

A Preschool Teacher's Action Research Using a Combination of Hands-On Manipulatives and Computer Software to Help Preschoolers Understand Number Concepts

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Abstract

This is a case study involving a preschool teacher who produced and tested a design called “Combined Activity,” which uses a combination of hands-on mathematics manipulatives and computer software to help preschoolers understand number concepts. The purpose of the action research was to describe how the children experienced the Combined Activity in learning number concepts by using a combination of hands-on manipulatives and computer software. The participants were a preschool teacher and 20 three- to five-year-old preschoolers who spent three weeks using the Combined Activity at a preschool in an urban area in Florida, U. S. A. Results of this study show that the participants in the Combined Activity were able to interact with the teacher and peers using diverse communication skills in much more varied mathematical learning environments than by lecture alone. The findings imply that a teacher needs to design the physical setting taking into consideration the culturally and developmentally appropriate learning environment (Copple & Bredekamp, 2009; Gestwicki, 2009; Tobin, 2011) through on-going observation. The teacher also needs developmentally appropriate materials, reflective activity plans, and clear guidelines as well as attention to the children’s linguistic and cultural backgrounds.

Keywords : action research, young children, mathematics education, computer games, card and board game sets

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Introduction

Teacher Research

According to Vockell and Asher (1995), “action research refers to the practical application of the scientific method or other forms of disciplined inquiry to the process of dealing with everyday problems, especially about specific classes and programs” (p. 10). Some teachers have been doing action research because they think that such efforts can make their teaching or educational activities better or more productive (Harmer, 2002). Specifically, many researchers have conducted “curriculum action research” (Riding et al., 1995) focused on two goals:

(1) to search for the evidence needed to solve practical problems; and (2) to help those who are doing the action research to acquire more adequate perspective regarding their problems, to deepen their insights as to what is involved in their task and to extend their orientation toward children - toward methods of teaching them or toward what is significant in the content of learning (Taba & Noel, 1957, p. 2).

I considered the above definition and criteria for action research for the framework of this study and used the procedure of practitioner research (or, more specifically, *teacher research*) which is framed in action cycles (Herr & Anderson, 2005, p. 5) to do the following:

1. develop a plan of action to improve what is already happening;
2. act to implement the plan;
3. observe the effects of action in the context in which it occurs; and
4. reflect on these effects as a basis for further planning, subsequent action and so on through a succession of cycles.

The Cycle of Action Research in the Current Study

The purpose of this study was to describe how children experienced learning number concepts by using a combination of hands-on manipulatives and computer software. The process of this action research is based on the cycle of inquiry: planning-acting-observing-reflecting (Herr & Anderson, 2005; Johnson, 2005).

As a preschool teacher, I have observed that many young children have a hard time understanding number concepts such as counting, sorting, small number addition, and even the relationship between quantity and numerals under 10. Some of them did not have positive attitudes about learning number concepts in teacher-directed and repetitive activities such as counting manipulative objects on a table. As I thought about how to engage young children in learning number concepts and developing a positive attitude, I noticed that some instructional games such as card games and board games using a die or dice appeared to help them learn number concepts through on-going social interaction (Kamii, 2000, 2004; Kamii & DeVries, 1980). Although Kamii and DeVries mainly studied the relationship between the instructional games and understanding number concepts with children in kindergarten to second grade, I wondered how younger children (three- to five-year-olds) would experience the social games I designed with a focus on the preschool level math skills of number concepts (i.e., counting, sorting, adding, and matching objects with numerals).

For my research plan, I set up goals and developed a three-week-long activity (see Appendix A) based on research (my on-going case studies) and teaching experiences. Appendix B shows a brief summary of how I used the activity, including the dates. My original plan was to use the Activity Plans for Nine Sessions (Appendix B), but I changed the weekly activity reviewing process to a daily reviewing process. For instance, if many children were not interested in a specific activity, I changed the next activity plan after reviewing the observations with my research assistants. In the act and observe phase, I played with the learning materials and games with the preschoolers in a small group setting while two research assistants observed the children's activities with the materials. After each session, the two assistants and I engaged in on-going reflection as we reviewed the observation notes, my reflections, and video clips and modified the activity plans for future planning if necessary.

Literature Review

Research on Instructional Game Effects

Many teachers and researchers have indicated that games are an effective instructional

device in mathematics education. Many math games have been used in classroom settings, including card, board, and computer games which were made by classroom teachers, researchers, companies, or a combination (Bright, Harvey, & Wheeler, 1985; Kamii, 2000, 2004; Randel, Morris, Wetzel, & Whitehill, 1992). Randel et al. reviewed 67 empirical research studies comparing the instructional effectiveness of games to conventional classroom instruction spanning the period 1963 to 1991. In 38 of these studies, there was no difference between games and conventional instruction. However, in 22 of these studies, games were effective but their controls were questionable, and conventional instruction was found to be better than using games in 3 of the studies. Although the authors did not find overall positive results of game effects (e.g., no difference in 38 studies), they concluded that many instructional games for learning math were more effective than conventional instruction. Vogel et al. (2006) conducted another meta-review of 32 studies from the mid-1980s to the mid-2000s on the effects of using games in instruction and found that many traditional games and interactive simulations in combination with traditional teaching methods (except for teacher's heavy control) significantly influenced the participants' cognitive gains.

Pange (2003) investigated the effects of using a combination of hands-on manipulatives (i.e., dice and coins) and computer-based games (e.g., using dice patterns on the screen) to teach probability and statistics to four- and five-year-old children and found that the games helped the preschoolers understand advanced concepts of probabilities and statistics.

Chituk (2003) investigated whether or not instructional intervention using hands-on manipulatives and instructional games such as board games and computer games improved the counting skills of young children with developmental delays. In this study, one of three different experimental groups used manipulative objects for counting, another group used a board game set ("Chutes and Ladders") and the third group used computer software ("Chutes and Ladders"). The three groups' progress was compared with a control group (no specific mathematics instruction). From the participants' pretest and posttest results, Chituk concluded that the young children who received the instructional intervention using hands-on manipulatives or computer software demonstrated better counting skills after intervention. Specifically, the participants in the board game group and in the computer group improved about two times more than the participants in the control group.

Clements and Sarama (2004, 2007a) developed a research-based mathematics curriculum

from the “Building Blocks Project” (from Pre-K to grade 2) using the scientific process: (a) setting up the objectives, (b) designing a curriculum and software based on theory and research, (c) pilot testing the curriculum and software, and (d) producing the materials and retesting the products on a large scale. The materials consisted of a print curriculum, computer software, and hands-on manipulatives which were linked together according to the content area, mainly number and geometry. Clements and Sarama (2007a) conducted an experimental study in classrooms with four-year-old children from low-income families. The experimental group used the Building Blocks curriculum materials in number and geometry and the control group followed the conventional curriculum. The children in the experimental group understood the concepts of number and geometry better than the children in the control group because of the strong positive effects of the combination of hands-on manipulatives and computer software in the Building Blocks materials. According to their published curriculum, Clements and Sarama (2007b) used a variety of curriculum materials such as card and board games with a die or dice for number concepts as well as computer software containing similar patterns to the card and board games.

Siegler and Ramani (2008) found that playing a numerical board game very similar to the board game “Chutes and Ladders” over the course of nine weeks promoted disadvantaged pre-kindergarten students’ numerical development, specifically their proficiency on four kinds of numerical tasks: numerical magnitude comparison, number line estimation, counting, and numeral identification. Siegler and Ramani also examined the relations between young children’s number knowledge and their game playing experience and investigated the relationship of the children’s home experience with games (such as board games, cards games, and video games) to their numerical knowledge. They concluded that home experience playing number board games correlated positively with numerical knowledge and insisted that both teachers and parents should provide a social learning environment using inexpensive number board game sets for young children. However, few researchers have explored how preschoolers experience a teacher-made combined activity using a combination of cards, board game sets, and computer software. The current study is necessary as a foundation for developing learning materials for research-based preschool curricula (Clements, 2007).

Teacher-created Games

What is an appropriate game to improve young children's cognitive development such as in number concepts? In my opinion, many people would indicate that an appropriate mathematics game allows children to explore two kinds of interaction in the game play: (a) interaction with real tools (e.g., card or board game sets and computer games) and (b) interaction between game players using psychological tools such as signs and symbols (in this case, numbers and mathematical systems) and language (in this case, mathematical communication). In game play, the interaction between the children using the tools called "cultural tools" such as (a) real tools and (b) psychological tools can help the children develop number concepts (Wertsch & Ruburt, 1993). In other words, young children can learn number concepts based on their interactions with objects and phenomena as well as with other players in the social environment built in the game rules and physical settings (Vygotsky, 1978). Within the game play environment, a variety of interaction among players can be expected. More advanced children or teachers can help less advanced children reach the zone of proximal development (ZPD; Vygotsky, 1978), which is what the child cannot do by himself or herself, but can do with guidance. For instance, as the person with the most knowledge, a teacher can kindly correct less advanced children's miscounting dots on the dice. If less advanced children can understand the correction about the miscounting, they can practice and master it later on with the teacher's guidance. When the less advanced children fully understand the game play including accuracy of counting, sorting, adding, and matching objects with numerals, the teacher gradually shifts responsibility to the children as the teaching strategy. This concept of "scaffolding" (Berk & Winsler, 1995) is applicable to the social context of the game. In a school setting, the social context is a vital part of the learning environment because children learn from people as much as they learn facts or procedures (Bodrova & Leong, 2004, 2007). This concept is also related to the standards of the National Association for the Education of Young Children (NAEYC), including "Children learn through play" and "Children learn through social interaction with adults and other children" (NAEYC & NAEYC, 1991). The social context of processing the game can be connected to a variety of types of mathematical communication among the teacher and children, one of the process standards from the National Council of Mathematics of Teachers (NCTM, 2000).

Furthermore, Vygotsky pointed out the relationship between the games and age-appropriateness: "The development of playing games with rules begins in the late preschool period and develops during school age". For preschoolers, activities with simple rules involving dice, cards, and board games are especially good settings for games (Kamii, 2000) because these activities are based on social interaction and basic counting skills and strategies appropriate for their age.

It is possible for young children to positively learn number concepts through social play depending on teacher's guidance of game rules. Teachers can reinvent mathematics instruction by creating interactive mathematics games. This process is good not only for children but also for teachers: "As their students reinvented arithmetic, the teachers' own understanding for math instruction was transformed" (Wakefield, 1998, p. vii).

In creating activities for the preschoolers in my class, I assumed that mathematics games featuring peer interaction with real tools can meaningfully facilitate understanding and acquiring proficiency in counting, sorting, adding skills, and learning about the relationship between objects and numerals. I focused on creating activities using dice, cards, and board game sets which can positively improve young children's mathematical communication and cognition of number concept learning through play. For the games I developed, I concentrated on traditional dice patterns and developed dice, cards, and board game sets by adding grids. I produced three different kinds of software: "Twin Silly Robots," "Candlelight Activity," and "Froebelian Design Software" (Appendix A). These game sets were based on the idea of combining dice patterns and grids (3x3, 5x5, or 10x10).

Research Question

My action research led to the main research question: How do children experience the Combined Activity in learning number concepts by using a combination of hands-on manipulatives and computer software? To answer this question, I had the following four sub-research questions:

1. How did the children show their interest in the Combined Activity?
2. How did the participating children communicate their thoughts with peers and the

teacher in the process of the Combined Activity?

3. What kinds of intellectual and social behavior did the children exhibit in the Combined Activity?

4. How did children understand number concepts in the Combined Activity?

Methodology

Participants and Research Site

For the site of this action research, I chose a half-day, private, center-based preschool program located in an urban area of southern Florida, U. S. A. The location was chosen for convenience: the preschool program was located in the college where I worked. Many children who attended the preschool were from middle- to high-income families. Twenty-five three- to five-year-old children participated in the study. For the small groups, the students ranged in age from 3 years and 6 months to 5 years, with the average being 4 years and 2 months. Concerning ethnicity and gender, 44% of the students were Caucasian males, 40% were Caucasian females, 4% were other male (all Asian Americans) and 12% were other female (Asian American, Hispanic American, and African American); 52% of the children were male and 48% were female. I actively participated (Spradley, 1980) in the study to teach and observe the participant children and videotaped children's interaction with each other and with me while using the hands-on manipulatives and software for three weeks in the classroom.

Procedures

The experiment was conducted over a three-week period following the Activity Plans (See Appendix B). Throughout the three weeks, I worked with four small groups consisting of five children each (4 groups x 5 children = total 20 children) for about one hour (60 minutes - 80 minutes for every session) each day Monday through Thursday. I spent approximately 20 minutes with each small group (5 children). The time period (20 minutes) was divided into

10 minutes for my hands-on activity and 10 minutes for my computer activity.

There were two levels of treatment condition: (a) activities with hands-on manipulatives, and (b) activities with computer software. Two research assistants observed me in person apart from the teaching space and described my sessions using field notes of observation. After every session, the research assistants and I discussed the lesson I had given using a combination of hands-on manipulatives and computer software. I also took reflective teaching notes (i.e., reflection) that took into consideration the research assistants' comments and reflection on each lesson.

Data Collection

Consent forms were distributed to each child's parents and the study began after all forms had been signed and returned. Data were collected over a three-week period by entering the preschool classroom, taking field notes, videotaping and observing the participants (Creswell, 1997). I assigned one research assistant to observe and fill out observation notes for the hands-on activity part of my combined activity and the other research assistant to do the same thing for the computer activity part. I also encouraged the research assistants to observe any unexpected behavior. I made my own reflective notes after each session. A video camera was set up next to one of the research assistants to capture video of both the hands-on and computer activities.

Data Analysis

Two research assistants and I analyzed the research assistants' field notes, my reflective journals, and videotapes from the small groups to obtain insight on each session through triangulation (Creswell, 2003). All the transcripts were read and coded by hand according to coding methods suggested by Huberman and Miles (1994). For instance, three people (two research assistants and I) met to discuss our respective coding schemes and to discuss any discrepancies. We identified the factors (e.g., the children's most frequent verbal and non-verbal expressions) jointly after reflecting on the discussion and reviewing the video clips (both hands-on and computer activity) from each session. There were complete transcripts for

9 sessions of the Combined Activity including 72 video clip segments of the hands-on activity (36 segments = 4 groups x 9 sessions) and computer activity (36 segments = 4 groups x 9 sessions). The data were coded using the factors and themes that were common in the Combined Activity.

Results

The main research question guiding this study was: “How do children experience the Combined Activity?” The results from the qualitative data analyses revealed four themes of the children’s interest, three themes of communication patterns, and four themes of social and intellectual behaviors. Each result is displayed in a table including the frequency (%) of the themes for each sub-research question. I also present below some relevant dialogues that illustrate my analysis. The results of the three sub-questions are summarized and discussed in the following sections.

Children’s Interest in the Combined Activity

I found a total of 80 patterns that fit into four categories of showing interest: participating, gazing, showing enjoyment, and acting bored. These categories are relevant to the question of how the children showed their interest in the Combined Activity (see Table 1).

Participating vs. acting bored. The category “Participating” includes whether or not the children verbally expressed their interest in participating in the Combined Activity. For instance, when the teacher explained how to play the game, the children’s responses may have included such statements as “I want to play!”, “I want to play it more!”, or “Can I play the game now?” I counted these types of responses as the pattern for “Participating.” Negative expressions of interest such as “I do not want to play the game anymore” or “I want to do something else” were counted as “Acting bored.” For my participants, 45% of the reactions were classified as “Participating,” versus 14% which were classified as “Acting bored.” Here is the one example from the computer activity using Froebelian Design Software:

Table 1. *Types of Children's Interest by Combined Activity*

Types of Interest	Combined Activity	
	Hands-on Activity	Computer Activity
Participating	24%	21%
Gazing	8%	8%
Showing Enjoyment	12%	13%
Acting Bored	10%	4%
Sub-total	54%	46%
Total	100%	

Peter (to Teacher): Are you done? Can I play the computer game?

Susan: I want to play! (pointing at the computer screen)

Ryan: Can I play it now? (pointing at the computer game)

Teacher: (switching the hands-on activity to the computer activity) Okay. Today, I am going to set up for building blocks (moving the visual blocks on the screen using the touch pad of the laptop). How many blocks did I use?

Susan: (pointing at each visual block on the screen and counting them all) Five.

Teacher: (pointing at the rest of the blocks that were not used yet) How many blocks were left?

Susan: (counting the blocks and pointing at the blocks on the screen) Four!

Gazing. “Gazing” refers to task-oriented non-verbal behaviors such as looking long and intently at the board game sets or computer games (e.g., looking at dice, board game set, or computer screen). 16% of the children showed their interest in the activity by gazing at the materials from the hands-on activity (8%) and the computer activity (8%). In particular, several three-year-olds showed various patterns of gazing. Here is one example from the hands-on activity using the YJ Number Cube:

Teacher: Jane! It is your turn now (pointing at the dice).

Jane: (pause) (looking at the dice and holding up high for a moment) (pause) (dropping the dice on the floor)

Teacher: How many shiny squares did you get altogether (pointing at the dice)?

For the computer activity, there were a variety of patterns of gazing. The children especially gazed at the simulations on the screen when they played the “whole to part” activity from the “Frobelian Design Software.” Several three-year-olds gazed at Twin Silly Robots or Old Grandpa’s House on the screen and even pushed the number buttons using their index fingers on the screen instead of using the touch pad on the laptop.

Showing enjoyment. The pattern “Showing Enjoyment” was counted only if the children verbally showed their enjoyment (e.g., “I love it!” or “I like to play the game.”). We found similar results between hands-on activity (12%) and computer activity (13%). The following dialogue was recorded between two boys playing “Twin Silly Robots:”

John: (with smile, pointing at Twin Silly Robots on the screen) I like to play the game.

They look silly, but I love them all.

Jimmy: (looking at John) I like it too. Can I play it now?

In sum, the children showed their interest in the Combined Activity in three positive categories, including participating (total 45% including the hands-on and computer activity), gazing (total 16%), and showing their enjoyment (total 25%). There was one negative category, acting bored (total 14%). The children showed much more positive interest (total 86%) in the Combined Activity and its materials than negative expression. Many children expressed their interest in both the hands-on activity (total 44%) and computer activity (total 42%). However, several three-year-olds showed “Acting bored” related to the card or board game sets as a part of the hands-on activity and some of them easily forgot the game rules. The three-year-olds could not reach their ZPD of number concepts because the lack of interaction with real tools made them lose interest in the Combined Activity.

Children’s Communication in the Process of Combined Activity

Table 2 shows how frequently the children communicated their thoughts with peers and the teacher. I found 101 patterns for 3 categories of children’s communication: spontaneously verbalizing to peers, spontaneously verbalizing about the task, and responding to questions from the teacher.

Table 2. *Types of Children's Communication by Combined Activity*

Types of Communication	Combined Activity	
	Hands-on Activity	Computer Activity
Spontaneously Verbalizing to Peers	12%	18%
Spontaneously Verbalizing about the Task	20%	15%
Responding to Questions from the Teacher	17%	18%
Sub-total	49%	51%
Total	100%	

Spontaneously verbalizing to peers. This pattern was observed more often in the computer activity (18%) than in the hands-on activity (12%). For the computer activity, the most frequent expression to peers was “My turn!” or “It’s time for me to play the computer game now.” For the hands-on activity, it was “I am ahead of you!” One example from the computer activity “Candlelight Activity” is presented below:

Karen: (watching the candles and starting to count the candles with her finger on the screen) One, two, three, four, five, six, seven, eight, nine. It’s NINE! (and then pointing at the number button of 9)

Rick: Nay! That’s not 9. That’s eight. Four and Four... EIGHT!

Karen: (recounting the candles with her finger) One, two, three, four...

Lim: (clicking the number 8) (giggling and looking at Karen)

Karen: (recounting the candles with her finger again) One, two...

Rick: Now, MY TURN!

Spontaneously verbalizing about the task. The pattern of verbalizing about the task was more common in the hands-on activity (20%) than in the computer activity (15%). For the hands-on activity, the most frequent verbal expressions were “Am I right?” and “I am ahead of you!” as shown in the following dialogues:

Michelle: (after rolling the YJ number cubes and counting the shiny squares) One, two, three, four, five, six (while moving her bear on the board). Am I RIGHT?

Susan: Aha.

Michelle: (looking at Susan with smile) Look! I am ahead of you! I am going to win this game.

For the computer activity, the most common verbalization was an excited “I DID IT!” after completing the game or task.

Teacher: (moving his position from the other group for the Candlelight Activity) How does it go?

Briana: Almost!

Teacher: Oh, you almost did it. Good job!

Briana: (with smile) I DID IT! See?

Aerial: (moving her spot near the touch pad) I didn’t have a turn.

Responding to questions from the teacher. The pattern of responding to the teacher’s questions was seen a little bit more in the computer activity (18%) than in the hands-on activity (17%). There were very diverse patterns in the interaction with the teacher. The most frequent responding expression to questions from the teacher was the verbal expression, “I know!” Many children wanted to let the teacher know how well they could do on the game by answering the teacher’s questions, as shown below in a dialogue during the hands-on activity “YJ Number Cube:”

Ryan: Yes (checking out how many he had). I’ve got, I’ve got, three and three.

Teacher: (looking at others and showing his six fingers) Three and three makes...

Patrick: I know! THREE and THREE!

Teacher: (putting the YJ’s number cubes at the center) How many are there altogether?

Patrick: (bending over to look at the cubes closer and pointing at each shiny square) THREE... and THREE! (looking at Ryan) Three and three makes what? Do you know?

Ryan: (looking at the teacher with smile) I KNOW! It’s SIX! (moving his bear six steps forward on the board)

Patrick: Yes! It is six.

In sum, for the Combined Activity, I found three main patterns of the children's communications with peers and teacher about the Combined Activity: (a) spontaneously verbalizing about the task (total 35%), (b) responding to questions from the teacher (total 32%), and (c) spontaneously verbalizing to peers (total 30%). Many children expressed their thoughts in both the hands-on activity (total 49%) and computer activity (total 51%). It should be noted that several three-year-olds did not often verbally express their thoughts, while four- and five-year-olds fully expressed their thoughts through the communication patterns. Furthermore, the four- and five-year-olds participated in the task-oriented communication not only with the teacher but also with peers during the Combined Activity, while the three-year-olds did not show competency in using psychological tools such as language even though I encouraged them to communicate with others by modeling and demonstrating the game play. This lack of competency among the younger children negatively affected peer interaction with the real tools.

Children's Social and Intellectual Behaviors

I found 72 patterns in 4 categories (see Table 3). The participants (many four- and five-year-olds) showed a tendency to work with others while most three-year-olds showed a tendency to work alone.

Tendency to work alone. The pattern "Tendency to work with alone" was more frequently observed in the hands-on activity (21%) than in the computer activity (15%). One of the frequent verbal expressions was "I can do it by myself." I do not consider this a negative social behavior because it was used to show the child's ability to engage in independent work which is necessary for the game play. For instance, many children, including most three-year-olds, wanted to count the shiny squares on the dice by themselves, as shown below during the hands-on activity "YJ Board Game Set:"

Rick: (pointing at each shiny square on the dice) One, two, three ...

John: (with a smile) That's five! See? Two and three there. I know.

Rick: (looking at John with a firm face) I can do it by myself.

John: Okay!

Table 3. *Types of Children's Social and Intellectual Behaviors for Combined Activity*

Type of Social And Intellectual Behaviors	Combined Activity	
	Hands-on Activity	Computer Activity
Tendency to Work Alone	21%	15%
Tendency to Work with Peers	6%	11%
Tendency to Work with the Teacher	8%	11%
Spontaneous Requests for Task-relevant Information from the Teacher	13%	15%
Sub-total	48%	52%
Total	100%	

There were similar patterns in the computer activity. For instance, many children wanted to manipulate the computer (controlling the touch pad or keyboard) by themselves, independently, when they took their turn, saying “I can do it by myself!”

Tendency to work with peers. I found that the children showed the pattern “Tendency to work with peers” more often in the computer activity (11%) than in the hands-on activity (6%). Many more four- and five-year-olds than three-year-olds showed a tendency to work on the task with peers as shown in this exchange during the computer activity “Understanding the Wholeness” (Froebel Design Software):

Bryan: (after looking at the cube which kept moving up and down) I know what to do.

(touching the space bar) The cube stopped on the screen.

Cathy: It stopped! (giggling)

Bryan: No! Don't do that! Push this button (the space bar) and it will stop! (pointing at the cube on the screen and pointing at the space bar)

Angela: No, I want it (the cube) to move.

Cathy: (giggling and clicking the space bar) Ha!

Bryan: See?

Cathy: That's cool. I can do that.

Angela: Okay. I want to do it. (grabbing C's hand near the space bar and pulling it away)

Bryan: (pointing at the cube near the grid board) Stop! Stop it there!

Angela: Okay. I will do that. (making the cube stop) (giggling)

Bryan: (giggling)

Cathy: (giggling)

Teacher: (coming from the other group and observing what A did) Okay. Can you try to spin it (the cube) on the screen? Is it the same cube or different one?

Tendency to work with the teacher. I found that there were 11% of the pattern, “Tendency to work with the teacher,” in the computer activity and 8% of the pattern in the hands-on activity. The most interesting finding was that during the computer activity, many three-year-olds treated the teacher as a facilitator who helped with turn-taking and fixed any problems with the computer games. They showed a tendency to work with the teacher many times, such as in the exchange presented below:

John: Teacher! It is not working (moving the index finger around on the touch pad)!

Ryan: You broke it!

John: No, I don't. (looking at the teacher) Can you fix it?

Teacher: (clicking the window to maximize it) Here we go.

Ryan: My turn now!

In the hands-on activity, the children (especially the three-year-olds) regarded the teacher as the facilitator because I acted as a facilitator in the beginning of the session. By the end of the session, they regarded the teacher as one of the game players as they came to understand the game rules and the teacher decreased his use of power to control the game. This is shown in the dialogue below that occurred during the hands-on activity “YJ Board Game Set:”

Teacher: (after rolling the YJ cube) I've got one and...

Megan, Angela, and Ryan: (simultaneously) Two!

Teacher: So, how many steps can I move for my bear?

Ryan: (after looking at the YJ cube) (pointing at the place where I have to put my bear)

Here! (with his index finger)

Teacher: Thank you. (passing the cube to P)

Spontaneous requests for task-relevant information from the teacher. I found the

pattern of asking for task-relevant information from the teacher during both the computer activity (15%) and the hands-on activity (13%). Overall, the children mostly showed this pattern in the beginning of the session for both the hands-on activity and the computer activity. Most of the task-relevant information requested by the children was about how to play the games, as shown below during the computer activity “Candlelight Activity:”

Rick: (looking at the computer screen and then looking at the teacher) This is not working.

Tell me how to play please!

Teacher: (approaching R) Which one? (looking at Rick and then the computer screen) Did he (the invisible voice character in the computer game) say how many candles he needs? Did you hear how many?

Rick: Um... (looking at the screen)

Teacher: How many?

Rick: (pause) (moving the arrow and clicking the button of number 4)

Computer: Good job!

In sum, in the Combined Activity, I found that the children showed four different social and intellectual behaviors: (a) tendency to work by himself or herself (total 36%), (b) tendency to work with the teacher (total 19%), (c) tendency to work with peers (total 17%), and (d) spontaneous requests for task-relevant information from the teacher (total 28%). Many children showed these social and intellectual behaviors in both the hands-on activity (total 48%) and the computer activity (total 52%). These children (except for several three-year-olds, who did not exhibit as many behaviors as the older children) had a variety of social and intellectual experiences such as working by themselves, with peers, and with the teacher through both the hands-on and computer activities

Children’s Understanding Number Concepts in the Combined Activity

I found 150 patterns in 4 categories (see Table 4). The participants (many four- and five-year-olds) showed their understanding of number concepts such as counting skills, simple addition, seriation, and logico-classification while many three-year-olds did not show much understanding of logico-classification.

Table 4. *Types of Number Concepts that the Children Understood in the Combined Activity*

Type of Number Concepts	Learning Materials		Combined Activity	
	Hands-on Activity	Computer Activity	Hands-on Activity	Computer Activity
Counting Skills	YJ Board Game & Card Game Set	Twin Silly Robots and Candlelight Activity	30%	25%
Simple Addition	YJ Board Game & Card Game Set	Candlelight Activity	10%	10%
Seriation	YJ Card Game Set	Twin Silly Robots	10%	5%
Logico-Classification	YJ Card Game Set	Froebelian Design Software and Twin Silly Robots	5%	5%
Sub-total			55%	45%
Total			100%	

Counting skills. I found that there were 30% of the pattern “counting skills” in the hands-on activity and 25% of the pattern in the computer activity. For the hands-on activity, the pattern “counting skills” occurred frequently when the children played YJ Card and Board Game Sets. For the computer activity, the counting skills were often observed when they played Twin Silly Robots and Candlelight Activity. The most interesting finding was that during both the hands-on activity and the computer activity, many children showed their counting all strategy (counting objects one by one) when the Combined Activity was first introduced and then gradually showed their counting on strategy during the second and third weeks. This (i.e., counting on strategy) is shown in the dialogue below that occurred during the hands-on activity “YJ Board Game Set:”

Megan: (after rolling the YJ cube and looking down two YJ cubes) I know! (pause)

Ryan: (looking at Megan) What?

Megan: (murmuring) Three squares (looking at YJ cube) here and four, five six, seven
(counting each square on the face of the other YJ cube). It's SEVEN. See?

Simple addition. I found that there were 10% of the pattern “simple addition” in the hands-on activity and 10% of the pattern in the computer activity. For the hands-on activity,

the pattern “simple addition” occurred frequently when the children played YJ Card and Board Game Sets. For the computer activity, simple addition skills were often observed when they played Candlelight Activity. The most interesting finding was that during the computer activity, many children used their simple addition skills to solve each question (i.e., double number addition: $1+1$, $2+2$, $3+3$, $4+4$ and $5+5$) during the second and third week although they solved the same question using their counting skills in the beginning. This is shown in the dialogue below that occurred during the computer activity “Candlelight Activity:”

Computer: How many candles are there all together now? (the screen shows 4 candles on a window frame and 4 candles on the other window frame.)

Angela: I remember! It is EIGHT!

Teacher: How do you know?

Angela: (pointing at each window frame) See? Four and four is eight!

Seriation. I found 10% of the pattern “seriation” in the hands-on activity and 5% in the computer activity. For the hands-on activity, the pattern “seriation” was shown frequently when the children played YJ Card Game Sets. For the computer activity, seriation was sometimes observed when they played Twin Silly Robots. This is shown in the dialogue below that occurred during the hands-on activity “YJ Card Game Set:”

Teacher: Can you put your cards in order? From number one to number ten?

John: (holding each card which includes the quantity and numeral) One, two, three, where is four? (talking to himself)

Jimmy: (pointing at his cards on the floor) I did it!

Logico-classification. I found 5% of the pattern “logico-classification” in the hands-on activity and 5% in the computer activity. For the hands-on activity, the pattern “logico-classification” was sometimes revealed when the children played YJ Card Game Sets. For the computer activity, logico-classification was sometimes observed when they played Froebelian Design Software or Twin Silly Robots. This is shown in the dialogue below that occurred during the computer activity “Froebelian Design Software:”

Teacher: (showing the simulation about how one big cube can be divided into 27 small cubes and stopping it) What did you see?

Bryan: (after watching the simulation) Um... I don't know! (looking at Angela) Did you see that?

Angela: (after looking at the simulation) You (teacher) broke the cube.

Teacher: How did I break the big cube?

Angela: (with smile) You dropped it for many times and then it became small ones!

Discussion

In this section, I briefly summarize and discuss the results of the children's experience with the Combined Activity because it is related to my original research question and findings. Next, I discuss my role (i.e., teacher's role) in the Combined Activity because my role was varied and could influence the children's experience depending on which role I was playing at the time. Finally, I discuss the physical learning environment of the Combined Activity and how it may affect the children's experience.

The Children in the Combined Activity

The purpose of this study was to understand how the children experience the combined activity in learning number concepts by using a combination of hands-on manipulatives and computer software. To answer the main research question, I adopted a triangulation method (Creswell, 2003) that involved collecting and analyzing the data from different resources such as the research assistants' field notes, my reflective notes, and videotapes from four different small groups (20 children). For the results, I answered the main research question using four sub-questions:

1. How did the children show their interest in the Combined Activity?
2. How did the participating children communicate their thoughts with peers and the teacher in the process of the Combined Activity?
3. What kinds of intellectual and social behavior did the children exhibit in the Combined Activity?

4. How did the children understand number concepts in the Combined Activity?

In answer to the first research question, many children showed positive interest using various verbal or non-verbal expressions in the Combined Activity. Specifically, three positive categories emerged from the data: participating (total 45%), gazing (total 16%), and showing their enjoyment (total 25%). These behaviors were in contrast to the negative category, acting bored (total 14 %). This means that many children showed a clear interest in participating in the Combined Activity.

Regarding the second research question, I found three main patterns of the children's communications with peers and the teacher such as spontaneously verbalizing about the task (total 35%), responding to questions from the teacher (total 32%), and spontaneously verbalizing to peers (total 30%) about the Combined Activity. Many four- and five-year-olds spontaneously communicated their thoughts with peers and the teacher, while many three-year-olds did not. This means that many children communicated with others in the process of Combined Activity although several three year olds just did not exhibit as many communication skills as the older children. For the next cycle, it would be necessary to teach three-year-olds how to communicate with others.

In answer to the third research question, many children exhibited a variety of social and intellectual behaviors through the Combined Activity. Four social and intellectual behavior categories emerged from the data: tendency to work by themselves (total 36%), with the teacher (total 19%), and with peers (total 17%), and spontaneous requests for task-relevant information from the teacher (total 28%). Because many three-year-olds did not work with peers, it would be necessary to create multi-age groups based on mathematics skills before the Combined Activity.

According to the fourth question, the findings in answer to the fourth question lead me to understand that the Combined Activity could provide the preschoolers to use their various counting skills (55%) and simple addition skills (20%), but not much about seriation (15%) and logico-classification (10%) through the hands-on manipulatives and computer software. For the next cycle, I think that I should make specific lesson plans for helping the preschoolers understand logico-classification of numbers (e.g., 5 can be 0 and 5, 5 and 0, 1 and 4, 4 and 1, 2 and 3, 3 and 2.). When the preschoolers played Froebelian Design Software

(i.e., the simulation of how a big box can be divided by 27 small cubes) and Twin Silly Robots (i.e., selecting batteries for the Twin Silly Robots from the Repair Shop), I briefly asked some questions about logico-classification. For the better results, I believe that much more specific plans are necessary. For instance, I think that a block-building activity (Kamii et al, 2004), YJ card game activity and my computer activity can help them better understand aspects of logico-classification.

Table 5. *Sub-research Questions by Total Percentage of Hands-on Activity and Computer Activity*

Research Questions	Combined Activity		Percentage(100%)
	Hands-on Activity	Computer Activity	
Research Question 1	54%	46%	100%
Research Questions 2	49%	51%	100%
Research Questions 3	48%	52%	100%
Research Question 4	55%	45%	100%

As shown above, overall, I found that there was not a big difference of total percentage of children's behavior patterns between the hands-on activity and computer activity in the Combined Activity for each research question, though there were some differences. This may imply that the Combined Activity could provide a balanced social learning environment for many children even though the learning materials and the physical settings are different.

The age-appropriate practice for many three-year-olds is still in doubt for the Combined Activity. Based on my reflective teaching notes, I thought that the children needed more time and specific guidance (or help) during the Combined Activity.

Teacher's Roles in the Combined Activity

Vygotsky believed that most children can achieve the ZPD depending on how effectively adults (including a teacher) guide them. In this study, it is important to discuss my role as a teacher. I took various roles such as demonstrating, coaching, modeling, and even participating in the activities in order to achieve the "best practice" (Zemelman, Daniels, & Hyde, 2005) based on my activity plans (see Appendix B). I introduced the Combined

Activity and interacted with the children for all nine sessions. As a teacher, it was not easy to control many factors which contributed to the results of the study. For instance, I had to assign twenty children into four different small groups and conduct nine sessions (see Appendix B) using six new and different learning materials (i.e., YJ number cubes, YJ card game set, YJ board game set, Twin Silly Robots, Candlelight Activity, and Froebelian Design Software) within two different learning environments (i.e., hands-on and computer activity).

As the learning materials and the game rules were new to the children, my appropriate guidance for their interaction with the tools and other game players was necessary in the process of the Combined Activity. Thus I often demonstrated how to play the games and coached the less advanced children whenever it was necessary. Kamii (2000) pointed out that good games should provide a learning environment in which to create peer interaction in a classroom; the games can have different levels of competition depending on game rules and the level of players' interaction and collaboration. In this study, I found that "good games" for the preschool level could depend on the teacher's clear guidance (e.g., how to introduce and manage the game environment), especially if the game is new to the children. For instance, in order to promote intellectual and pro-social communication or interaction, I encouraged the children to use the terms (e.g., "Am I right?" or "Am I correct?") to others when they were not sure about their action such as counting and adding up the shiny squares on the dice. I think that this simple recommendation let the children kindly help less knowledgeable peers when they miscounted objects or wrongly added numbers while also increasing the level of players' interaction (Bodrova & Leong, 2007). Another example is the children's spontaneous expressions of competition (e.g., "I am ahead of you," "I won!," and "You lost!") during the Combined Activity. As the game environment could create competition in general, the teacher should carefully create and discuss the game rules with the children in the beginning and remind the children of the game rules at the end of the game, for instance, saying, "When every bear comes back home, we can complete the game, so we need to help each other (the children) and then the bears can come back home" or "When everybody completes the mission, we complete our goal today." Thus, as a dynamic mediator, my changing role as a model or a participating game player is also important for the Combined Activity because I had to guide the responses in the beginning.

The Learning Environment of the Combined Activity

For this study, the physical settings for the hands-on activity and computer activity were different although I designed each material using the core idea of combining the traditional dice patterns and 3x3 matrix patterns for both the hands-on manipulatives and the computer games. For instance, in the hands-on activity, the teacher and children sat on the carpet and played the card and board game sets rather than at a table. My intention in doing this was to decrease the opportunities for children to become distracted such as by dropping the die or dice off the table. However, we found that sitting on the carpet sometimes caused distracting behaviors such as lying down or rolling on the carpet. For the computer activity, I utilized a limited number of computers. For instance, I set up two laptops for four or five children on the table with the intention of increasing the children's interaction. Based on the results from the study, I agree that the learning environment of a computer activity with two or three players (Clements, 1997, 1999) per computer can help young children learn mathematical skills because of their engagement in learning number concepts interactively using computer technology (Sarama, 2004). Therefore, the findings of this study can imply that the appropriate physical setting for the Combined Activity could be different for the hands-on and computer activity depending on what the teacher wants to accomplish. The teacher needs to design the physical setting taking into consideration the culturally and developmentally appropriate learning environment for the children (Copple & Bredekamp, 2009; Gestwicki, 2009; Tobin, 2011) through on-going observation. For such an appropriate learning environment, the teacher needs developmentally appropriate materials, reflective activity plans, and clear guidelines. The teacher also needs to pay attention to the young children's linguistic and cultural backgrounds related to number concepts.

Conclusions

Piaget (1963) indicated that children's development of logico-mathematical knowledge can effectively occur in social interaction. Kamii's (2000) statement about the effectiveness of social games such as card or board games also applies to the Combined Activity, which could

provide the kind of social learning environment which can engage four- and five-year-olds in mathematical understanding of number concepts for, though not as much for three-year-olds. Computer activity using developmentally appropriate games has been investigated and found to be effective for teaching mathematical skills in the early grades (National Mathematics Advisory Panel, 2008). As a part of the Combined Activity, I think that the physical setting (i.e., 2 or 3 children for one computer) and content of computer activity (three different games) provided the possibility for social interaction with learning number concepts as much as the hands-on activity provided. When the preschoolers participated in the mathematics game activities, they showed the following main characteristics: (a) participating well in both hands-on and computer activity rather than acting bored, (b) spontaneously verbalizing out loud about the task and responding to questions from the teacher, (c) working with others (especially the four- and five-year-olds), and (d) spontaneously asking for task-relevant information from the teacher. Thus, in light of Vygotsky's (1978) statements about games with rules beginning in the later preschool years, the Combined Activity seems to be developmentally appropriate for at least four- and five-year-olds. In addition, the findings of this study showed that the combination of hands-on activity and computer activity could provide a positive social learning environment for preschoolers to gain an understanding of number concepts.

Reflection

This study has some methodological limitations. First, the preschool program in the study is not representative of all early childhood centers located in the area because it is a half-day and private early childhood program for children who come from middle and high socioeconomic status. Second, my research assistants and I agreed that differentiated and specific guidelines or instruction would be necessary for many three-year-olds who participated in both the hands-on and computer activity. Therefore, the findings of this study cannot be generalized to other circumstances or transferred to other contexts, though the case itself can serve as an example of teacher research (Herr & Anderson, 2005) into

understanding how preschoolers experience the Combined Activity and its teacher-created manipulatives and software.

Kim's (1993) investigation of the relative effectiveness of hands-on manipulatives and computer software originally motivated me to investigate the children's experience with the Combined Activity as she implied that it would be necessary to do an in-depth study of a combination of hands-on manipulatives and computer software. Although it is not necessary for early childhood educators to become material developers or designers, I have enjoyed developing and testing the learning materials (i.e., hands-on and computer games) while studying the effectiveness of educational games and learning materials which have already been produced. I believe that the process motivated me to become more creative and excited about helping young children understand number concepts. While working on this action research, the research assistants' and young children's priceless feedback and comments about the materials have helped me think and act better as a teacher in my pursuit of the goal of helping young children understand number concepts. For instance, during this particular action cycle, as a teacher, I learned that early childhood educators need to take much more diverse roles such as coaching, demonstrating, modeling, and participating in the Combined Activity than I had previously assumed. Thus, in-depth analysis or reflection of the teacher's diverse roles in the combined activity will be necessary before going on to the next cycle of action research. However, after observing the preschoolers' creativity in this cycle, in the next cycle I would like to do more to empower them (Manabu et al., 2007) such as working with them by revisiting the current hands-on and computer activities, redesigning the game rules and format of the game board, and participating in redesigning the computer games. For instance, some preschoolers liked to create their own game rules by communicating with peers. This implies that I have to redesign "culturally and developmentally appropriate learning environment" for future studies. For example, I will use the appropriate physical setting (e.g., using a kidney-shaped table and small chairs for the hands-on activity near the computer table) in which I can prevent any distractive behaviors (e.g., lying down on the carpet) and increase the preschoolers' attention and engagement. I also need to consider individual children's linguistic and cultural backgrounds related to number concepts. For instance, some three-year-olds did not fully participate in the Combined Activity. I should have investigated more thoroughly to discover why they did not want to participate at that

time because their reluctance could have been related to their language competency and cultural backgrounds related to number concepts.

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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

Activity Plans for the Nine Sessions

	Friday	Monday	Tuesday	Thursday
	1 st Session	2 nd Session	3 rd Session	4 th Session
	1. YJ Cube Box and YJ Number Cubes I	1.9 Grid Card Game Set I	1. YJ Board Game Set with YJ Number Cubes I	1. YJ Number Cubes II
1 st Week (100 minutes for each session)	2. Computer Software: "Froebelian Design Software" and "Twin Silly Robots"	2. Computer Software: "Froebelian Design Software" and "Twin Silly Robots"	2. Computer Software: "Froebelian Design Software" and "Twin Silly Robots"	2. Computer Software: "Candlelight Activity" and "Twin Silly Robots"
	Review activities with the research assistants and set up the following lesson plan.	Review activities with the research assistants and set up the following lesson plan.	Review activities with the research assistants and set up the following lesson plan.	Review activities with the research assistants and set up the following lesson plan.
	5 th Session	6 th Session	7 th Session	8 th Session
	1. 9 Grid Card Game Set II	1. YJ Board Game Set with YJ Number Cubes II	1. YJ Number Cubes III	1.9 Grid Card Game Set III
2 nd Week (100 minutes for each session)	2. Computer Software: "Candlelight Activity" and "Twin Silly Robots"	2. Computer Software: "Candlelight Activity" and "Twin Silly Robots"	2. Computer Software: "Froebelian Design Software" and "Candlelight Activity"	2. Computer Software: "Froebelian Design Software" and "Candlelight Activity"
	Review activities with the research assistants and set up the following lesson plan.	Review activities with the research assistants and set up the following lesson plan.	Review activities with the research assistants and set up the following lesson plan.	Review activities with the research assistants and set up the following lesson plan.
	9 th Session	Discussion with research assistants about 1 st , 2 nd and 3 rd activity plans	Discussion with research assistants about 4 th , 5 th , and 6 th activity plans	Discussion with research assistants about 7 th , 8 th , and 9 th activity plans
3 rd Week (100 minutes for each session)	1. YJ Board Game Set with YJ Number Cubes III			
	2. Computer Software: "Froebelian Design Software" and "Candlelight Activity"			
	Review activities with the research assistants and set up the following lesson plan.			