How should technology, if any, be implemented into a kindergarten mathematics curriculum?

1. Introduction

   While computers and technology have become abundant in many aspects of contemporary life, there is still a debate over whether or not these technologies are appropriate tools for early childhood education. Elkind (1996) believed that computers had the potential to be detrimental to student’s social and intellectual development. He believes that “technology may free us from the necessity of developing our sensory motor functions” (Elkind 133). Other researchers refute Elkind’s findings though by suggesting that technology is beneficial. In fact Hall and Higgins (2002) find that the more technology one uses (at home or at school) the better. “Today there is no question as to whether we should use technology or not. Instead the question is where and how technology can be used to enrich the learning experience” (Hall and Higgins 301). A recurring problem is that some teachers may have the technology, but they are not using it correctly. For example, teachers who are just graduating college and heading into the workforce should be able to use technology more effectively with their students, because they have the training and a basic level knowledge of computers and technology. Likewise, teachers who have been in the field for years often do not view technology as positively, because they do not know how to use it. Teachers need to understand how to use the technology they are given in the classroom; otherwise they will not know how to take advantage of it in order to enhance their students’ learning. There are convincing arguments both for and against the use of technology. Unfortunately, there is not a clear answer yet as to whether technology should be integrated into the learning process or how it should be integrated. We decided to conduct our own experiment to try and determine if the use of virtual manipulatives, through the use of iPad applications specifically, would in fact enhance the learning by working one-on-one with six kindergartners using various materials to assess.

1.1 Implementing Technology

   Teachers need to be proficient in and knowledgeable of implementing technology effectively into their classrooms. “The ratio of computers to young children is important-at most 1 to 7, preferably 1 to 5. Equal access for children is essential; even the most talented teachers will have difficulty integrating computers into his or her classroom with only one computer” (Haugland, 2000). Since technology is constantly changing, teachers need to have continued support in developing their knowledge and skill regarding technology (Haugland, 2000). Many teachers do not use technology in an effective way. For example some teachers use computer games as a reward or filler if students finish their work early (Hall and Higgins, 2002). Hall’s and Higgins’ research shows the implications of using computers as a reward. They found that it is often counter-productive as far as children’s learning is concerned. This may be where certain behavior issues stem from. If a student is supposed to be practicing their skills on the computer, but is used to viewing computers as a source for games, than the student may just end up pushing buttons and not taking the practice seriously.

   Another way teachers misuse technology is when they use it to drill the basic skills such as multiplication facts without teaching their students what multiplication, division, etc. means and the reasoning behind our methods or tricks for solving certain equations, such as the multiplication by 9’s hand trick (Haugland, 2000). The problem here, according to Clements (1994), as cited in Haugland, is that educators are doing exactly what research and National Association for the Education of Young Children guidelines say we should be doing less of. Computer experiences should be used as a supplement to guide our understanding or practice of various math methods and facts. Teachers need to include additional experiences throughout their curriculum to explain the reasoning behind the math we do.

   Although technology should not be used as a reward for student’s behavior, it does have significant impacts on their behavior. Technology can hold a student’s attention longer and motivate them to stay on task and complete assignments (Din and Calao, 2001). When the students can see real pictures of animals or places it makes the learning more relevant and natural for the students. Ke (2008) has similar findings in that computer games produce learning motivation much more than traditional paper-pencil drills. This learning motivation can be used to direct a student’s behavior in a positive manner.

   Along with behavior management, teachers can use computers to introduce the fundamentals of technology. Experience is key. As early as preschool, students should begin exploring the basic functions of computers. Many
educators believe that at an early age there is a window for learning and mastering technology. Children should be introduced to formal computer usage before this window closes and they are no longer able to master this higher order thinking skill (Craig, 2000; Haugland, 2000). Giving students time to explore computers allows them to discover while making sense of its functions before they have to apply the functions to educational concepts (D’Angelo and Iliiev, 2012).

1.2 Physical Manipulatives

A concern of educators, psychologists and researchers is that technology is taking away from the beneficial concrete manipulatives educators have been taught to use in their early education classrooms. Most education specialists categorize “concrete” into hands-on, physical objects (Sarama & Clements, 2009), and this idea that concrete (physical) manipulatives are the most appropriate materials to be using when explaining basic mathematical concepts arose from Piaget’s theory on development (Maches, O’Malley & Benford, 2009). He emphasized that children between the ages of 6 to early adolescence fall under the concrete operational stage (Steinberg, 2011). Specialists have interpreted his theory to conclude that physical manipulatives would best help young children develop their understanding of the world (Maches et al., 2009). D’Angelo and Iliiev (2012) believe that the constructivist theory, where students construct their own knowledge by interacting with the world around them, is an advantage in using physical manipulatives. However, there are many issues found when using physical manipulatives. For example, teachers sometimes assume that physical manipulatives alone will lead to mathematical understanding. The problem is that most students will not know, before any previous explanation or demonstration, to use 2 and 3 to make 5, because they do not yet know how to manipulate the objects put in front of them.

Physical manipulatives instead should be used as an aid in learning about concepts. Children cannot be, however often are, expected to solely understand the concepts once given physical manipulatives. Additional supplementary lessons and explanations need to be used along with the manipulatives; however, some teachers seem to believe that by simply handing physical manipulatives over to students will allow them to connect to mathematical concepts. Another concern presented by Sarama & Clements, as well as other researchers, is that some physical manipulatives may require using different mental connections than intended. After all, students are eventually expected to mentally grasp concepts without needing concrete materials to lead them towards understandings. Sarama and Clements explain how mental connections can differ, when using physical manipulatives, from the intended mental connection. When a student is adding two numbers together (4+3) he/she often will begin with the first addend (4) and count “1, 2, 3” to find the sum (7). However, an objective when adding is to eventually be able to count on (“5, 6, 7”) from the initial addend to find the sum. When working with larger numbers, students will be expected to have mastered the concept of counting on. Manipulatives help bridge the gap between concrete and abstract concepts (D’Angelo and Iliiev, 2012). Therefore, physical manipulatives may be appropriate to aid in developing meaning; however, reflection on these actions with manipulatives is needed to fully develop the mental connections in which one understands mathematical concepts (Sarama & Clements, 2009).

1.3 Virtual versus Physical Manipulatives

Lee and Ginsburg (2009) state, “It is not so much important that they simply have their hands on, but rather their minds on.” Many researchers state that the medium students are presented with, in order to construct mathematical meanings, does not matter as much as how the teacher presents the lesson’s objective. The main importance is that the students are actively engaged while using whatever medium they are presented with, virtual or physical. It is the well-planned experience that will make the lesson meaningful and helpful to arrive at their learning target (Baroody, 2013; Lee & Ginsburg, 2009). As it is not enough to simply provide students with physical manipulatives, students will also need support when given virtual manipulatives. No matter how well designed base-10-blocks, Cuisenaire rods, pattern blocks or any virtual manipulative may be, no manipulative is assured to be educationally effective. Therefore, virtual and physical manipulatives are interchangeable. Many may say they are equal in value, since it is the perceived lesson that holds the significance of the learning experience. “It makes as little sense to say that computers are bad for children as it does to say that books or manipulatives are good” (Lee & Ginsburg, 2009). Computers should be used to extend the range of materials students use to advance their understanding.
There is some reasoning researchers are for or against virtual manipulatives. Sarama and Clements (2009) would argue that computer manipulatives can often be more manageable, free from distracting features and precise. For example, computers are able to represent specific mathematical patterns, such as different types of grouping, to lead a student in their mathematical understanding. However, it is often the method a student uses that can make virtual manipulatives either useful or limited in their capabilities.

Manches et al. (2009) conducted a study to further research their opinions on whether virtual manipulatives are adequate learning materials for a classroom. They compared young children’s use of physical and virtual materials, which is supportive of many of the concerns previously mentioned about the use of virtual manipulatives. First, these researchers studied young children’s abilities to solve problems with different materials and made sure to counterbalance which materials the students would use. The materials under observation were: physical manipulatives, paper and pencil or no materials at all. The no materials assessment was included as a baseline measure of the child’s performance. The students under observation were expected to find as many possible solutions as they could when given a certain number of objects and asked to sort the objects into two groups. Manches et al. were testing to see which use of materials would lead to the most successful results; and they discovered that the physical condition lead to students finding more correct solutions than the paper and no materials condition. With paper, students were not as easily able to imagine possible solutions; even though, they had a concrete trace of the groups they had already found as solutions. Having physical manipulatives significantly helped the students in their problem solving task. Gathering multiple combinations was more beneficial with these manipulatives, because the students were able to physically represent different groupings, and the combinations were easy to manipulate to gain multiple solutions, often times at random. For example, one would be able to move a single manipulative from one group to another and arrive at a new solution.

Once Manches et al. decided that manipulatives really were the best condition for students to problem solve under, they tested whether physical or virtual manipulatives were best. Using the same concept as before, separating a given number of objects into two groups to find as many combinations as possible, students were observed and the number of correct solutions were counted. Manches et al. discovered that there was really no significant difference in the number of correct solutions when physical or virtual manipulatives were being used. However, they elaborated on various observations they came across, hinting at significant impacts on a student’s success with physical or virtual materials.

Manches’ et al. explained how the limited amount of room on a screen made some students frustrated. When working with children, it is often to their advantage to have as much space as possible to work with. Some children found it difficult to maneuver the manipulatives when they were looking to recollect objects before working on a new solution; and, unless the computer is programmed to recollect, the children are constrained in moving each manipulative one by one. This constraint was also a problem when students wanted to count by twos or group certain manipulatives together. Physical manipulatives are much easier to move around while grouping and regrouping.

Manches’ et al. came to the conclusion that manipulatives should be used in math lessons; however, when deciding to use physical or virtual manipulatives, there really is no simple answer. Both manipulatives were found to provide for successful results, but there are certain aspects of each type that may be more beneficial to a certain intended learning target or a certain individual.

2. Study: Which type of materials, paper and pencil, physical manipulatives or virtual manipulatives prove to be most effective, allowing the students to score the highest when given certain grouping problems?

2.1 Focus

The work of Manches et al. aligned best to what we chose to research. Our aim was to focus our studies on whether students, individually, performed better, or equally as well, while focusing on grouping problems, while either using paper and pencil (Figure I), physical manipulatives (Figure II) or virtual manipulatives (Figure III) (specifically with iPad applications) as their source of materials. Using iPads within an elementary school classroom is a fairly new notion, and there have been few definitive research findings on correlational effects of computer usage in the classroom and academic success let alone the effects iPads have on student learning. We have reviewed literature that supports or refutes computer usage in the classroom, because computers and iPads are very similar. The main difference between computers and tablets is the way the user interfaces with the screen. We decided to use similar methods and procedures that Manches et al. have used, except we decided to focus
specifically on how the conditions of an iPad application (using virtual manipulatives), physical manipulatives or paper and pencil will affect Kindergartener’s success on problem solving. In short, our actual goal was to evaluate students’ fluency by using the various materials in approaching grouping problems. The grouping problems we refer to consists of a given value, either identified by drawn dots, physical manipulatives or virtual manipulatives (depending on which materials the students were currently testing with), and requires students to separate the value into 2 groups.

We were not as concerned about the students’ performance levels while problem solving compared to their peers’, as we were about how the different materials (virtual manipulatives, physical manipulatives or paper and pencil) would affect the students’ individual ability to solve the grouping problems.

Figure I: Paper and Pencil

![Figure I: Paper and Pencil](image)

Figure II: Physical Manipulatives

![Figure II: Physical Manipulatives](image)

Figure III: Virtual Manipulatives

![Figure III: Virtual Manipulatives](image)
2.2 Method

2.2.1 Design

This study’s independent variables were the materials provided during a given session, which either consisted of virtual manipulatives (from the iPad application “Count Sort”), physical manipulatives (counters) or paper and pencil (written). Each student was to solve three grouping problems once with virtual manipulatives, once with physical manipulatives and also with paper and pencil. Students have used all of these materials before when working on their problem solving. “Count Sort” provides the student so many manipulatives (dots) and contains 2 boxes on the right of the screen for students to sort their groups into. During the physical manipulative activity, the interviewer provided the student with a certain amount of counters and 2 trays to separate their groups into. The paper and pencil activity was much like a worksheet in that the students were provided with so many drawn dots on the left of their paper and 2 drawn boxes, for groups, to the right of the counters. A total of 3 different grouping problems were provided on a single sheet of paper, and because having all previous problems to view while creating new groups is unique to this material, we decided to conduct a short study Maches et al. carried out in their research. We gave our participants a grouping problem, with a value dissimilar to the ones they had already worked with in the main study, and had them group the value differently three times, each time using a separate sheet of paper. Once the students partitioned the value into 2 groups, that sheet of paper was set aside, but in eye sight of the students. They then were presented with a new sheet of paper and asked to group the same value into 2 groups differently. Our results showed that the students created each separate grouping without using/looking at their previous work, which matched up to Manches’ et al. findings. We determined from this study that providing the students with the paper and pencil sheet where they could see their previous work, does not interfere with the validity of comparing their work on this task with the solutions they found on the physical manipulative and virtual manipulative task, since they did not glance at their previous work to help them create new groupings anyways.

The dependent variable was the measurement of the number of correct unique groupings for each problem.

2.2.2 Participants

This study contained a sample of 6 Kindergarten students, 3 obtaining higher achievement in math and 3 with lower achievement scores, from the same class. All participants were familiar with us, the “interviewers”, as we have been working with their class on number sense concepts for about thirteen weeks.

2.2.3 Materials and Procedure

Testing took place in a library, a fairly quiet setting, during the school day. There were always one or two other studies being conducted at separate tables in the room. For every testing session, the students were videotaped by one of the two interviewers, while the other interviewer conducted the study. The students are used to being frequently videotaped by us and this aspect has not affected the student’s performance in the past.

We alternated the order of each material so that 2 students, one high achieving and one low achieving, would begin with the virtual manipulatives, move on to the paper and pencil activity and conclude with the physical manipulatives. Another 2 students, of similar achievement levels, began with the physical manipulatives, moved on to the virtual manipulatives and finished with the paper and pencil portion. The final 2 students started with the paper and pencil portion, then completed the physical manipulatives and concluded with the virtual manipulatives (Table I). We wanted to prevent any indication that one material was proven more effective than another, because it was consistently completed last. With this arrangement we alternated the order of materials the students will be working with.

While working with one student at a time, we tested them once with a certain material for about five minutes at a time and then sent them back to the classroom. Focusing on one set of students at a time, we alternated the materials they were to use during each session until they completed tests with all three materials. Then we moved on to the next set of students.
Table 1: Conditioning of Materials

<table>
<thead>
<tr>
<th></th>
<th>Virtual Manipulatives</th>
<th>Paper and Pencil</th>
<th>Physical Manipulatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1A</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Student 1B</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Student 2A</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Student 2B</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Student 3A</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Student 3B</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

1 = First Testing Material, 2 = Second Testing Material, 3 = Third Testing Material

At the beginning of the session, the students were all shown the specific number value as well as the 2 groups they were expected to use during the process. Each student was to count on their own the value they were working with. If the student was incorrect, we asked “How many dots/counters do you have?” Usually only a careless mistake was made when counting the visuals and often times the student corrected themselves.

Once they had stated the correct value, we asked them, “How many ways can you put “x amount” of objects into 2 groups?” Each student used the value of 4, 6 and 7 objects. If the students were hesitant or in need of assistance, the interviewer made the decision to prompt the student as much as possible without giving away a solution the grouping problem. A prompt may be, “How could you put x (value) into these 2 groups?” or “Can you find another way x could be put into 2 groups.”

The level and amount of prompting was noted, as well as any off task behavior, interest levels, frustrations and/or difficulties the students may have during testing that may have affected their performance with a given material.

If the student was able to demonstrate putting a value into 2 groups, either with counters, virtual circles or pencil markings, they were then expected to state the cardinal amount of each grouping. This aspect of the testing is necessary to ensure that students are not misinterpreting what is being asked of them during these sessions. Without a verbal statement correlating to their demonstration, the students may have been creating groups without understanding the purpose. If students did not offer an equation statement on their own, we posed the questions and comments in the following order...

How do you see the number _?_

If student was unable to provide the correct equation, we continued with the following questions. If the student provided the correct equation, we moved on to the next problem.

How many do you have in this group?

Interviewer points to first grouping and waits for student’s response.

How many in this group?

Interviewer points to second grouping and waits for student’s response.

So,

Interviewer points to first group, student responds as to how many is in that group.

plus

Interviewer points to second group, student responds to how many is in that group.

equals

Student is expected to respond with the sum.

Prior to this study, the students have practiced creating addition equations and stating correlating equations with support from us, as seen above. Therefore, the students were already familiar with the wording we used in this study, and as a result should have been aware of what we were requesting of them.
The session ended when an unnecessary amount of prompting was given or the students demonstrated that they were able to complete the task asked of them.

2.3 Results

2.3.1 Student Solutions

To fairly evaluate every student’s performance on each test, we created a rubric addressing two very important aspects of the grouping problems presented.

The first aspect of our rubric shows at what level the student is at when asked to split a given value, such as 5, into 2 groups, such as a group of 2 and a group of 3. The grouping should be visually seen through the use of either pencil markings, counters or virtual circles, whichever correlates to the materials being used in that session.

The second aspect allowed us to rate the student’s accurateness of being able to explain that the 2 grouped values can be added together to make our beginning value. At this time the student would have the groups they have just created in front of them. We looked for wording along the lines of \(2 + 3 = 5\). In this example, after the students were given a value of five and had broken it into two groups (2 and 3), the student was able to see \(2 + 3 = 5\) from their visual representation.

**Rubric: Performance**

5: Student is able to split a given value into two groups in several different ways (3+) with all three values presented. Able to verbally state the correct equation and sum correlating with the groups they created.

4: Student is able to split a given value into two groups in 2 different ways with all three values presented. Able to verbally state the correct equation and sum correlating with the groups they created.

3: Student is able to split a given value into two groups in 2 different ways with at least two values presented. Unable to verbally state the correct equation and sum correlating with the groups they created, although some equation and sum were provided.

2: Student is able to split a given value into two groups in only one way with at least two values presented. Unable to verbally state the correct equation and sum correlating with the groups they created, although some equation and sum were provided.

1: Student is unable to split a given value into two groups, and therefore unable to state an equation and sum.

We believe that a student who can demonstrate multiple ways to divide a given value into two groups and state what those two groups mean in a correlating equation problem is successful and comprehends the problem solving task. These students received a 5, a perfect score. A 4 was given to a student who can only separate a value into two groups, but could still make sense out of their groupings by stating a correlating equation problem. These students were successful at the problem solving task; however, they could not express their understanding in a surplus of ways. A score of 3 represents that a student was still in the progress of demonstrating this certain problem solving skill. They did not show an ability to verbally explain the few groups that they were able to create given a certain value. A score of 2 represents a student who was in the very initial stages of progression towards demonstrating this problem solving skill. They were able to make one group, but could not provide the correct equation to correlate with and back up their visual grouping. A student with a score of 1 shows no signs of progress towards this problem solving skill.

The students’ scores in Table II reflect how each individual performed on either the paper and pencil, physical manipulative or virtual manipulative grouping problems. After conducting this study and looking at the students’ different ability levels when using different materials, we can conclude that using virtual manipulatives is not any more effective than using physical manipulatives with students.

With each activity the students scored progressively better. It did not matter what material they started with, because in the end their abilities to perform this specific task improved. Student 1A started off low with only a 2, but was able to raise that and get to a 4 by the end third activity. Student 1B started off with a 4 on the first activity and was able to get to a 5 by the third activity. Student 2A started off with a 3 in the first activity and
ended with a 5 in the third activity. Student 2B started with a 4 and ended with a 5. Student 3A started off with a 2 and ended with a 3, and Student 3B started and ended with a 5. Even though Student 3B’s score did not, and could not, improve based on our rubric, we noticed the speed at which she could complete the activity increased.

Table II: Student’s Quantitative Results

<table>
<thead>
<tr>
<th>Student 1A</th>
<th>1st Activity</th>
<th>2nd Activity</th>
<th>3rd Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Manipulative</td>
<td>X</td>
<td>X</td>
<td>4</td>
</tr>
<tr>
<td>Virtual Manipulative</td>
<td>2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Paper and Pencil</td>
<td>X</td>
<td>4</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student 1B</th>
<th>1st Activity</th>
<th>2nd Activity</th>
<th>3rd Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Manipulative</td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Virtual Manipulative</td>
<td>4</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Paper and Pencil</td>
<td>X</td>
<td>5</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student 2A</th>
<th>1st Activity</th>
<th>2nd Activity</th>
<th>3rd Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Manipulative</td>
<td>X</td>
<td>4</td>
<td>X</td>
</tr>
<tr>
<td>Virtual Manipulative</td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Paper and Pencil</td>
<td>3</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student 2B</th>
<th>1st Activity</th>
<th>2nd Activity</th>
<th>3rd Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Manipulative</td>
<td>X</td>
<td>5</td>
<td>X</td>
</tr>
<tr>
<td>Virtual Manipulative</td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Paper and Pencil</td>
<td>4</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student 3A</th>
<th>1st Activity</th>
<th>2nd Activity</th>
<th>3rd Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Manipulative</td>
<td>2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Virtual Manipulative</td>
<td>X</td>
<td>3</td>
<td>X</td>
</tr>
<tr>
<td>Paper and Pencil</td>
<td>X</td>
<td>X</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student 3B</th>
<th>1st Activity</th>
<th>2nd Activity</th>
<th>3rd Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Manipulative</td>
<td>5</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Virtual Manipulative</td>
<td>X</td>
<td>5</td>
<td>X</td>
</tr>
<tr>
<td>Paper and Pencil</td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
</tbody>
</table>
2.3.2 Qualitative Analysis: use of materials and impact on performance

In our study we saw the students improve with each activity, regardless of what material was used first. We are able to conclude that, like Manches et al. stated, using manipulatives is better than paper and pencil, but there is no significant difference between using physical or virtual manipulatives. However, where we did see a difference was in the levels of frustration and/or motivation to complete various activities.

For example, Student 1A had trouble moving the virtual manipulatives across the screen and needed a lot of prompting during the first activity. As Student 1A moved on the other activities she needed less prompting. Student 1B started off with the visual manipulatives and while he was supposed to be working he became distracted by a book that he saw in the library. He also had difficulties moving the virtual manipulatives around. Student 2A was very timid at first, but by the final activity she was eager to show what she knew.

Student 2B had a difficult time with the paper and pencil activity. He kept getting confused with the number value he was being shown. For example, during one of the problems on the written activity, where the students have to divide up the number 7, Student 2B was convinced that he was dividing up the number 6. Student 2B also chose to write the number values in each box instead of drawing dots which was different from all of the other students. Also, while Student 2B was doing the paper and pencil activity he used his fingers as manipulatives to help him. While Student 2B was working with the physical manipulatives he asked if he could use the virtual manipulatives instead, showing little interest in the activity he was currently doing. For the final activity when Student 2B was finally able to use the virtual manipulatives, he had trouble moving them across the screen. He tried to move multiple virtual counters with the heal of his hand which the iPad would not let him do, because on the iPad you have to move the manipulatives one at a time.

Student 3A was the most unmotivated and unfocused working on the first activity which was the paper and pencil activity. She was having a difficult time sitting in her chair and conversed about off task subjects. When Student 3A was working on the paper and pencil activity and the physical manipulative activity she was unaware that she had a certain value to be working with. For the final activity Student 3A was drastically more focused on the work. Although she accidentally hit the options button when she was working so the options screen popped up. Also Student 3B tried to move the virtual manipulatives with two fingers, which did not work, because the iPad only lets you use one finger. When she was working on the paper and pencil activity she lost track of the value she was working with just like Student 2B did.

Overall, even though the students did encounter minor frustrations these frustrations did not affect the students’ learning outcomes. Also, it is important to remember that when we were assigning the students a score on each activity we were not comparing the students against one another. Rather we were testing the different materials and how they affected the students’ individual abilities to solve the grouping problems.

2.4 Discussion

In this study wanted to see if kindergarten students learned best by using, paper and pencil, physical manipulatives, or virtual manipulatives. While looking at the data collected, we can conclude that Manches et al. findings matched similarly to our own. For example, we both found that using manipulatives is better than paper and pencil, but there is no significant difference between using physical or virtual manipulatives. However, Manches et al. results from his study showed that his participants performed higher on their portioning tasks when using manipulatives over paper and pencil. In our study, the students’ performances did not clearly show whether one material was better than the other at allowing the students to acquire the correct solution. Although the paper and pencil activity seemed to be more challenging for our students when going through the process of solving for each grouping problem.

For example, in the pencil and paper activity, some students lost track of the values they were supposed to be dividing up into the two boxes. Student 2B counted the number of dots he was supposed to be dividing correctly, but then when he went to split them up into two groups he was dividing the wrong value up. Also, when Student 2B was working on the paper and pencil activity he used his fingers as manipulatives to help him figure out the answers. We also saw, across most of the student sessions, that when they were working on the paper and pencil activity, they were less motivated and less interested in doing the work. Student 3A for example was acting silly during the written session and would not remain sitting in her chair correctly.

We conclude that no matter what activity the students started with, they improved over the course of the three activities. Student 1A was able to improve from a two to a four, and Student 3A was able to improve from a
two to a three. Although our study’s results did not prove that either the paper and pencil, virtual manipulative nor physical manipulative material was more beneficial to the students’ ending solutions, we did observe the virtual and physical manipulatives being more motivating, attention retaining, and overall easier (on average) for our students when working towards the grouping problem solutions.
References


Haugland, S. W., & ERIC Clearinghouse on elementary and early childhood education, C. L. (2000). *Computers and Young Children. ERIC Digest.*


