

The Relative Effectiveness of Teacher-made Games for Preschoolers' Understanding Number Concepts

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Abstract

The purpose of this case study was to determine the relative effectiveness of a Combined Activity (using both computer software and hands-on manipulatives that the author produced) in comparison with a traditional mathematics activity (using commercial hands-on manipulatives only) in promoting preschool children's learning of seriation, logico-classification, counting, and addition. The participants were 37 three to five-year-old preschoolers at two preschools in Florida, U.S.A. The research design was a quasi-experimental (pretest-posttest) control group design, and analysis of covariance (ANCOVA) was used to analyze the data. Results of this study showed that the Combined Activity had a significantly more positive effect on the participants' understanding of number concepts ($F = 6.253$, $p < 0.05$), especially seriation and addition, than did the traditional activities.

Key words : number concepts, games, mathematics, preschoolers¹

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Introduction

Many researchers have assumed that young children's early mathematical knowledge and skills during the period of preschool and kindergarten are related to later achievement in mathematics (National Mathematics Advisory Panel, 2008). These researchers indicate that early mathematics education should and can start in preschool (Clements, Sarama, & DiBiase, 2004).

As part of the effort to provide better early mathematics experiences, a variety of manipulatives have been created and introduced. Most teachers believe that manipulative materials should be used for mathematics instruction (Babara & Santoro, 2004), and the results of empirical studies suggest that such learning manipulatives including mathematical computer games can help young children's learning of early mathematics (Clements & Sarama, 2004b; Clements & Sarama, 2007a; Clements & Sarama, 2007b; Park, 2012; Sarama, 2004; Tattre, 2003). Many meaningful manipulatives can be used "to bridge the gap between informal learning and abstract ideas" (Smith, 2001, p. 10). In other words, in early mathematics education, a teacher should often use a good manipulative to link young children's informal mathematical knowledge with formal school mathematics education (Baroody, 1989). In addition, many educators think that educational games are an excellent device to engage young children in early mathematics (Badrova & Leong, 2004).

Purpose of the Study

The National Council of Teachers of Mathematics (NCTM; 2000) lists five content standards for preschool through 12th grade mathematics: (1) number and operations, (2) algebra, (3) geometry, (4) measurement, and (5) data analysis and probability. Although the content standards are highly interconnected, educators consider the standards related to number and operations and geometry to be the major components of preschool curriculum of early mathematics. Trafton and Midgett (2001) indicated that "mathematically comprehensive materials also pay attention to the development of useful skills along with concepts and mathematical processes" (p. 2). Clements (2001) stated that the appropriate way to effectively develop preschoolers' mathematical knowledge was to engage in a variety of activities that

specifically deal with mathematics. He introduced both hands-on manipulatives and computer software for the activities, including games that use number cubes, such as War, or board games with number cubes that provide experiences with counting and comparison.

With an understanding of NCTM standards and the importance of mathematical activities for preschool children, as a preschool teacher the author had introduced various learning materials and activities in his classroom setting. The author had mainly focused on the following inquiry in his teaching in general: "What kinds of materials can positively affect young children's mathematical thinking?" Games using number cubes and other board games were easy to apply and modify to match weekly themes.

The author often used them to help young children understand number concepts through play in the classroom. After the author designed and developed his own learning materials ("YJ Number Cubes," "YJ Card Game Sets," and "YJ Board Game Sets" and computer games such as "Twin Silly Robots," "Candlelight Activity," and "Froebelian Design Software"), the author wondered how combining these activities would affect young children's mathematical thinking.

The purpose of this study is to determine the relative effectiveness of the combined activity in comparison with a traditional mathematics activity (not using the author's hands-on manipulatives and computer software but using commercial hands-on manipulatives and worksheets) in promoting the learning of seriation, logico-classification, counting, and addition by preschool children.

Research Questions

The major research questions were:

1. What is the relative effectiveness of the combined activity and a traditional mathematics activity in developing children's skills in seriation, logico-classification, counting, and addition?
2. Is the effectiveness affected by the participants' gender, amount of time spent playing the games, and age in the experimental group?

Review of literature

Piaget's Developmental Theory

Piaget (1964) indicated that children's intellectual development period from birth to adolescence can be divided into four major periods: sensorimotor (birth to 2 years), preoperational (2 years to 7 years), concrete operational (7 years to 11 years), and formal operational (11 years and above). Piaget pointed out that intellectual development is a gradual, continuous process. These age norms and the timing of the stages are not rigid, but can vary for each individual child. His early work focused on children's abilities in verbal communication, concepts of physical causality, and moral judgment and behavior, but in his later work he investigated children's understanding of number and classification. As the current research topic is related to young children (three- to five-year-olds in the preoperational stage) and their understanding of number concepts, Piaget's later work related to young children's learning of concepts of conservation, seriation, and classification was the foundation for developing and testing the Combined Activity (see Appendix A.).

Piaget's Constructivism of Number

Number conservation, seriation, and classification are critical elements of the number system. Young children's understanding of these concepts in the preoperational stage is closely connected with their understanding of number concepts and with mathematics achievement.

Piaget (1963) was convinced that a child acquires logico-mathematical knowledge, including number concepts, from the process of internal understanding of number, that is, through the active inner process of organization and application (assimilation and accommodation) in interaction with the environment, as opposed to passively receiving it from the environment (Ginsburg & Oppen, 1988). Piaget and his followers believed that conservation-related tasks cannot be solved by a child who has only physical knowledge such as recognition of the physical situation of the objects; the child must have logico-mathematical knowledge of the conservation of number. In the preoperational period, young

children (2 to 7 years old) start to conserve certain objects even when the appearance of the objects changes (Siegler, 1998). Although Piaget believed that conservation cannot be taught in this period, children can learn the concept of conservation through their own experiences and interactions (Wadsworth, 1989). In the current study, the purpose of the Combined Activity was to create a mathematical learning environment based on games or interactive play among preschoolers who were empowered by the teacher.

Seriation can be defined as the ability to create a series by ordering different objects by size. Piaget regarded seriation as the ability to find out or construct the ordinal relations of objects and to manipulate objects in various ways (Ginsburg & Oppen, 1988). In the current study, the author adopted the concept of seriation in creating "YJ Card Game Sets," which consist of two different sets of cards: one with only dots (from one to ten) and one with dots and numerals for the quantity of dots (from one to ten).

Inhelder and Piaget (1969) stated that "the true significance of classification is the fact that the child who can classify can reason logically about the properties of things by adhering to unambiguous criteria" (p. xxii). Based on Piaget's theory, Kamii (2000) also indicated that in the process of solving the task of conservation of number the child must be proficient at counting and keep one to one correspondence. Therefore, young children's developing understanding and proficiency in counting are the major part of preschoolers' understanding of number. For young children, counting a set of objects is not an easy task. They must think, perceive, and move (finger counting, verbal counting, etc.) "with much of [the task's] complexity obscured by familiarity" (Kilparick, Swafford, & Findell, 2001, p. 159).

Kamii (1985) indicated that children who constructed number concepts including the conservation of number could mentally construct number relationships and invent arithmetic because all numbers consist of "the repeated addition of one." For example, the number 3 is also $1 + 1 + 1$ or $(1 + 1) + 1$. Using two dice to show a variety of representations of number relationships under 10 is meaningful play. In this study, the author used Kamii's idea of interpreting Piaget's logico-classification into understanding mathematical concepts, particularly in the design of the computer simulation and games *Froebelian Design Software* and *Twin Silly Robots* and added the concept of whole-to-parts and parts-to-whole relationship.

Piaget's constructivism, learning environment, and instructional games. How can a preschool teacher create a "learning environment" for young children? Kamii (2000) indicated that children's development of logico-mathematical knowledge can effectively occur in social interaction by "cooperation, exchanging points of views, and negotiating solutions in case of disagreement" (p. 43). Specifically, Kamii suggested that a teacher should consider children's autonomy when creating an interactive environment for learning of number concepts. For example, if there is a conflict during the game play, a teacher should let the players (i.e., children) solve it for themselves through communication rather than direct them to do certain things. Kamii believed that a teacher should provide a variety of learning tools such as card and board games using a die or dice to promote children's interaction. She mentions several reasons why repetition in games is much better than worksheets: (1) in games, children can supervise each other and give immediate feedback, but with worksheets, children work on each problem mechanically and individually; (2) in games, children can have a meaningful time to work together by exchanging viewpoints and negotiating possible answers in case of disagreement, but with worksheets, it is easy to obtain the truth only from the teacher; (3) games are flexible for many levels in various ways, but worksheets are limited such that children find the right answers mechanically; and (4) children can construct a network of numerical relationships of composition/decomposition of number in social games, but in worksheets, children only face each problem mechanically as a separate problem. Kamii (1985) interviewed first graders who played only math games for about 50 minutes every day for a year without using worksheets and found that they showed significant progress in solving problems adding two numbers from 1 to 6 over the four consecutive interviews. Her research indicated that children could learn sums only by playing math games and without worksheets, timed tests, or pressure. She thought that children who did not have clear number concepts should play Fifty Chips (filling the number of spaces with chips after rolling a die or dice) rather than a path game such as "Hop to It" or "Dinosaurs" (moving a player's marble forward on the steps) because the Fifty Chips game could clearly show the children the visible pathway with chips. Later, Kamii (2000) focused on kindergartners and first graders rather than preschoolers. Can a preschool teacher apply her suggested games to preschool settings? In the author's preschool teaching experience, the author used one die and then two dice (each side featuring zero to five dots) with preschoolers (4- to 5-year-old

children) from middle income families. Most children could count dots on each face (or side) and answer how many there were. After playing games with the dice for three months, some of the children could combine each group of dots, such as four dots on one face and five dots on the other face. They consequently obtained the knowledge that four dots and five dots were equal to nine dots, although it was not easy for them to understand the hierarchical inclusion of the number nine. The author thinks that it is possible to apply Kamii's suggested card or board games (1985) to preschool children (four to five years old) who are social and communicate through play. The author strongly believes that it is necessary for young children to be proficient at counting to achieve the goal of understanding number concepts. One might ask, what is the relationship between counting and games? Next, the author explains the connection between them.

Piaget's constructivism, counting, and interactive games. Many educators insist that "the act of counting a set of objects is not entirely a rote activity but is guided by children's mathematical understanding" (Kilparick et al., 2001, p. 159). Kamii (2000) also indicated that to complete the task of conservation of number, the child must have the proficiency in counting and keep one to one correspondence. Therefore, developing understanding and proficiency in counting are the major part of preschoolers' understanding of number.

For young children, counting a set of objects is not an easy task. It requires them to think, to perceive, and to move (finger counting, verbal counting, etc), "with much of its complexity obscured by familiarity" (Kilparick et al., 2001, p. 159). They must also distinguish which items should be counted. When they start to count the items, they should know "the procedures to make each utterance of a number word correspond with one of the items to be counted" (Steffe, Cobb, & von Glasersfeld, 1983, p. 24). They should perceive and conceive of the items as each item is counted. Later, they should be able to count any sets of items (visible, audible, or tangible items) whether they are readily perceivable or not. Research has been conducted on children's understanding of the mathematical basis for counting, focusing on five principles that their thinking must follow for meaningful counting (Gelman & Gallistel, 1978; Kilparick et al., 2001):

1. *One-to-one correspondence*: there must be a one-to-one relation between counting words and objects;

2. *Stable order* (of the counting words): these counting words must be recited in a consistent, reproducible order;
3. *Cardinality*: the last counting word spoken indicates how many objects are in the set as a whole (rather than being a property of a particular object in the set);
4. *Abstraction*: any kinds of objects can be collected together for purposes of a count;
5. *Order irrelevance* (for the objects counted): objects can be counted in any sequence without altering the outcome.

There are three controversial viewpoints of young children's understanding and proficiency of counting:

1. Children's emerging understanding of these counting principles organizes and motivates their acquisition of conventional counting procedures (e.g., starting from a usual starting point and counting all of a set of items);
2. Children's conceptual understanding of counting follows (and may be based on) an initial mastery of conventional counting procedures; and
3. Children's conceptual and procedural knowledge of counting develop interactively between the understanding of counting and the mastery of counting (Kilparick et al., 2001, p. 161).

"The issue of the developmental relation between understanding concepts and implementing procedures is of practical as well as theoretical importance" (Rittle-Johnson & Siegler, 1998, p. 4). For the principles and procedures of counting, many researchers have indicated that young children can effectively understand and master counting through peer interaction and using a board game set (Siegler & Ramani, 2008).

Teacher-made games and their objectives. What aspects of teacher-made games are different from those of commercial hands-on games? Piagetian constructivists believe that teacher's constructive interventions considering children's mathematical reasoning can be educational as they engage in a group game (DeVries, Zan, Hildebrandt, Edmiaston, & Sales, 2002). A variety of activities played with dice, cards, and boards can be good settings for the group game (Kamii & DeVries, 1980; Siegler & Ramani, 2008). These activities are based on

social interaction as well as on basic counting skills and strategies. In particular, it is possible for young children to positively learn number concepts through social play because basic number concepts are necessary to do such activities. Based on the constructivist perspective, the author hypothesized that mathematics games with peer interaction can be meaningful activities to facilitate understanding and acquiring proficiency in understanding number concepts for preschoolers and early elementary graders. As a preschool teacher, the author focused on creating activities using dice, cards, and board game sets which can positively improve young children's mathematical communication and cognition of number concepts learning through play. The author concentrated on traditional dice patterns, developed the dice, cards and board game sets with added grids, and produced three different kinds of computer games: *Twin Silly Robots*, *Candlelight Activity*, and *Froebelian Design Software* including three-week-long Combined Activity Teacher's Manual (See Appendix A-Teacher's Manual), all of which were based on dice patterns and matrices. The author assumed that young children might obtain the conceptual model of composition of numbers through repetition and various counting skills as part of their meaningful practice with patterns of one die and two dice. Therefore, for the experimental group, the fundamental part of the combined activity is to use a die, dice, cards, board game set, and the computer games.

Method

Participants and Research Sites

For the site of this action research, the author chose two different preschools. One was selected for an experimental group (EG) using YJ Combined Activity and the other preschool was selected for the control group (CG) using traditional mathematics activities. For the selection, the author chose two different preschools located in an urban area of southern Florida. Both randomly selected schools had a good reputation among parents living in the area. A total of 41 children from two different preschools participated in this study.

The participants' (children's) demographic information of age, socio-economic status, gender, and ethnicity is summarized in Table 1.

Table 1. *Participant Demographics*

Group	N	Age			SES			Gender		Ethnicity			
		3	4	5	L	M	H	Male	Female	Caucasian	African American	Hispanic	Asian
Experi-mental Group	21	8	6	7	0	15	10	12	13	21	1	1	2
Control Group	16	5	8	3	4	4	8	7	9	11	3	2	0
Total	37	13	14	10	4	19	18	19	22	32	4	3	2

Research Design and Measures

The author used a quasi-experimental (pretest-posttest) control group design which is commonly used in educational experimentation (Creswell, 2003). The independent variable was instructional intervention (“Combined Activity” with Teacher’s Manual) with practice. The dependent variables were early numerical abilities (seriation and logico-classification) and counting and addition skills, which were assessed via standardized measures before and after the intervention and classroom observation over the course of the three-week activity plan. To test the research questions, the author used 16 questions from a number assessment based on “classroom-based teaching experiments” suggested in Clements’ (2007) Curriculum Research Framework (CRF; see Appendix B: Number Assessment). Classroom-based teaching experiments have been used “to track and evaluate student learning, with the goal of making sense of the curricular activities as they are experienced by individual students” (Clements, 2007, p. 48). These research questions were important for developing the learning materials because the questions led the author to gather information the author could use to decide whether the materials were more effective at helping young children understand number concepts compared with a traditional math activity. The author needed objective tools to obtain clear evidence of these effects when using a combination of hands-on and computer manipulatives. Therefore, the author used the exemplary questions that Clements and Sarama (2007b) introduced in the appendix of *Real Math Building Blocks (Pre-K)*. The author used the 16 questions for the pre- and posttest and assessed the children who participated in the study two times before and after using the combined activity, coded the quantitative data from the assessment, and analyzed the data.

Procedures and Data Analysis

The author collected the data over the course of three weeks in two preschool classrooms, first distributing consent forms to the participant children's parents, then after receiving consent, taking field notes, observing the participants, and interviewing the participant children (testing them using the assessment tools). The author used two laptop computers for the computer activities, one digital video camera and field notes for observation, and assessment tools for pre- and posttest of each participant. The author used Clements and Sarama's (2004a; 2004b) number assessment process to analyze the pre- and posttests, comparing the videotape data with the assessor's paper data to identify administration errors, coding each item according to the scales, entering the data into a Microsoft Excel file, and then analyzing the individual child's data using statistical analysis software (SPSS). The research questions were answered by analyzing results obtained from analysis of covariance (ANCOVA) to determine if there are significant differences in the two groups' posttest scores in seriation, logico-classification, counting, and addition. For all statistical tests, the level adopted to determine significance was $p = .05$

Results

The purpose of this study was to investigate the relative effectiveness of the Combined Activity (using a combination of YJ hands-on manipulatives and YJ computer software) and a traditional math activity (a whole group activity using commercial hands-on manipulatives and worksheets) in developing children's number concepts. The major hypothesis was that the participants who received the instructional intervention (Combined Activity) would demonstrate better knowledge on the posttest of number concepts including seriation, logico-classification, counting, and addition after the intervention than the participants in the control group. The means and standard deviations of the pretests and posttests for the groups are presented in Table 2. The results revealed that mean scores increased for the experimental groups, but the total score did not show significant gains from pretest to posttest for the control group. This demonstrates that the treatment in the experimental groups significantly improved students' understanding of number concepts.

Table 2. *Mean and Standard Deviation of Variables in Control and Experimental Group*

Variable	Experimental Group			Control Group		
	M	SD	N	M	SD	N
Pre-test	28.8	16.7	21	26	15.7	16
Post-test	41	21	21	26.6	18	16

As shown in Table 3, analysis of the data shows that $F(1,34) = 6.253$, $p < 0.05$. There is a significant difference between the posttest scores in the experimental group and the control group. Thus, the first research hypothesis was confirmed. In other words, the treatment (Combined Activity using teacher-made hands-on and computer games) was more effective at enhancing the preschoolers' understanding of number concepts than the control method (using commercial hands-on materials and worksheets without computer games).

Table 3. *Analysis of Covariance on Posttest as Dependent Variable*

Source	Type III Sum of			Observed		
	Squares	df	Mean Square	F	Sig.	Power ^b
Pretest	6903.124 ^a	1	6903.124	33.019	.000	1
Group	1307.263	1	1307.263	6.253	.017	.681
Error	7108.269	34	209.067			

a. R Squared = .553 (Adjusted R Squared = .527)

b. Computed using alpha = .05

Specific Findings from the Quantitative Data

Both pre- and posttest consisted of sixteen questions on seriation, logico-classification, counting, and addition. The specific findings for each research question are presented in the tables below. To determine which group had more gain, a descriptive analysis was conducted to compare the raw scores of the two groups from the four subtests of number concepts. ANCOVA was used to analyze the raw scores of each subtest of the two groups. The main results follow:

1. The results of the descriptive analysis indicated that both groups increased their scores on the posttests in seriation, counting, and addition. The experimental group made larger gains. Both groups had lower scores on the posttests in classification, and the experimental group had a larger loss. The experimental group had the largest gain on their posttest scores in addition, but the control group had lower scores in addition (see Table 4).

Table 4. Mean Scores of Four Subtests for Experimental and Control Group

Group	Test Time	M	Diff*	M	Diff*	M	Diff*	M	Diff*
Experimental	Pretest	6		7.08		8.36		4.88	
	Posttest	9.82	3.82	6.88	-1.8	11.28	2.92	8.76	3.88
Control	Pretest	4.69		9		8.06		4.5	
	Posttest	5.75	1.06	7.88	-1.12	8.69	0.63	4.31	-0.19

* Diff means difference between pretest and posttest means.

2. Results from the ANCOVA analyses indicated that the experimental group made significantly more gain than the control group in seriation and addition, but no difference was found in classification or counting (see Table 5).

Table 5. ANCOVA Results for Experimental and Control Group

Subtest	Source	df	MS	F	Sig	Observed P ^b
Seriation	Pretest*	1	575.273	23.868	.000	.997
	Group**	1	160.286	6.650	.014	.707
	Error	34	24.102			
Classification	Pretest	1	417.016	15.617	.000	.970
	Group	1	.440	.016	.899	.052
	Error	34	.24.702			
Counting	Pretest	1	308.245	5.747	.022	.644
	Group	1	58.345	1.929	.174	.271
	Error	34	51.572			
Addition	Pretest	1	74.043	2.658	.112	.354
	Group	1	262.758	9.395	.004	.846
	Error	34	27.859			

* Pretest = Correlation between pretest and posttest.

** Group = Comparison between experimental and control group

b. Computed using alpha = .05

To determine whether the effectiveness of the Combined Activity is affected by the participants' gender, amount of time spent playing the games, and age, a descriptive analysis was conducted to compare the raw scores of boys and girls, time span of four categories (between 1 and 50 minutes, between 51 and 100 minutes, between 101 and 150 minutes, between 151 and 200 minutes, and between 200 and 250 minutes.), and age (i.e., 3-, 4-, and 5-year olds) in the experimental group. ANCOVA was used to analyze the raw scores of each factor. As shown in Table 6, analysis of the data shows that there is no significant difference between the posttest scores between boys and girls, among 3- to 5-year-olds, or among individual time-spans for the Combined Activity in the experimental group. Thus, the first research hypothesis was rejected. In other words, factors such as gender, age, and time span did not affect the posttest scores related to the treatment. The Combined Activity (using teacher-made hands-on and computer games) was effective for both boys and girls and for all 3- to 5-year-olds, but spending a long time playing the Combined Activity does not promise better performance on tests of number concepts (see Table 6).

Table 6. ANCOVA Results of Gender, Age, and Time Span for Experimental Group

Subtest	Source	df	MS	F	Sig.	Observed P ^b
Gender	Pretest *	1	5435.108	29.509	.000	.999
	Gender **	1	89.964	0.118	.735	.062
	Error	18	184.185			
Age	Pretest	1	2912.613	15.532	.001	.960
	Age ***	2	74.609	.398	.678	.104
	Error	17	187.519			
Time Span	Pretest	1	4473.750	28.366	.000	.999
	Time Span ****	1	271.205		.203	.364
	Error	16	157.714	1.720		

* Pretest = Correlation between pretest and posttest.

** Gender = Comparison between boys and girls in the experimental group.

*** Age = Comparison among 3 year olds, 4 year olds, and 5 year olds

**** Time Span = Comparison among five different time span groups for individual participant (between 1 and 50 minutes, between 51 and 100 minutes, between 101 and 150 minutes, between 151 and 200 minutes, and between 200 and 250 minutes)

b. Computed using alpha = .05

Discussion

The results of the pretest and posttest data showed that the participants in the experimental group performed better than the participants in the control group. The four sub-categories (seriation, logico-classification, counting, and addition) were analyzed and separated. There was a significant difference between the two groups in the categories of seriation and addition problems but not in the categories of counting and logico-classification problems. In particular, the combined activity did not significantly affect the results of logico-classification and counting test scores from pretest to posttest; the posttest scores for logico-classification did not increase, though the posttest scores for counting increased a little bit.

Seriation

Why did the participants who experienced the Combined Activity perform well on the posttest for seriation but not for logico-classification? Seriation is important to the mathematical structure of ordering (Piaget, 1970). One of Piaget's experiments showed that children in the early preoperational stage (between 2 and 4 years of age) had a difficult time with seriation tests, but children in the later preoperational stage (between 4 and 7 years of age) could solve seriation problems well. In this study, the author provided a variety of seriation activities using *YJ card game sets*. For instance, the children were able to order 10 cards containing from one dot with the numeral 1 to ten dots with the numeral 10 and compare the cards to understand which card had more dots or which card had fewer dots while playing the game. The younger children (3-year-olds) had a hard time following the tasks of seriation using the YJ Cards, but 4- and 5-year-olds performed well on the same tasks. This supports Piaget's (1964) developmental theory in terms of how well younger children perform on tasks of seriation compared to older children. Furthermore, although there was no significant difference between the experimental group and the control group for the seriation posttest scores, the posttest scores of the experimental group were different (i.e., higher) from the pretest scores, indicating that many participant children had a clearer knowledge of seriation at the end of this learning intervention and developed their knowledge of seriation through the Combined Activity.

Classification

Inhelder and Piaget (1969) stated that “the true significance of classification is the fact that the child who can classify can reason logically about the properties of things by adhering to unambiguous criteria” (p.xxii). The task of classification can be divided into three stages: (1) graphic collection, (2) non-graphical collection, and (3) hierarchical classification based on logico-operations. The first two stages are relevant to children in the preoperational stage (2 to 7 years of age); the third stage is most relevant to children in the concrete operational stage (7 to 9 years of age; Ginsburg & Oppen, 1988). According to Piaget’s (1964) developmental theory, the 3 to 5 year old children who participated in this experimental group belonged to the preoperational stage. This means that many of the children in this study could perform graphic and non-graphical collection, but hierarchical classification may have been beyond their abilities at this stage. In this study, the results for classification suggest that this is the case, as the preoperational-stage children who participated in this study did not perform well on the classification questions.

Counting

As mentioned above, research has been conducted on children’s understanding of the mathematical basis for counting, focusing on five principles that their thinking must follow in order to engage in meaningful counting: one-to-one correspondence, stable order, cardinality, abstraction, and order irrelevance (Gelman & Gallistel, 1978; Kilpatrick, et al., 2001). In this study, the children who engaged in the Combined Activity had a variety of counting experiences such as rolling *YJ Number Cubes*, moving the counting bear on the board, and counting dots on the YJ Card Game Set, all of which are related to these principles of meaningful counting, especially one-to-one correspondence, stable order, and cardinality. The author hypothesized that the experimental group who experienced the Combined Activity would perform much better on the counting test than the control group. However, there was no significant difference between the experimental group and the control group although there was an increase in counting skills between the pretest and the posttest for both groups. Therefore, the author concluded that the Combined Activity helped the participants develop

their counting skills although there was no significant difference between the experimental group and control group.

Addition

The author believes that a variety of addition activities helped the young children perform well on the posttest for addition. Kamii (2000) suggested that a teacher should use various card and board games to create cooperative and interactive learning environments for children who did not comprehend the concrete conservation of number during the preoperational period. The author added simple addition games for the computer activity such as *Candlelight Activity* and *Twin Silly Robots*. The author thinks that both the hands-on activity and computer activity for the simple addition games worked well for the preschoolers. The participant children demonstrated mathematical problem solving and communication skills (see NCTM, 2000) by using questions (e.g., “Am I right?” or “Am I correct?” after taking a turn) in these social math game activities (Bodrova & Leong, 2004). In addition, the author strongly assumed that the material, *YJ Number Cube*, which had the combination of 3 X 3 matrix and traditional dice patterns, worked well for young children. Currently, many researchers and early childhood educators insist that it is important for young children to recognize common visual patterns and develop part-part-whole concepts of numbers (Clements, 2001; Payne & Huinker, 1993; Resnick, 1983; Van de Walle, 1988).

The children had many chances to use YJ game sets with matrix and traditional die patterns such as *YJ Board Game Sets* and *YJ Card Game Sets* (hands-on activities) and *Twin Silly Robots* and *Candlelight Activity* (computer software). The Combined Activity significantly affected young children’s learning of addition (under 10 objects) in the experimental group compared to the traditional activity (the control group).

Within the experimental group with combined activity. There was a significant difference in the experimental group’s performance between the pretest and posttest, but no significant difference in the boys’ and girls’ and 3- to 5-year olds’ performance in the experimental group. The YJ Combined Activity positively affected both boys’ and girls’ and 3- to 5-year-olds’ better understanding of number concepts.

There was no significant relationship between the participants' performance and the participants' time span in the experimental group. In other words, the author cannot expect that a child who spends more time engaging the combined activity can obtain much higher test scores of number concepts between the posttest than at the pretest. Does this mean that the Combined Activity may be not effective? The effectiveness of the Combined Activity can be clarified from individual's engagement in each activity and understanding of the main concept of *Combined Activity*.

Piaget (1964) indicated that intellectual development is a gradual, continuous process, and his age norms and the timing of the developmental stages are not rigid; it can vary for each individual child. It is notable that in this study, the children's age was still related to their performance or understanding of number concepts. Based on the results, the author assumes that the learning materials such as a combination of hands-on manipulatives and computer games used in the combined activity would be developmentally appropriate for preschoolers.

Conclusion

The author concluded that the Combined Activity relatively influenced the participants' understanding of number concepts, especially addition. In the experimental group, the combined activity significantly influenced both the boys' and girls' performance in number concepts, although there was no significant relationship between the participants' time span and performance. The most interesting result was that the experimental group (or Combined Activity group) test scores were not significantly related to the participants' age. Thus the Combined Activity with YJ hands-on manipulatives and computer software was effective and developmentally appropriate for 3-, 4-, and 5-year-olds in the experimental group.

There are many suggestions for future study. First, the treatment duration could be longer than three weeks. The several non-significant differences might have been because the amount of time the children were able to engage in the Combined Activity was too short for significant differences to occur. Second, the group sizes and number of treatments can be increased for the future of this study. For example, the Combined Activity, which consisted of hands-on manipulatives and computer software, could be divided into three treatments for

three groups; (1) YJ computer software only, (2) YJ hands-on manipulatives only, and (3) both YJ computer software and YJ computer software. A different pattern of results could be expected, especially to test the necessity of combining the two activities (i.e., both hands-on activity and computer activity). Third, there should be further study of children in different socio-economic levels. Lastly, the samples of two groups were not homogeneous in their ratios of age, gender, and SES. The sample size for the current study was small ($N = 37$). It could be extended for large-scale research.

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Appendix A

Teacher's Manual

All contents can be found at www.newfroebel.in

1. Hands-on Activity Manipulatives and Manual

http://www.gfkhope.org/PARK/YJ_Hands-on_Manipulatives.pdf

2. Computer Activity Materials

a. Froebelian Design Software:

<http://www.gfkhope.org/PARK/Froebelian.pdf>

b. Twin Silly Robots:

http://www.gfkhope.org/PARK/Twin_Silly_Robots.pdf

c. Candlelight Activity:

<http://www.gfkhope.org/PARK/Silly%20Yongjoon's%20candlelight%20activity.swf>

Appendix B

Number Assessment

Child's Name:

Child's Age:

Assessor's Name:

Assessment Time: to

Assessment Date:

Assessment place:

Comments:

Pre- and Post- test Questions of Number Concepts

Categories of Pre-and Post-test: total 16 questions (100 points)

- Seriation (questions 1, 2, 3 and 4): 4 pts + 6 pts + 7 pts + 8 pts = 25 points
- Logico-Classification (questions 5, 6, 7 and 8): 4 pts + 6 pts + 7 pts + 8 pts = 25 points
- Counting (questions 9, 10, 11 and 12): 4 pts + 6 pts + 7 pts + 8 pts = 25 points
- Addition (questions 13, 14, 15 and 16): 4 pts + 6 pts + 7 pts + 8 pts = 25 points

* All test questions are based on Learning Trajectories for Primary Grades (Number Concepts).

Test Category	Age Range	Level Name	Level	Description	Test question	Test Material	Child's Answer
Seriation (or Comparing and Ordering)	4	Counting Comparer (Same Size)	8	At this level, children make accurate comparisons via counting, but only when objects are about the same size and groups are small (about 1-5 items)	"There are different sized buildings (blocks) here. I have the biggest (or largest) one of them. If this is the biggest one, could you make the same building like mine using some other blocks?" (pointing to the rest of the blocks instead of the biggest one)	5 Rec-tangular Blocks (different sized blocks)	Yes (4 pts.) Partial (2 pts.) No (0 pts.) N/A (0 pts.) Comments:
	5	Counting Comparer (5)	9	As children develop their ability to compare sets, they compare accurately by counting, even when a larger collection's objects are smaller. A child at this level can figure out how many more or less.	"Here is my card (with 4 dots). There is your card (with 7 dots). How many more dots do you have than I have?"	2 Ten Frame Cards (about 4 and 7)	Yes (6 pts.) Partial (3 pts.) No (0 pts.) N/A (0 pts.) Comments:
	5	Ordinal Counter	10	At this level, a child identifies and uses ordinal numbers from "first" to "tenth." For example, the child can identify who is "third in line."	"10 Bears made a line for a picnic. Where is the yellow bear in line?"	10 Counting Bears (1 yellow bear and 9 different colored bears)	Yes (7 pts.) Partial (3.5 pts.) No (0 pts.) N/A (0 pts.) Comments:
	6	Mental Number Line to 10	12	As children move into this level, they begin to use mental images and knowledge of number relationships to determine relative size and position. For example, a child at this level can answer which number is closer to 6, 4 or 9 without counting physical objects	"I have number 6. Here are two cards. Which number is closer to 6?" (pointing at number 4 and number 9 card)	3 numeral Cards (4, 6, and 9)	Yes (8 pts.) Partial (4 pts.) No (0 pts.) N/A (0 pts.) Comments:

The Relative Effectiveness of Teacher-made Games for Preschoolers' Understanding Number Concepts

Test Category	Age Range	Level Name	Level	Description	Test question	Test Material	Child's Answer
Logico Classification (composing Knowing combinations of Numbers)	4	Pre-Part-Whole Recognizer	1	At the earliest levels of composing, a child only nonverbally recognizes parts and wholes. For example, when shown 4 red blocks and 2 blue blocks, a young child may intuitively appreciate that "all the blocks" includes the red and blue blocks, but when asked how many there are in all, the child may name a small number, such as 1.	(Showing a child 2 blue blocks first and then showing the child 4 uncolored blocks on a table) "How many are there in all (or altogether)?" (pointing around the blue and plain blocks)	2 blue blocks and 4 plain blocks	Yes (4 pts.) Partial (2 pts.) No (0 pts.) N/A (0 pts.) Comments:
	5	Composer to 4, then 5	3	At this level, a child knows number combinations. A child at this level quickly names parts of any whole, or the whole given the parts. For example, when shown 4, then 1 is secretly hidden, and then shown the 3 remaining, the child may quickly say "1" is hidden.	(Showing 5 plain blocks first and then hiding 2 blocks under the assessor's right hand) "How many blocks are hidden?"	5 plain blocks	Yes (6 pts.) Partial (3 pts.) No (0 pts.) N/A (0 pts.) Comments:
	6	Composer to 7	4	The next sign of development is when a child knows number combinations to totals of 7. A child at this level quickly names parts of any whole, or the whole when given parts, and can double numbers to 10. For example, when shown 6, then 4 are secretly hidden, and then shown the 2 remaining, the child may quickly say "4" are hidden.	(Showing 7 plain blocks first and then hiding 2 blocks under the assessor's right hand) "How many blocks are hidden?"	7 plain blocks	Yes (7 pts.) Partial (3.5 pts.) No (0 pts.) N/A (0 pts.) Comments:
	6	Composer to 10	5	At this level, a child knows number combinations to totals of 10. A child at this level may quickly name parts of any whole, or the whole when given parts, and can double numbers to 20. For example, this child would be able to say "9 and 9 is 18."	(Showing the number 5 card first and then showing another number 5 card) "What is the total of 5 and 5?"	3 number cards (2 number 5 cards)	Yes (8 pts.) Partial (4 pts.) No (0 pts.) N/A (0 pts.) Comments:

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Test Category	Age Range	Level Name	Level	Description	Test question	Test Material	Child's Answer
Counting	4	Producer (Small Number)	7	The next level after counting small numbers is to count out objects to 5. When asked to show four of something, for example, this child may give four objects.	(Showing 5 blocks) "Can you count them all? How many are there?" (Pointing around the blocks)	5 plain blocks	Yes (4 pts.) Partial (2 pts.) No (0 pts.) N/A (0 pts.) Comments:
	4	Counter (10)	8	The child may count structured arrangements of objects to 10. He or she may be able to write or draw to represent 1-10. A child at this level may be able to tell the number just after or just before another number, but only by counting up from 1.	(Showing 10 blocks) "Can you count them all? How many are there?" (Pointing around the blocks)	10 plain blocks	Yes (6 pts.) Partial (3 pts.) No (0 pts.) N/A (0 pts.) Comments:
	5	Counter And producer-Counter to (10+)	9	Around 5 years of age, a child may begin to count out objects accurately to 10 and then beyond to 30. He or she has explicit understanding of cardinality (that numbers tell how many). The child may keep track of objects that have and have not been counted, even in different arrangements. He or she may write or draw to represent 1 to 10 and then 20 and 30, and may give the next number to 20 and 30. The child also begins to recognize errors in others' counting and is able to eliminate most errors in his or her own counting.	(Showing 10 blue marbles and 10 gray marbles) "Can you count them all? How many are there?" (Pointing around the marbles)	10 blue Marbles And 10 gray marbles	Yes (7 pts.) Partial (3.5 pts.) No (0 pts.) N/A (0 pts.) Comments:
	6	Counter from N (N+1, N-1)	11	Around 6 years of age, the child may begin to use counting-on strategy, counting verbally and with objects from numbers other than 1. Another noticeable accomplishment is that the child may determine the number immediately before or after another number. without having to start back at 1.	(Showing 10 blue marbles and hiding 5 of them under the assessor's right hand) "I am going to hide 5 of them with my hand. Can you count them all now? How many?"	10 blue marbles	Yes (8 pts.) Partial (4 pts.) No (0 pts.) N/A (0 pts.) Comments:

The Relative Effectiveness of Teacher-made Games for Preschoolers' Understanding Number Concepts

Test Category	Age Range	Level Name	Level	Description	Test question	Test Material	Child's Answer
Addition	4	Small Number	3	At this level, a child can find sums for joining problems up to $3 + 2$ by counting with objects. For example, when asked, "You have 2 balls and get 1 more. How many in all?" the child may count out 2, then count out 1 more, then count all 3: "1, 2, 3 – 3!"	"You have 3 balls and get 2 more. How many in all?"	No material needed	Yes (4 pts.) Partial (2 pts.) No (0 pts.) N/A Comments:
	5	Find Change	5	At this level, a child can find the missing addend ($5 + = 7$) by adding on objects. For example, when asked, "You have 5 balls and then get some more. Now you have 7 in all. How many did you get?" The child may count out 5, then count those 5 again starting at 1, then add more, counting "6, 7," then count the balls added to find the answer, 2.	"You have 5 balls and then get some more. Now you have 7 in all. How many did you get?"	No material needed	Yes (6 pts.) Partial (3 pts.) No (0 pts.) N/A Comments:
	5	Make It	6	A significant advancement occurs when a child is able to count on. This child can add on objects to make one number into another without counting from 1. For example, when told, "This puppet has 4 balls, but she should have 6. Make it 6," the child may put up 4 fingers on one hand, immediately count up from 4 while putting up 2 fingers on the other hand, saying, "5, 6," and then count or recognize the 2 fingers.	"This puppet has 4 balls, but she should have 6. Make it 6 using your fingers."	A hand puppet	Yes (7 pts.) Partial (3.5 pts.) No (0 pts.) N/A Comments:
	6	Part-Whole	8	Further development has occurred when the child has part-whole understanding. This child can solve problems using flexible strategies and some derived quantities sometimes do start-unknown problems ($_ + 6 = 11$), but only by trial and error. When asked, "You had some balls. Then you get 6 more. Now you have 11 balls. How many did you start with?"	"You had some balls. Then you get 6 more. Now you have 11 balls. How many did you start with?"	No material needed	Yes (8 pts.) Partial (4 pts.) No (0 pts.) N/A Comments: