0.05$). The intervention group of children achieved a significantly higher score than those from the control group.

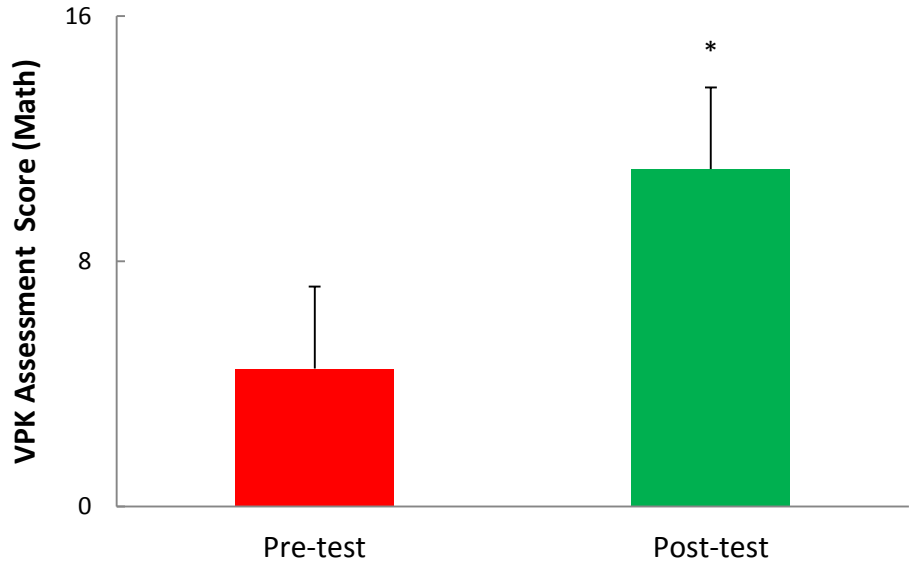

Figure 1. Comparison of pre- and post- VPK assessment for intervention group (n=10, * p<0.001).

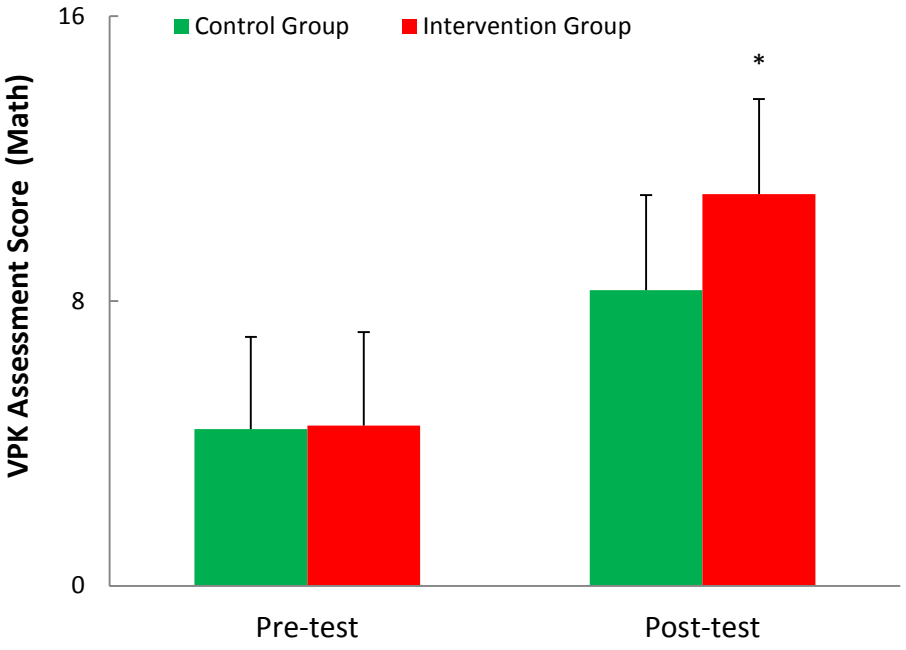

Figure 2. Group statistics of pre- and post- VPK assessment (n=10, * p<0.05).

Discussion

The test results provided evidence for the two research questions were stated earlier. For the research question about the effect of the mathematical intervention, the result of this study showed that the experimental group significantly promoted their mathematical competence through the game-based curriculum (Figure 1). For the second hypothesis of this study that the

intervention group may achieve better assessment scores than the control group, we observed a significant difference between children who received the intervention and children who were not exposed to the curriculum (Figure 2). Furthermore, the results of this study supported the effectiveness of the game-based mathematical curriculum.

Previous research has shown that children can develop further potential with a teacher's positive intervention (Hammond, 2002; Jacobs, 2001). This was later on accepted as a common sense that successful intervention depends on the quality of the teacher's instruction. For early mathematical teaching, the strategies that teachers employed to introduce mathematic concepts and integrate learning are essential. Teachers often assume that all children have already acquired simple concepts such as one plus one yields two or they can count from 1 to 10. As a matter of fact, the simple but important concepts are the basis of mathematical learning, which has a profound influence on future learning. Children need a great deal of practice to lay a solid foundation for later comprehension. Consequently, it is necessary for teachers to encourage children to reinforce their mathematic concepts in all kinds of activities. In order to illustrate how to practice the fundamental early mathematics knowledge in number games, Number-Way provided a series of videos of all the number games in the curriculum.

The children who participated in this study showed great enthusiasm to these mathematical games. Moreover, their passion lasted from the beginning to post-test period. According to our observation, Number-Way curriculum was very attractive for the children. It was believed that several reasons could explain why these games were appealing and pleasing. First of all, the intervention provided children opportunities for one-on-one interaction with teachers. Most activities at school were in class or small groups, therefore one-on-one games were novel and interesting for them. In addition, the process of communication between teachers and children not only helped the children to show their learning abilities and boost their self-confidence, but it also benefited the teacher to gain a comprehensive understanding of the children's learning level. What is more, the games in Number-Way curriculum were hands-on activities, facilitating children to build up their individual learning experience. Dewey advocated "learning by experience" (p. 164). He believed it's crucial for children to gain knowledge through meaningful and real-life experience (Dewey, 1922). When the children actively participated in the math games, they were discovering their own needs and interests at the same time.

In conclusion, it is valuable to provide better instruction for disadvantaged children from low-income families to eliminate the mathematics achievement gap with higher socioeconomic status children. In addition, preschool educators have a significant effect on children's performance in mathematics. To a great extent, a high-quality curriculum depends on the teacher's assistance and instruction. Therefore, it is vital to provide more professional mathematics instruction training to preschool teachers. Future studies should focus on implementing the curriculum to a larger number of participants.

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Appendix: Number Games in Number-Way

Name	Description	Number principles
1.Hide and seek	The teacher hides the cards in different places. Students find the numbers in order from 1 to 10.	Number identification
2.Jump jump	A board games with 30 squares. Students throw the dice and jump the spaces. First to 30 wins.	Number identification One-to-one correspondence
3.Animal number train	The teacher shows the locomotive. Students put the carriages with animals and numbers behind the locomotive.	Number identification Number comparison and sequence
4.Bigger number card wins	Teacher and students choose a card randomly, and compare the numbers of animals on the card. The person who has more animals wins this round and takes the two cards.	One-to-one correspondence Number comparison and sequence
5.Making a ruler	Prepare a blank paper and a ruler. The students draw the ruler on the paper and mark with numbers.	Number writing and identification
6.Cookie handout	Each of the animals has a number. The student distributes the same amount of cookies to the animals.	One-to-one correspondence
7.Stairs	The students use *Unifix* cubes to make stairs and draw the stairs on the paper.	Number writing and identification Number comparison and sequence
8.Tall building	Students arrange the same color *Unifix* cubes together and count how many cubes there are for each color, then make a tall building.	One-to-one correspondence
9.Kitty and Bear	The teacher shows two stuffed toys, Kitty and Bear. Make Kitty and Bear throw dice to get the same number of crayons as the dice indicates.	Number writing and identification Number comparison and sequence
10.Colorful beads	Throw the dice and get beads, then string the beads together.	One-to-one correspondence Number comparison and sequence

11.Animal puzzles	Puzzles are facing down. Let the students guess which number is on the puzzle. Once the students get the right answer, the puzzle can be turned around.	Number comparison and sequence
12.String numbers	Use a string to make different numbers.	Number writing and identification
13.Memory number match	Cards are placed face down. Students choose two cards each time and try to find matches. Player with the most matches wins.	Number identification
14.Bowling	Prepare ten bottles and a ball. Use the ball to hit down bottles.	Number comparison Number-bonds
15. Number Bingo	The students choose 10 numbers for their number cards. Then the teacher calls the numbers. The student who has a match of all cards first calls “Bingo”	Number identification