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Improving Preschoolers' Number Sense Using Computer Math Games

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Abstract

The purpose of this action research study was to determine whether a preschool child's number sense skills could be improved by using the iPad application ABCya! Games. The research study was conducted in a preschool classroom of 19 students at an elementary school in central Iowa. A mixed methods approach was used to collect data as students were assessed prior to and after the intervention, and were observed playing the technology-based math games during the intervention period. Given the limitations of the study, the findings of this study determined that the technology did not significantly improve student learning outcomes in the area of number sense.

Keywords: number sense, technology, preschool

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Improving Preschoolers' Number Sense Using Computer Math Games

Number sense is an important part of a preschooler's foundational mathematics skill set, yet so many children struggle with this area of early childhood mathematics. When children have a solid math foundation in preschool and kindergarten, they are more likely to be successful with mathematics in the future (Witzel et al., 2012). Research shows that pre-k and kindergarten math assessment scores are strongly correlated to later mathematics achievement (Polignano, 2014). Despite educators' best efforts at teaching mathematics throughout the school years, young adults in the United States are more deficient in mathematics skills compared to those in other countries and are entering college needing to take remedial math courses (Reid, 2010).

Research indicates that children who physically manipulate materials (e.g., counting bears) have a better chance at succeeding with learning these early math concepts including, but not limited to, number sense, patterning, and measurement in comparison to those children who miss these opportunities (Kermani, 2017). However, in the researcher's local preschool, children are displaying a deficit in number sense skills despite daily practice using manipulatives, number cards, subitizing cards, etc. The one thing that no preschool teacher has tried yet this year in the district in this action research study is using technology to try and bridge this gap in order to help these young children become skilled in mathematics throughout their lives.

The purpose of this action research project is to determine whether mathematics games played on an iPad, tablet, or other computer device can improve preschoolers' number sense skills. While physical manipulatives give young children the most benefit to learning mathematics, technology is becoming an increasingly prevalent learning tool in the homes and classrooms of young children and can be used in developmentally appropriate ways to engage children in challenging yet fun mathematics learning (Kermani, 2017). Preschool children

included in this research study are already very familiar with technology, and some use it daily either at home or at preschool. This research project analyzed whether these children could grow in the area of number sense during early childhood and increase proficiency in mathematics throughout the course of their education.

All of the previously completed research studies referenced in this research project were found through the databases available within the DeWitt Library. The database most used was ERIC & Education Database (ProQuest). Articles included in this study were from the years 2010-2020 and included *number sense, preschool, early childhood, technology,* and *mathematics* in the various search terms.

This action research study will describe whether preschoolers demonstrated growth in the area of number sense after using computer math games to practice those skills. A mixed-methods approach will be used for data analysis. Quantitative data will be collected in the form of a pre- and post-assessment examining all areas of number sense, while the qualitative data will be collected via observation notes from viewing screen recordings of the children playing the computer mathematics games.

The review of the literature for this action research covers topics about number sense. The first section of the literature review will explain number sense: how it is defined and what specific skills of mathematics it includes. In addition to defining number sense, the literature review will describe the important aspects of number sense instruction, including beliefs and mathematics content knowledge of teachers. This literature review will also include research related to play-based learning, especially in mathematics, in early childhood, and how preschoolers with low socioeconomic statuses perform in relation to mathematics. The final section of the literature review will detail how technology has impacted student learning of

number sense and which online mathematics games have demonstrated the most benefit to improving number sense in young children.

Review of the Literature

Defining and Measuring Number Sense

Number sense has been defined and measured in various ways, and it can be a difficult concept for educators to grasp. In one instance, Smith (2010) considers a child's acquisition of number sense to "include number identification, counting (the skill rather than understanding the basic principles . . .), understanding the magnitude of objects, and the ability to complete informal addition and subtraction tasks (p. 5). In Smith's study, young children were assessed on these four skills along with specific counting concepts in order to determine an overall mathematics development model for early childhood and kindergarten readiness. The findings of this study concluded that each of the individual assessment tasks all strongly correlated to measure an overall concept of number sense. However, the informal addition and subtraction task had the strongest correlation while the magnitude task had the weakest (Smith, 2010). This study suggests that when it comes to number sense, magnitude of numbers may not be an important part of learning number sense. More importantly, the complete understanding of number sense concepts in early childhood may help young children gain the skills needed to be successful in future mathematics.

Related to magnitude understanding, Genzmer (2011) tested whether preschool children who take part in an intervention using magnitude manipulatives to compare numbers are able to outperform other preschoolers on a mathematics assessment who either participate in extra counting activities or do not receive extra mathematics practice. Genzmer (2011) collected data from 80 children who completed a standardized assessment consisting of four mathematical

subtests. These children were randomly assigned to a magnitude manipulatives group, a counting group, or a control group for a three-week intervention period. The post-assessment results showed that even after using magnitude manipulatives or having extra counting practice, children made no significant gains from the pretest. Once again, magnitude of numbers appears be a lesser important piece of the number sense puzzle. However, Genzmer (2011) suggests that a mismatch in teacher language during the interventions and the assessment language may have contributed to the results of the research. This statement implies that language can largely affect how young children learn mathematics. It also indicates that magnitude of numbers is an essential part of early childhood foundational mathematics, and should still be taught alongside other number sense skills.

While the idea that number sense concepts work better together than individually is important to remember, a study conducted by Polignano (2014) sought to define which number sense measures on a curriculum-based assessment screener for early childhood mathematics (the myIDGDI-EN) illustrate the largest growth rates among preschool children. The measures of number sense on the screener included Number Naming Fluency (NNF), Oral Counting Fluency (OCF), One-to-One Correspondence Counting Fluency (OOCCF), and Quantity Comparison Fluency (QCF). Over three school years, data was collected and analyzed from 444 preschool children who completed the myIGDI-EN mathematics tasks to determine the progression of math development throughout the preschool year. The results of the study showed that "OCF and OOCCF demonstrated . . . the greatest rate of growth over time" while "the NNF demonstrated the lowest initial performance level" (Polignano, 2014, p. 59). Polignano (2014) was not surprised by the NNF result:

> The lower growth rate on NNF is not surprising given that it takes children repeated exposures before numerals can be accurately and consistently identified. Naming numerals requires the construction of a mental image of each number and the ability to distinguish between numerals with similar features (e.g., 2/5 and 6/9). (p. 60)

The implications of this study suggest that with increased practice, children may show improved growth rates in all areas of number sense. In order for substantial growth be achieved, it is important to consistently expose children to these early mathematical skills throughout the preschool year.

Similar to Polignano's study, Moomaw et al. (2010) discuss how curriculum-based assessments can align with classroom curriculum; the assessments can give teachers insight into their students' mathematical and number sense development. What they learned is that using play-based or game-based assessments "provides a more natural context for young children than typical test situations" (Moomaw et al., p. 336, 2010). Like the myIGDI-EN assessment that Polignano (2014) used, the Arlitt Preschool Curriculum-Based Measure for Math (APCBM-Math) uses an interactive approach to assess number sense for all types of children. Children must quantify, count, and compare objects; identify numerals; and use informal addition (Moomaw et al., 2010). This research suggests that these skills, like in various other research studies mentioned here, are foundational to the number sense that all preschoolers need to be successful throughout their school years. Educators have an important role in fostering these foundational number sense skills to help young children become successful mathematicians.

Mathematics in the Preschool Classroom

Preschool children everywhere are learning early mathematics concepts, but some early childhood teachers may wonder which of these math skills are the most important to focus on in

their instruction. In a study by Jung et al. (2013), the researchers sought to determine the value and importance of teaching relationships between numbers, such as subitizing, more or less, and part-whole, rather than focusing only on counting, cardinality, and one-to-one correspondence. This study included 73 children and split them into a control group and an intervention group to determine if extra practice of number relationships skills would help children in the treatment group score higher on a standardized mathematics assessment. Children in the intervention group received 12 weeks of extra practice using Rekenreks, a mathematics software called *Building Blocks*, and ten-frames. The results of this study determined that children who received the intervention with number relationships activities significantly outscored the children who received regular mathematics instruction (Jung, et al., 2013). The study suggests that while basic number sense instruction is critical in early childhood, the inclusion of these number relationships in day-to-day math instruction in addition to counting and cardinality can increase a child's overall number sense skills.

It is the hope of all early childhood educators that their students successfully enter kindergarten with the skills and readiness they've instilled throughout the preschool year. Malcolm (2011) sought to determine the level of number sense skills these children are bringing into kindergarten by assessing incoming kindergarteners using the Early Mathematics Diagnostic Assessment (EMDA). He found that the most frequently occurring raw score of the assessment was 11, compared to the national average of 13 as referenced in the assessment manual. Malcolm (2011) determined that children are entering kindergarten with "insufficient grade level attributes when it comes to number sense" (p. 60). This research suggests that children in preschool are not continuing to gain the number sense skills needed to be successful to enter kindergarten, and that

mathematics interventions may be needed throughout the preschool year in order to bridge this gap.

Teacher knowledge of preschool mathematics development is crucial in order to understand how young children acquire mathematics concepts (Lema, 2019). Lee (2017) states that pedagogical content knowledge (PCK) in mathematics is an important part of an early childhood educator's repertoire in order to effectively provide high-quality math instruction to preschool children. The study investigated the PCK in mathematics of preschool teachers in Korea and found that number sense, measurement, and classification were the most recognized concepts by teachers; however, their ability to recognize these concepts in classroom situations was low. Lee's findings suggest that teacher education programs should focus on educating teachers on how to interpret math activities and the mathematical thinking of children during play (Lee, 2017).

While Lee's research focused on teachers' mathematical content knowledge, a study by Lohse (2018) sought to find what teachers believe about number sense instruction and how those beliefs influence instruction. In this research study, the researcher interviewed, observed, and analyzed materials from three early childhood teachers in different early childhood programs. Some themes teachers mentioned as important math influences in early childhood were parent and family influence on learning, age and its role in math readiness and development, the inconsistent definitions of number sense, and how math doesn't come naturally to all children. The teachers also shared in their interviews how they plan for instruction; compile materials and strategies for teaching mathematics; and address the math skills of counting, comparing, calculation, subitizing, and numeral knowledge in their classrooms (Lohse, 2018). This research implies that early childhood teachers share similar beliefs when it comes to teaching

mathematics even in different early childhood settings, and that children in these separate settings learn number sense in similar ways.

Instructional Practices for Low-SES Children and the Impact on Mathematics Learning

There are many factors that can affect how a child learns and acquires mathematics skills in school, including student demographics. In one study, Reid (2010) discusses how an early intervention mathematics program titled Number*Fun* impacted children in a Head Start program. According to the U.S. Department of Health and Human Services (2020), Head Start is a no-cost early learning program that supports children from low-income families and promotes school readiness in the way of health, child development, and family wellness. The findings from this study determined that the children in the Number*Fun* intervention classrooms did not show a significant improvement over the children who received regular math instruction. Reid (2010) mentions that the intervention classroom teachers believed Number*Fun* to be too broad of a program and short on more focused math skills, and that some activities were too long or too difficult for the students to complete.

Similarly, a study by Dyson (2011) sought to determine the effectiveness of a kindergarten number sense intervention for low-income students. This study assessed 121 urban children who fall into the low socioeconomic status category. The eight-week intervention consisted of various 30-minute activities that included the following: Magic Number, number recognition, numeral sequencing, subitizing, number comparisons, and number problem solving (Dyson, 2011). The results from the post-assessment showed that children who participated in the intervention group made larger gains in number sense knowledge than children in the control group, although both groups made significant gains after the study. The results of this study and

the study by Reid (2010) implicate that all children, no matter their socioeconomic status, can make significant mathematical gains with extra practice.

Kindergarten students who have a low-socioeconomic status (SES) but attended preschool have a higher numeracy knowledge percentage than children who did not attend (Waltemire, 2018). The researcher analyzed STAR Early Numeracy assessment results from kindergarteners in both the winter and spring assessment periods. The spring assessment results sample determined that children from low SES backgrounds who attended preschool significantly improved over children from the same income status but did not attend preschool the year prior. Waltemire (2018) also found that the mean scores of the low SES students in the spring was comparable to the winter sample of the whole kindergarten population sample. The findings support the idea that children from low-income backgrounds and did not attend preschool typically have a large gap to close in order to make the same gains as their peers.

Similar to socioeconomic status, age is a student demographic that can play a large role in the development of a child's number sense. Researcher Yilmaz (2017) wanted to observe the levels of early numeracy development of three different children aged four, six, and seven. The researcher conducted semi-structured interviews over a period of two weeks, focusing on two main areas of number sense: Number Word Sequences and Numerals, and Counting. The findings determined that number sense follows a sequential developmental progression in young children (Yilmaz, 2017). For example, the four-year-old child could not fluently name numbers in forward or backward sequences, but the six-year-old could name forward and backward numeral sequences within a certain range. This study suggests that task-based interviews of young children can help teachers determine a child's level of number sense based on the developmental progression of number sequences and counting sequences.

Using Math-Based Technology in Play-Based Environments

Technology is becoming increasingly more prevalent in the lives of preschoolers, whether it be at home or at school. Schools are beginning to play with the idea of digital play-based learning experiences to improve student achievement in mathematics for early childhood classrooms (Disney et al., 2019). For example, Miller (2018) studied the impact of using iPad applications on kindergarteners' number sense learning within a play-based environment. For two weeks, children either played mathematics games on the iPads as an intervention or participated in play-based math activities in the regular classroom setting. The results of the post-assessment concluded that neither the comparison group and the intervention group showed significant gains from the pre-assessment. However, Miller determined that although the results were not significant and only slight improvement was made from pre- to post-test, using iPad applications does not hinder learning early numeracy skills (2018, p. 8).

Schacter & Jo (2017) also wanted to research whether children who participated in an intervention using a specific Montessori-based iPad app called Math Shelf would improve more than their peers who received only research-based mathematics instruction. Math Shelf consists of digital mathematics games in the areas of sorting, matching, subitizing, counting, and sequencing. Children played these games two days per week for ten minutes each session. Classroom teachers who participated in Schacter & Jo's study received extensive training on skills to be taught and how to use the Math Shelf application (2017). Results from the 22-week study determined that children who took part in the Math Shelf intervention had nearly nine months more growth in mathematics than the children in the comparison group on the post-assessment (Schacter & Jo, 2017). This study implies that, given ample time for interaction, children who play digital mathematics games at school can significantly improve their learning

and can even begin to bridge the gap educators are seeing in mathematics across the grade levels, as long as teachers are receiving adequate support and training for using these applications.

In other research about the effect of technology on mathematics instruction, Adkins (2018) completed a case study on the role that iPads can play in developing early mathematics concepts in young children. During the 14-week intervention period, children were recorded while interacting with various mathematics applications, including an app called ST Math, which was already used routinely in the students' classrooms (Adkins, 2018, p. 70). ST Math is an app that uses game-like puzzles and virtual manipulatives in the areas of counting and cardinality, operations and algebraic thinking, geometry, and measurement to help preschool children investigate number sense, use their critical thinking skills, and problem solve. Children also had access to the apps Montessori Numbers, Math Shelf, Elmo Loves 123, and ToDo Mathematics during the intervention (Adkins, 2018). Based on the findings, the researchers determined that all children showed an increase in their number sense knowledge at the completion of the study. Children also enjoyed playing math games on the iPads because they see them as playing games for fun rather than a learning opportunity (Adkins, 2018). This study supports the idea that iPads, or any technology devices available in a classroom setting, are appropriate tools to help young children successfully gain number sense skills.

Summary

The research studies in this literature review provide evidence that technology can be a powerful mathematics intervention tool within the early childhood classroom. After reading the various successes previous researchers have found using a technology-based intervention to help young children succeed with number sense learning, a study was conducted in the local preschool classroom to compare findings.

Methods

Research Question and Variables

The research question this study will hope to answer is *do technology-based math games positively effect preschool children's number sense?* Some of the preschool children in this study have been showing deficiencies in early mathematics skills in the classroom compared to their peers. While many teaching strategies for math have been implemented within the classroom this year to try to bridge the gaps in their learning, the students are not making adequate growth in this subject area. Technology is one tool that has not yet been tried. The independent variable, the technology-based math games, was studied to determine its effect on the way children learn mathematics. The effect the math games might have on number sense growth (the dependent variable in this study) could make technology a more utilized tool in the preschool classroom, depending on the results of this study.

Participants and Research Site

The action research study took place in a state-funded, four-year-old preschool classroom within an elementary school. The school is located in a small town and part of an exponentially growing school district in central Iowa. Children in the district attend either morning or afternoon preschool classes that meet four days per week for three hours each day. There are 19 students in each preschool class, but for the purpose of this study only one class of students participated because of their greater need for mathematics intervention. The classroom has one full-time certified Early Childhood Special Education teacher. There is also one full-time preschool classroom paraeducator due to the required 10:1 student/teacher ratio.

Eighteen of the preschoolers are Caucasian and one is Asian. The children's ages range from four to five years old, and 98% of the children come from high-income families. One student currently receives speech services during the school day through an Individualized Education Plan, but no other students receive any special education services. Of the 19 students in the class, only 16 completed the study due to absences the day the post-assessments were administered.

Intervention

The number sense intervention used iPads and the application ABCya! Games (specifically, the number sense games in the mathematics section) for this action research project. Within the ABCya! Games application, there are only eight games within the Pre-K numbers and mathematics section, but only a few of those really focus on early number sense. According to Can (2020), the games in ABCya! support the learning trajectories of recognizing numbers, subitizing, and verbal and object counting for children ages four to six. Because of this previous research, the three games the children were guided to play during this intervention were Counting Fish, Connect the Dots, and Monster Mansion–Number Match. These games focus on counting, number matching and identification, and number sequencing (Can, 2020).

The nine preschool children who were part of the intervention group were each assigned an iPad and played number sense games for 10 minutes each session. These sessions occurred during the scheduled free play centers time so that the children would not miss any instructional time during the morning. Children who were in the control group received only regular mathematics instruction in the classroom and did not play the ABCya! math games during this time. There are only five student iPads in the classroom, so the intervention group was divided in half and took turns playing the games in a quiet part of the hallway outside of the classroom.

The sessions were recorded using the Record It! application while the children played the games in order to see how the children interacted with them. However, not all of the sessions were recorded due to user error or the iPad screens timing out from the children getting distracted during gameplay.

Data Collection

The measurement instrument for this research study is a teacher-created number sense assessment (see Appendix A). The same assessment was used for both the pre- and post-assessment. It targets four number sense skills: Number Identification (1-10), Oral Counting to 20, One-to-One Correspondence, and Quantification (matching numbers to counted objects). The assessment consists of research-based number sense math tasks. Students can score a total of 40 points on the assessment. There is no validity or reliability for this instrument as it was created by the researcher.

Students were randomly assigned a number and placed into either the control group or the intervention group. Regardless of their placement, all children were individually taken into the hallway to complete the assessment with the teacher-researcher. After the pre-assessment was completed by all children in the study, the children in the intervention group played number sense math games during the intervention period on the ABCya application, and the sessions were screen recorded using the application Record It! for observational purposes. The other group of students received only regular mathematics instruction in the classroom. It was quickly realized when checking the screen recordings to see how the children in the intervention group were interacting with the games that not all the gameplaying sessions recorded due to an error with the app or by the children accidentally exiting the recording software before it started. Once the intervention ended, all students were given the post-assessment, which was the same test as

the pre-assessment. Both the pre- and post-assessments each took between two to three days to complete with all students.

The proposed timeline for the intervention was three weeks of sessions, but due to time constraints with unexpected late start mornings, no preschool days during conferences, and the school's scheduled Spring Break, children were able to complete the intervention for only one week. These time constraints could impact the results of the assessment because the children did not have adequate time to practice number sense skills during the intervention period.

Whereas all 19 students took the pretest, three students were absent at the time of the post-test due to either illness or an early start to spring break, leaving only 16 completed assessments for analysis. The assessment data is available only on the individual student assessment sheets and will be stored in the classroom's lockable filing cabinet for the remainder of the school year.

The Four-Way Factorial Design statistical analysis model was used to analyze the data. Two independent two-sample t-tests and two dependent paired sample t-tests were performed on the independent and dependent variables. This model compares the assessment results to see if the group that received the intervention improved more in the area of number sense than the control group.

This study has been determined exempt from Internal Review Board approval as no adverse impact to the children's learning occurred. In order to protect the students' anonymity, all children's assessment data is labeled with student numbers for data analysis purposes. The data was collected only by the teacher-researcher and kept confidential.

Findings

Data Analysis

Out of the 19 total students who took the initial pre-assessment for the study, only 16 children completed the post-assessment due to student absences on the days of the assessment. The results of this study include only the 16 completed assessments. The assessment that was used for both the pre- and post-test included four questions about number sense in which children could score a total of 40 points. To determine whether the students in both the control group and intervention group showed a significant difference in their knowledge of number sense on the pre-test, an independent samples t-test was conducted on the data. The mean scores for the control group (M = 36.2, SD = 4.86) and the intervention group (M = 38.7, SD = 7.44) on the pre-assessment showed a significant difference in the scores: $t(14) = 2.56$, $p = .022$. The two groups of students were not at the same level of mathematical knowledge at the beginning of the intervention.

Following the post-assessment, a dependent samples t-test was performed to determine whether the control group improved in their mean scores. According to the analysis, the pre-test scores (M = 36.2, SD = 4.86) and the post-test scores (M = 34.6, SD = 7.54) determined that the preschool children in the control group did not show significant growth $t(8) = 1$, $p = .34$.

Once the intervention group completed their intervention and post-test, a dependent samples t-test was conducted to determine if the students in the treatment group had a significant difference in their mean scores from pre-assessment to post-assessment. Students in this intervention group did not show significant growth between the pre-test (M = 28.7, SD = 7.44) and the post-test (M = 29.7, SD = 6.23), $t(6) = -.654$, $p = .53$. When looking at the raw data of these students from both assessments, some children actually had decreased their scores. This

information was initially surprising to the researcher as the children had just completed the intervention, yet when thinking about the circumstances of the time constraints, how the children responded to the iPad games, and their shorter attention spans during final assessment, it made sense that some of their scores dropped by a point or two.

Finally, an independent samples t-test was conducted to determine whether the number sense intervention the children in the treatment group received resulted in a difference in mean scores versus the children who did not receive any extra intervention. This t-test did not show any significant difference in the control group's post-test mean scores (M = 34.6, SD = 7.54) and the treatment group's mean scores (M = 29.7, SD = 6.23), $t(14) = 1.4$, $p = .18$. The student outcomes of the preschoolers in the intervention group were not significantly different than those children who did not receive any extra number sense practice, determining that the selected intervention did not increase student gains as much as the researcher had predicted.

Discussion

The purpose of this research study was to determine whether playing the iPad application ABCya! Games could improve a preschooler's number sense understanding. The t-test results from the data analysis concluded that there was not a significant increase in learning from pre-test to post-test for the children in the intervention group, and that these students did not show a significant gain in their learning over the control group who did not receive extra number sense instruction. Previous research such as the study by Schacter & Jo (2016) states that children playing an iPad-based mathematics curriculum had statistically significant growth compared to a control group after an intervention period of 22 weeks. This study suggests that technology can in fact be a useful and beneficial intervention tool and can greatly improve a child's understanding of number sense in preschool and beyond. However, the time constraints of this

action research project compared to time allotted in the previous research may have been a factor in the divergent results; a longer intervention time in this case study may have led to a different outcome. Other factors, such as the sample size of this study, may have been at play in regards to the outcome.

This research study can have a positive impact on teaching and learning, regardless of the insignificant growth from the assessment results. According to Papadakis et al. (2018), children who are engaged with stimuli-rich digital environments that imitate real life mathematics situations are positively affected in mathematics skills (p. 1863). Most schools and classrooms have technology readily available from the beginning of the school year. If teachers are noticing discrepancies in student learning in mathematics or even literacy skills early on, technology can be a great supplemental tool to help support these students from the beginning. The various math-based technology and applications that are accessible within schools would give young children extra opportunities to practice number sense skills and would hopefully close the gap in early childhood mathematics.

Limitations of the Study

This study had some limitations that may have affected the outcome of the research. First, the researcher had originally planned for the intervention period to last three weeks, but there were issues with time constraints. The morning preschool class lost a few school days because of unexpected late start mornings for winter weather. In addition, two intervention days were also lost due to having no preschool classes on parent-teacher conference days. Yet another limitation was that Spring Break also fell when the intervention was planned to be completed, so completing post-assessments became the priority during this time. Because of the problems with time, the intervention was completed over a period of only one week. This short period may have

been a significant factor in the results as children may have needed more time to interact with the ABCya! Games application for significant growth to occur.

Another limitation may have been the sample size of this study. While the researcher chose one preschool class of 19 students to participate due to their discrepancies in early childhood mathematics, other preschool classes within the same elementary school building could have participated for a greater sample size of children, bringing the total to 72 students. This larger sample size would have provided a larger number of assessment results and better reliability. The sample size also became a limitation when only 16 children were able to complete the study due to student illnesses and families leaving on Spring Break vacations a day or two early.

Future Research

Additional research is needed on the most beneficial length of time an early childhood mathematics intervention should last. While the present study had time constraints during the intervention period and did not show significant growth from pre-test to post-test, other research discussed in this study had used various lengths of time during the interventions with positive student learning outcomes. There is limited knowledge of how long an effective number sense intervention should occur in order to see the highest rate of growth in young children's mathematical learning.

There is also a need for more research to determine which computer-based curriculums, games, or applications will give children the best opportunities to increase their number sense skills in the early years. Early childhood teachers and school districts could then have access to the finest mathematics-based technology for student interventions in number sense. This research study and others mentioned previously have utilized the ABCya! Games application, along with

Math Shelf, ST Math curriculum, MathemAntics, and even researcher-created applications, but there is limited knowledge about which of these applications would give young children the biggest increase in their early mathematics skills.

Conclusion

Number sense knowledge is an important skill set for preschoolers to master, but so many young children struggle with early math concepts. Previous research suggests that giving children extra practice with math-based technology and applications can significantly improve their number sense skills. The results of this action research study on using the ABCya Games! app to improve number sense in preschoolers did not show significant growth like the results of other similar studies. However, given an adequate amount of time to participate in this intervention using this or other similar digital math games, preschool children could considerably increase their number sense knowledge in order to better prepare them for entering kindergarten and beyond.

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Appendix A

Number Sense Assessment

Student Name/Number:

Number Identification

1 2 3 4 5 6 7 8 9 10

Score 1 point for each correctly identified numeral.

___/10

Oral Counting

1 2 3 4 5 6 7 8 9 10

11 12 13 14 15 16 17 18 19 20

Score 1 point for each number counted sequentially.

___/20

Object Counting – 9 objects

Did the child count 1:1?

Yes No

Score 1 point for each correctly counted object.

___/9

Number Matching

Did the child successfully match 2 of 3 sets?

Yes No

Score 1 point for 2 or more matched sets (score 0 for less than 2 matches)

___/1

Total Score ____/40