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Enriching Students With Developmental Delays In An Early Childhood Classroom Using Ipads With Mathematics Applications

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ENRICHING STUDENTS WITH DEVELOPMENTAL DELAYS IN AN EARLY CHILDHOOD CLASSROOM USING iPADS WITH MATHEMATICS APPLICATIONS

by

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ABSTRACT

Laws and legislation related to early childhood and special education have shaped the field and impacted the need for early intervention services, but the outcomes of those services both academically and socially at the forefront. Children with developmental delays today are eligible for school services beginning at birth across the country, the new challenging is determining the impact of services on the social and academic outcomes. Many children with developmental delays are served in inclusive early intervention classrooms. A need for developmentally appropriate quality mathematics instruction exists to prepare students to meet the demands of a global economy; students must demonstrate mastery of core subjects, such as mathematics, along with skills in information and communication technology (Partnership for 21st Century Skills, 2009). To promote mathematics achievement technology should be infused in instruction.

Data were collected through a variety of sources including: student records review, TEMA-3 test scores, researcher's observation field notes, transcripts from student exit interviews, teacher interviews pre and post data collection, and parent questionnaires. The data were analyzed using Atlas-ti and was triangulated from the various data sources. Inter-observer agreement was obtained for all the results. Researcher observations occurred for 19 days in a pre-kindergarten inclusive classroom. The data were analyzed to identify themes for the four individual cases as well as two overarching themes as it related to the investigation of utilizing handheld technology for mathematics instruction in an early childhood education setting.

My dissertation is dedicated to my husband and my daughters. During the countless hours I spent in classes, studying, and writing Kennedy and Olivia spent falling in love with their prince charming. Mike Powell, you are my rock, when my heart and emotions get the best of me and make me irrational and emotional, you are there to calm me and speak the truth. You are a huge motivation…the father and husband you have become during my time in school makes me so proud to be your wife.

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LIST OF ACRONYMS

AAIDD – American Association on Intellectual and Developmental Disabilities

ACTTT – Accessing Curriculum Through Technology Tools

AYP – Adequate Yearly Progress

CCSI – Common Core Standards Initiative

DAP – Developmentally Appropriate Practices

DD – Developmental Delay

DEC – Division of Early Childhood

ECLS-B – Early Childhood Longitudinal Study-birth

ECLS-K – Early Childhood Longitudinal Study-Kindergarten

EHA – Education of All Handicapped Children Act

EI – Early Intervention

ESEA – Elementary and Secondary Education Act

FAPE – Free and Appropriate Public Education

FLDOE – Florida Department of Education

HCEEP – Handicapped Children's Early Education Assistance Act

IDEA – Individuals with Disabilities Education Improvement Act

IEP – Individualized Education Programs

IFSP – Individualized Family Service Plans

LEA – Local Education Agencies

LRE – Least Restrictive Environment

NAEP – National Assessment of Educational Progress

NAEYC – National Association for the Education of Young Children

NCLB – No Child Left Behind Act (also known as ESEA)

NCTM – National Council of Teachers of Mathematics

NETP – National Educational Technology Plan

NHES – National Household Education Survey

STEM – Science, Technology, Engineering, and Mathematics

TEMA-3 – Test of Early Mathematics Ability-Third Edition

USDOE – U.S. Department of Education

WWC – What Works Clearinghouse

CHAPTER ONE: INTRODUCTION

As early as the 1800's the concept of early intervention in the field of education has evolved through research, legislation, litigation, and discussion for both the early childhood population in general and the population of students served under the umbrella of special education. However, within the field of early intervention the definition of what age group represents early childhood differs based upon the population. The National Association for the Education of Young Children (NAEYC) defines early childhood as all children from birth to age eight. According to the Individuals with Disabilities Education Act (IDEA) early childhood includes infants and toddlers with disabilities from birth to age two who are served under Part C of the Act and children ages three to five who are served under Part B of the Act. The purpose of this chapter is to illustrate the past, present, and future of early childhood education as it relates to early intervention educational services, specifically in the area of mathematics enhanced by technology. First, a historical perspective on early childhood will be discussed as it relates to early intervention in education. Next, relevant legislation that shaped the field of special education will be identified with a focus on the implications for early childhood education. Then, a discussion of high-quality early childhood classrooms as well as early intervention in the field of education will be outlined to establish the setting for a discussion of mathematic achievement and the need for high-quality early childhood classrooms. This discussion is followed by a description of the impact of technology on mathematics concepts in the early childhood classroom. Lastly, a statement of the problem and proposed solutions will be conceptualized.

Historical Perspective on Early Intervention in the Field of Education

The concept of intervention in general emerged as a point of discussion in France in the 1800s when Jean-Marc Itard attempted to teach the "Wild boy of Aveyron", a twelve-year-old boy who was raised with wolves for what was thought to be at least eight years. The child, Victor, was called an incurable idiot by some; however Itard attempted to teach him social skills and language. Victor responded with learning only a few words, demonstrating receptive language and on one documented incident showing a social emotional response to the housekeeper when she was crying. As a result of his work, Itard believed through intervention, learning potential could be enhanced (Itard, 1962). Edourad Seguin (1870), a student of Itard, built off of Itard's early work with a focus on children with disabilities. Seguin emphasized the importance of early intervention in the field of education by developing the idea of keeping detailed assessment information to create remediation plans for children with disabilities, and he became known as the Pioneer of Early Intervention in the field of education (Seguin, 1870).

Other pioneers in the field of early childhood and mathematics were Goodrich (1818) and Comenius (1896). Goodrich (1818) introduced and promoted the idea of utilizing concrete manipulatives, for young children to learn the concepts of arithmetic. He discouraged the idea of rote learning of mathematics concepts. Comenius described arithmetic as, "the foundation of which will be to know that something is much or little, be able to count to twenty, or even all the way to sixty…"(1896, p. 22). Comenius declared that children should learn by doing and demonstrating with real objects, contributing to the foundation of utilizing manipulatives in mathematics instruction.

Legislation

Additionally, legislation contributed to the field of special education with the passing of pivotal federal laws, The Education for All Handicapped Children Act (EHA, PL 94-142) in 1975 created a foundation to what would later be the Individuals with Disabilities Education Act (IDEA). The key components to the law included: provision of free and appropriate public education (FAPE) for all students, the use of nondiscriminatory evaluations, development of individualized education programs (IEP) or individualized family service plans (IFSP), education of the student in the least restrictive environment (LRE), implementation of due process procedures, and right of parental participation. States were given until 1978, later extended to 1981, to fully implement the law. Later, the Education for All Handicapped Children Act Amendments of 1986 (PL 99-457), also referred to as the Preschool Law, extended the services to provide financial incentives to states to provide FAPE opportunities to infants birth through age two and preschool children, ages three through five, with disabilities in their natural environment. The funding for states was used to plan, develop, and implement a comprehensive multidisciplinary team working with agencies to provide early intervention educational services. Specifically, Sec. 671 of PL-99-457 states:

> (1) to enhance the development of handicapped infants and toddlers and to minimize their potential for developmental delay; (2) to reduce the educational costs to our society, including our nation's schools, by minimizing the need for special education and related services after handicapped infants and toddlers reach school age; (3) to minimize the likelihood of institutionalization of handicapped individuals and maximize the potential of their independent living society; and (4) to enhance the capacity of families to meet the special needs of their infants and toddlers with handicaps (Sec. 671(a)1, pp. 3-4).

In 1990, the Individuals with Disabilities Education Act (IDEA) renamed and amended Public Law 94-142 by changing terminology from handicap to disability, mandating transition services, and adding autism and traumatic brain injury to the eligibility list. Additionally, changes included the expansion and improvement of the mandate for services to infants, toddlers and preschoolers with disabilities and their families, with an emphasis on the transition from Pre-Kindergarten to Kindergarten. In 1997, additional amendments were made to IDEA which added several major components such as changes directly related to early childhood including appealing and renaming part H to part C for toddlers and infants, including the requirement of collaborating with families, teachers, and other professionals to the IFSP development, and adding the term Developmental Delay (DD).

In 2001, No Child Left Behind (NCLB), approved by Congress and signed into law by President George W. Bush on January 8, 2002, increased the school's accountability for student achievement, specifically identifying academic performance of students with disabilities. Schools were penalized if students with disabilities did not make adequate yearly progress (AYP). When IDEA was reauthorized in 2004, it was aligned with NCLB, bringing both large pieces of federal legislation related to children with disabilities into alignment. The changes that directly affected early childhood and early intervention in the field of education included new criteria in the areas of IFSP development; emphasis on Child Find for underserved populations of infants and toddlers; transition to kindergarten and dispute resolution; mandating the use of scientifically based research to guide learning; allowing early intervention education services through kindergarten; enabling local education agencies (LEA) to use up to 15% of funding to provide early intervening services; increasing accountability for the success of early intervention educational services; clarifying certain definitions including specific early intervention educational services, qualified personnel, and natural environments; and streamlining Part C grant requirements. The changes are evident in the ongoing evolution and transformation of the field of early childhood which is in its legislative infancy compared to kindergarten high school services.

Early Childhood Classrooms

As the laws and legislation continued to shape the evolution of the field of early childhood education, the need for services grew. The 2007 National Household Education Survey (NHES) reported 74% of children attended a public or private program the year prior to kindergarten at age four (O'Donnell, 2008). According to *The State of Preschool: 2009 State Preschool Yearbook*, (Barnett, Epstein, Friedman, Sansanelli, & Hustedt), pre-K enrollment of three and four year olds exceeded 1.5 million in both general and special education programs which was approximately 30% of four year olds and 7% of three year olds. In April 2009, the Division of Early Childhood (DEC) and NAEYC, two leading associations in early childhood, jointly identified access, participation, and supports as three characteristics essential for a highly qualified early childhood program (DEC/NAEYC, 2009). To define a high-quality, center-based early childhood classroom, the researchers from the Center on the Developing Child at Harvard University (2007) have identified six characteristics:

> (1) highly skilled teachers; (2) small class sizes and high adult-to-child ratios; (3) age-appropriate curricula and stimulating materials in a safe physical setting; (4) a language-rich environment; (5) warm, responsive interactions between staff and children; and (6) high and consistent levels of child participation. (p. 4)

Additionally, Ramey and Ramey (1998a) stated with the increased demands for children with developmental delays, who require early intervention in early childhood classrooms, a highly qualified program should include a focus on high-quality instructional opportunities. One of the goals of early intervention educational services is to prevent children from developing academic disabilities and to ensure that, early in life, children with developmental delays access quality specialized services (Gervasoni, 2005; Ramey & Ramey, 1998b). With adequate language and cognitive experiences, children with developmental delays show intellectual and linguistic gains (Ramey & Ramey, 2004). With high-quality curriculum and instruction, an early childhood classroom can enhance the overall well-being and development as well as academic preparedness of children who are labeled or at risk for developmental delays (American Association on Intellectual and Developmental Disabilities, 2008; Campbell & Ramey, 1994).

Children who meet the criteria for developmental delays are eligible for school services, titled Early Intervention (EI) educational services, through Part B of IDEA (Ramey & Ramey, 1998a). Some students with developmental delays receive services in early intervention special education classroom; however services can also occur in inclusive pre-kindergarten classrooms (Stahmer & Carter, 2005). NCLB and IDEA (2004) have put an emphasis on inclusion within the general education classroom. The universal standards of NAEYC state, "All children means *all*: children with developmental delays or disabilities, children who are gifted and talented, children whose families are culturally and linguistically diverse, children from diverse socioeconomic groups, and other children with individual learning styles, strengths, and needs…"(DEC/NAEYC, 2009, p.1). Many parents of children with disabilities seek out childcare facilities and schools implementing inclusive practices because evidence supports positive impact on social and academic outcomes of the students (Odom & Diamond, 1998). Increased cognitive, linguist, and social stimulation occurs in inclusive classrooms versus segregated special education early childhood classrooms (Odom & Wolery, 2003). To enhance the inclusive early intervention classroom, the curriculum in the classroom should be developmentally appropriate and "meet children where they are…and help each child reach challenging and achievable goals" (Bredekamp & Copple, 2006, p. 3).

Developmentally appropriate practices (DAP) are based on empirical data of how children develop and learn and should be utilized in all content areas (NAEYC, 2009). In the area of early childhood, Stahmer and Carter (2005) examined the development of the typical toddler and found significant gains socially, in cognitive and language development for both the child with and without the disabilities. The DAPs are a framework of twelve principles, developed by NAEYC and five child focused guidelines for creating a developmentally appropriate learning environment to meet students at their current levels and challenge them to continue to expand their knowledge and skills at an individual developmentally appropriate level.

Mathematics Achievement

A need for developmentally appropriate quality mathematics instruction exists to prepare students to meet the demands of a global economy; students must demonstrate mastery of core subjects, such as mathematics, along with skills in information and communication technology (Partnership for 21st Century Skills, 2009). The National Council of Teachers of Mathematics (NCTM, 2000) promotes the use of mathematics curriculum and teaching practices based on developmentally appropriate practices and national standards for pre-kindergarten. Additionally, in a joint position statement, NCTM and the NAEYC recommend an accessible, high-quality, mathematics education for three to six year olds to provide the necessary foundation for future learning (NAEYC/NCTM, 2002). In 2009, 81% of students with disabilities were not at a proficient level for achievement in mathematics by fourth grade according to the National Assessment of Educational Progress (NAEP, 2009). Although the Committee on Early Childhood Mathematics found that most young learners have the potential to comprehend mathematic concepts, this potential may not be tapped in early childhood settings because many teachers are not providing adequate learning opportunities for children (Clements & Sarama, 2009). Additionally, findings in the Early Childhood Longitudinal Study-birth (ECLS-B; Flanagan & McPhee, 2009) indicate 42% of students who enter kindergarten cannot count 20 objects or read more difficult single-digit numerals, which is the required benchmark, and 6% cannot count 10 objects and identify simple numerals.

After analyzing data from the Early Childhood Longitudinal Study-kindergarten (ECLS-K), Bodovski and Farkas (2007) identified that the students' level of mathematical knowledge at the start of kindergarten, was an indicator of the students' subsequent mathematical gains. They also found that students who possessed the lowest amount of mathematical knowledge demonstrated the smallest gains indicating a need for high-quality mathematic instruction in preschool years, essential to future academic success (Bodovski & Farkas, 2007). Children begin kindergarten with a variation of different mathematical concepts and experiences (Powell & Fuchs, 2012). Tudge and Doucet (2004) urge the field to examine the types of mathematical experiences children have before entering kindergarten, whether those experiences occur naturally in the classroom through play and exploration or explicitly by instruction in a classroom.

Allowing young children to engage in deep investigation of mathematical concepts; experience their environment; develop a foundation of mathematics knowledge; and attain basic knowledge of patterns, size, quantity, and operations will also impact the outcomes in their overall content areas in grades K-12 (Clements, 1984; Clements & Sarama, 2009; Ginsburg, Lee, & Boyd, 2008; Ramey & Ramey, 2004). Specifically, Cutler (2011) recommends five principles to capitalize on learning concepts by embedding mathematics moments. One of Cutler's principles is to make mathematical moments playful, including playing with puzzles, games, patterns, and shapes. Exposure to numerical concepts through games and play prior to entering kindergarten improves the foundation of mathematics (Ramani & Siegler, 2008). In addition, Linder, Powers-Costello, and Stegelin (2011) emphasize that mathematical concepts should be embedded into the classroom routine and should engage the child in real-life activities to make meaningful connections.

Having a strong underlying foundation in mathematical concepts is a core component of cognition. Researchers have shown that mathematics competencies developed during in early intervention directly correlates with later mathematics achievement (Clements & Sarama, 2009). Siegler and Richards (1982) report children who have mastered developmental skills in high-quality early childhood settings are more likely to learn to read, write, and calculate earlier and more proficiently than those who have not. Also, the rate of acquiring mathematical skills is faster among students with higher initial mathematical skills (Aunola, Leskinen, Lerkkanene, &

Nurmi, 2004) which is significant since the skills children possess in kindergarten and first grade indicate mathematical and reading achievement in years to come (Clements & Sarama, 2009; National Math Panel, 2008). Actually, a student's mathematics skills at the start of kindergarten are a stronger predictor for school success than reading, social skills, or attention skills (Duncan, Dowsett, Claessens, Magnuson, Huston, Klebanov et al., 2007).

Early Childhood Standards Movement

High-quality early intervention educational services can support typical development (Coleman, Buysse, & Neitzel, 2006) and avoid a premature application of a disability label (DEC, 2009). Further, legislation calls for standards-based, high-quality instruction (ESEA, 2001; IDEA, 2004). In recent years, policy, research, and public interest have supported the development of curriculum standards that are critical to meeting the education goals for children (Clements, 2004; Schumacher, Irish, & Lombardi, 2003; Scott-Little, Kagan, & Frelow, 2006). The standards movement provided an opportunity to develop a framework for states and educators to develop instructional practices that most effectively help students learn the content for various ages and stages of development and education (Bodrova, Leong, Paynter, & Semenov, 2000). Bodrova et al. (2000) defined a standard as, "a general statement that represents the information, skills, or both, that students should understand or be able to do. Standards typically identify the knowledge students should master by the end of their K–12 school experience" (p. 7). Scott-Little, Kagan, & Frelow (2006) conducted an analysis of 47 states early childhood standards and determined an emphasis on cognition and language development, with mathematics and literacy as the focus (44% of the cognition standards focused on Logic-mathematical knowledge). According to Rous and Hyson (2007), the curriculum for young children with and without disabilities should include DAP guidelines and standards. NCTM (2000) developed standards for pre-kindergarten through grade twelve that are organized into four different grade bands (PK-2, 3-5, 6-8, 9-12), this was the first time NCTM included one set of mathematics standards specific for prekindergarten. These standards include five prekindergarten areas of mathematics instruction: (1) Number and Operations, (2) Algebra, (3) Geometry, (4) Measurement, and (5) Data Analysis and Probability. Along with these five content standards, NCTM also identified the five process standards for prekindergarten that are basic precepts fundamental to high-quality mathematics education in early childhood settings. These process standards include: (1) Problem Solving, (2) Reasoning and Proof, (3) Communication, (4) Connections, and (5) Representation. NCTM (2000) further organized the content and principle standards into grade level curriculum focal points. Focal points emphasize concepts by grade level to develop a solid foundation for future and more challenging mathematics. Similarly, the Committee on Early Childhood Mathematics of the National Research Council recommends high-quality early childhood instruction with an emphasis on number concepts (whole number, operations, and relations) with more mathematics learning time devoted to number than to other topics (Cross, Woods, & Schweingruber, 2009). Early childhood standards focus should specifically address the achievable knowledge, skills, and characteristics that children should learn and develop in an early childhood setting (Bredekamp, 2004). In 2006, NCTM released the curriculum focal points for PK-8th grade mathematics, which provided a framework for instruction by identifying the key mathematical ideas, and content that should be emphasized per grade level. More recently, the Council of Chief State

School Officers (CCSSO) and the National Governors Association Center for Best Practices created a state-led Common Core State Standards Initiative (2010) for kindergarten through eighth grade. The standards are organized by domains, clusters, and content standards and have five content standards: (1) Counting & Cardinality, (2) Operations & Algebraic Thinking, (3) Number & Operations in Base Ten, (4) Measurement & Data, and (5) Geometry. The content standards are divided into five strands that students should learn: number and operations, algebra, geometry, measurement, and data analysis and probability. Whereas, the process standards are divided into five strands of how students acquire and apply knowledge: problem solving, reasoning and proof, communication, connections and representation.

Mathematics and Technology

To address the standards and increase the breadth and depth of mathematics in high-quality early childhood classrooms NCTM (2000) recommended students have access to technology. Further, the Division for Early Childhood (DEC) of the Council for Exceptional Children (CEC) recommended incorporating technology into the classroom in three categories: assistive, instructional/educational, and informational (2009). National Association for the Education of Young Children, supporting the use of technology in early childhood classrooms, stated, "Early childhood programs have an obligation to use technology to bridge the digital divide" (2011, p. 4). Findings from the National Mathematics Advisory Panel (2008) indicated positive effects of instruction infused with technology on mathematic achievement. As emphasized in the National Educational Technology Plan (NETP), professional educators are supported when utilizing technology that enables them to be more effective teachers and inspire learners as well as help teachers meet the accountability goals of NCLB (NETP, 2010). Also, results from Accessing Curriculum Through Technology Tools (ACTTT) indicated that young children, grades K-2 increased their technology skills after participating in learning opportunities to utilize technology tools (Johanson, Clark, Daytner, & Robinson, 2009). Technology tools such as the computer can enhance mathematics instruction and increase the interactions students have with skills for mathematics and numeracy concepts (Little, 2009).

In 1996, NAEYC began promoting the integration of appropriate technology into the early childhood learning environment to enhance cognitive abilities, including those of students with disabilities. Lisenbee (2009) recommended capitalizing on young children's curiosity with technology and embedding technical tools into the classroom environment. Additionally, the Sesame Workshop (2010) educational initiative entitled Math Is Everywhere addressed the use of technology to promote Science, Technology, Engineering, and Mathematical (STEM) learning, related to early childhood. Along with the Math is Everywhere initiative, the Joan Ganz Cooney Center released the report, *Pockets of Potential: Using Mobile Technologies to Promote Children's Learning* advocating for anywhere, anytime learning through the use of handheld technology (Shuler, 2009a). To further support using technology to engage early childhood learners in high-quality classrooms, Clements and Sarama (2009) found the novelty of technology promoted interest and facilitated skill improvement, which can promote mastery in the area of mathematics. Meaningful opportunities and increased content mastery and technological skills occurred when the technology available was within the natural learning environment of a developmentally appropriate early childhood classroom (Clements, 2002; Finegan & Austin, 2002).

Statement of the Problem

The preponderance of a lack of research in early childhood mathematics, especially for students with disabilities is clearly supported in the literature. The use of technology to teach students at this level is equally shallow. Combining research in mathematics, early childhood with technology for students with disabilities is a clearly identified need in the field. For example, Fox and Diezmann (2007) concluded after a review of literature from 2000-2005, "a lack of peer-reviewed articles that discuss, investigate, examine, or debate early childhood mathematics; a limited emphasis in the prior-to-school years; and a paucity of literature on technology and problem solving, which are fundamental in the twenty-first century" (p. 301). Fox and Diezmann's statement aligns with the questions such as, how does technology enhance mathematics as it relates to young children by the well known Center on the Developing Child at Harvard University (2007). Additionally, Wang, Kinzie, McGuire and Pan (2010) reviewed multiple empirical studies and concluded that it is, "unknown whether technology-enhanced inquiry learning is effective for young children's learning, nor the required characteristics to ensure effectiveness…we need to investigate how young children actually learn—and identify the obstacles they often face—during technology enhanced inquiry learning" (p. 387). Wang et al. commend providing developmentally appropriate opportunities for technology to become integrated into early childhood classrooms and routines. The Division of Early Childhood recommends incorporating technology into the early childhood classroom in three categories: "assistive, instructional/educational, and informational" (p. 147). With the aforementioned gaps in knowledge, further exploration can contribute valuable information to the current literature and research base of incorporating technology in early childhood mathematics instruction.

Teacher shortage in the field of special education has been an issue that impacts services to students with disabilities, including those with developmental delays (COPSSE, 2004). Many early childhood special education teachers feel underprepared in their knowledge level of developmentally appropriate practices, standards, policies, and procedures of their schools and counties (Snider & Fu, 1990). According to the Trust of Early Education, every pre-kindergarten teacher credentials should include a bachelor's degree with a focus in child development (Whitebrook, 2003). These credentials enable the pre-kindergarten teacher to be more effective and improved student outcomes (Barnett, 2003).

Copley (2004) notes that many factors impact why pre-kindergarten teachers provide poor mathematics instruction such as inadequate preparation, little to no training in curriculum, and a lack of a systematic mathematics curriculum at this level. Additionally, many pre-kindergarten teachers are uncomfortable with mathematics instruction (Copley, 2004) and Clements and Sarama (2009) found limited mathematics instruction and student learning happening in the early childhood settings they observed. Specifically, Copley found that the early intervention educational instruction does not include concepts beyond counting, adding, subtracting, and identifying shapes. Even though, the Committee on Early Childhood Mathematics found that most young learners have the potential to comprehend mathematic concepts beyond the basics, this potential may not be tapped in early childhood settings because many teachers are not providing adequate learning opportunities for children (Clements & Sarama, 2009). These opportunities are important for all students, but critical for students with developmental delays. The purpose of early intervention in the field of education is to give students with special needs skills that make them ready equal to children without delays.

However, with many early intervention educational settings having limited opportunities or teachers with advanced knowledge in mathematics this gap may not be closed as it is in reading or language (Copley, 2004). Children with developmental delays, face many challenges attaining kindergarten readiness skills, and without a sound pre-kindergarten educational foundation in mathematics, they are likely to start kindergarten at least two years behind their peers (Ramey & Ramey, 2004).

Purpose of the Study

The research project attempted to investigate the utilization of technology, specifically the iPad, for mathematics instruction in early childhood education settings. Further, the research project explored the developmentally appropriate use of handheld technology for young children with disabilities for an instructional/educational use as recommended by DEC (2009).

Research Questions

1. How do students with developmental delay in an inclusive Pre-Kindergarten class use mathematical applications on the iPad?
2. How do students with developmental delay in an inclusive Pre-Kindergarten class change their engagement with mathematical applications on the iPad over time?

Research Design

A case study design is employed to address these research questions utilizing both qualitative and quantitative data to build theories and generate hypothesis for utilizing iPads in a pre-kindergarten inclusive classroom to increase pre-kindergarten mathematical concepts (Merriam, 1988). Case study research can be used to study a phenomenon systematically by conducting research to improve, inform, or understand (Yin, 2009). Case study research is often seen as the best method of research to understand practice and extend understanding within the field of education (Merriam, 1998). Additionally, the researcher was interested in insight, discovery, achievement, and interpretation as a result of the use of iPads in an early childhood classroom which were measured by interviews, questionnaires, observations, and the TEMA-3. The researcher conducted a records review based on teacher information to identify the participants with developmental delays in the inclusive pre-kindergarten classroom. Once the participants were identified, the researcher sought parent permission to administer the TEMA-3 and obtained a pre-test score. The TEMA-3 test scores allowed the researcher to identify four participants for the case study. Additionally, the pre and post results of the TEMA-3 provided quantitative data that, "may not be salient to the researcher" (Eisenhardt, 1989, p. 538). The researcher conducted a semi-structured interview with the teacher regarding her current practices regarding mathematics instruction and her attitudes toward technology, specifically the iPad. Additionally, a parent questionnaire was sent home to the parents of the participants which accessed the students prior use of technology, specifically iPads, iTouches, or iPhones. Then, the iPads were incorporated into the established pre-kindergarten class learning center activities which allowed the researcher to video record and observe the students during natural learning opportunities use the iPads with mathematics applications. After the study was conducted, informal interviews were conducted with the participants as well as the teacher to gather information on perceptions and attitudes regarding the use of iPads and mathematics applications.

Once the data were collected, all observation transcripts and interview transcripts were checked for accuracy by a research assistant and were analyzed. The teacher interview transcripts were given to the teacher for member checking. The researcher utilized ATLAS-ti software for theming analysis of the transcription notes and had a research assistant conduct inter observer agreement. Since the students were so young in the study, themes were not member checked with students, but were triangulated with parent questionnaires, field notes, record reviews, and teacher and student interviews and were reviewed by a content expert for inter observer agreement.

CHAPTER TWO: REVIEW OF LITERATURE

The researcher in this literature review examined aspects of mathematics and technology for students with developmental delays (DD) in early childhood classrooms. The chapter begins with historical accounts related to the field of early childhood and early intervention in education. The next section is devoted to a discussion of early childhood as well as a discussion of Piaget's theories related to early learning which provided a foundation for developmentally appropriate practices for all students, specifically those with developmental delays. Next, a discussion of relevant empirical evidence as it relates to early mathematics, special education and technology in early childhood classrooms as well as a thorough discussion of mobile technology. The chapter concludes with the presentation of a dearth of research in the field of mathematic and technology in early childhood special education classrooms.

Historical Perspective of Early Childhood

As early as the 1930's, researchers were testing the effects of early intervention educational services for children with disabilities. For example, Skeels and Dye in 1939 conducted a study comparing two groups of children where the experimental group of children (n = 13) were raised in an institution with care and attention and the control group of children (n = 12) lived in an orphanage and were not exposed to stimulation or training (1939). After the completion of the study, every child in the experimental group (n = 13) had IQ gains and all but one child in the control group had a loss in their IQ (Skeels & Dye, 1939). The study provided a foundation based in empirical evidence to support the positive impact of quality early intervention educational services on young children.

Similarly in the 1950's, Kirk conducted a study on the effects of preschool on children identified with a mental or social delay. The study consisted of an experimental group of children who received preschool instruction for two years and a control group who received no preschool instruction. At the conclusion of the study, the children who received preschool instruction out-performed the children who did not receive preschool instruction (Kirk, 1958).

A few years later, Maria Montessori (1964), a medical doctor and a pioneer in early childhood education, opened her House of Children (i.e. Casa dei Bambini for poor children in Rome). Using Seguin's (1870) educational strategies and materials, she tested her theory that mental deficiencies were a result of pedagogy versus a medical problem. Her philosophy was to observe children learning developmentally and then structure the teaching experiences appropriately. Montessori's philosophy of developmentally appropriate instruction, which provided the foundation for developmentally appropriate practices, was successful in educating children with learning disabilities in academic areas by using manipulatives to teach early mathematics such as number, geometry, and problem solving (1964).

At the same time in the United States, during World War II (WWII) the need for women workers increased resulting in the need for childcare, leading to the creation of the Lanham Act, which federally supported early childhood centers. This Act marked the first time the federal government provided childcare funding for students who were not poor and increased the number of early childhood centers. After WW II ended, the Lanham Act centers closed. Shortly thereafter, a climate of activism emerged. In the 1950s, the Parent Movement began across the nation. Parents of children with disabilities began to organize into groups and created support systems and societies. At that time, approximately 12% of children with disabilities received special education services in a variety of settings (Eugene, Lewit, & Baker, 1996).

Just after the Parent Movement was underway, Samuel Kirk (1958), a pioneer in the field of early childhood special education (ECSE), began an experimental preschool for young children considered mentally disabled while at the University of Illinois. He questioned whether inadequate learning environments were the origin of "mental retardation" in young children, which lead him to develop the Illinois Test of Psycholinguistic Abilities to assess the abilities and disabilities of young children. He conducted a study using a quasi-experimental research design to investigate the effects of two years of preschool on children who were considered mentally and socially delayed. One group of children received two years of preschool (experimental group) and another group of children received no preschool (control group). The experimental group outperformed the control group and the benefits of preschool were evidenced years later in a follow-up study (Kirk). Additionally, as part of Lyndon Johnson's (1964) "War on Poverty," two initiatives went into effect, Project Head Start and the Elementary and Secondary Education Act (ESEA) was passed. The original "Head Start" was an eight week education program for preschoolers, ages 4 and 5, from low-income families with a focus on health, education, social services, and parental involvement. Later, Head Start expanded to serve infants and toddlers and became a school program providing in a classroom setting.

Within legislation in 1968, early childhood was attracting attention as well, with the passing of Handicapped Children's Early Education Assistance Act (HCEEP, P.L. 90-538). The Department of Education allocated federal funds to support experimental centers known as "the first change network" and model demonstration programs for preschool children with disabilities, children who were at risk for disabilities, and their families. This Act was renamed in 1992 the Early Education Project for Children with Disabilities and ended in 1995 these specific programs no longer exists. These Acts provided the foundation for current inclusive early childhood classrooms and current Part C legislation to serve students with disabilities at an earlier age than traditional schooling.

Along with the legislation to create early childhood inclusion for students with disabilities, the ideas of free and appropriate public education (FAPE) and inclusion were emerging with the ruling of Mills v. Board of Education in District of Columbia and the Economic Opportunity Act (EOA) Amendments (1972). In Mills v. Board of Education in the District of Columbia, the judge found in favor of seven school-age children with special-needs who sought their right to FAPE, based on the students' individual needs, regardless of cost. In the same year, the EOA Amendments issued a preschool mandate that required that no less than 10% of the total number of Head Start placements be reserved for children with disabilities, which provided inclusion opportunities in public schools. Then, in 1974, definitions of the 10% were adapted to ensure that children, who met the economic requirement, and had more severe disabilities, could also be served in Head Start. Students with disabilities included in this group are: mental retardation, deafness or serious hearing impairment, serious speech or visual impairment, crippling orthopedic impairments, chronic heart disabilities or learning disabilities. As the populations of students served in EC became increasingly more diverse lawsuits, legislation, and mandates such as Head Start provided the opportunities for inclusive early childhood learning environments. The early childhood learning environments for preschool age students with developmental delays in need of early intervention in the field education and researchers have illustrated the positive outcomes for early intervention in the field of education.

Early Childhood Intervention in the Field of Education

The National Early Intervention Longitudinal Study (NEILS, 2009) documented the positive impact on students with developmental delays who receive early intervention educational services. Similarly, researchers report high-quality early intervention educational services and preschool experiences can positively impact a child's future school success, even IQ (e.g. Martin, Ramey, & Ramey, 1990; Ramey & Ramey, 1998a, 2004). Specifically, the researchers from the Carolina Abecedarian Project (ABC Study) conducted a randomly assigned and controlled longitudinal investigation of a high-quality, supportive early childhood educational programs and found that children with high needs at six months of age, in both the experimental and control groups, had IQ scores within the normal range. However, by 54 months, 100% of the children in the experimental group continued to have a normal range IQ score, while only 14% of the children in the control group maintained scores within the normal range (Martin, Ramey, & Ramey, 1990). In the control, 48% of the students were placed in special education by the age of 15 when only 12% of the students in the experimental group were, compared to the national average of special education placement of 11% (Ramey & Ramey, 2004). Ramey and Ramey concluded that an increase in a child's intellectual skills is a long-term benefit to the child, and an enhanced knowledge base resulting from high-quality early intervention in the field of education is also beneficial (1998a).

To further research the area of early intervention in academics, the Pre-Elementary Education Longitudinal Study (PEELS), funded by the U.S. Department of Education, looked at students receiving services in early childhood special education settings and their performance over time on academic assessments. The PEELS data consists of a representative sample of 3,104 children with disabilities (806 with developmental delay), ages 3-5 when the study began in 2003-04. The data for the study were collected through a variety of measures and activities in five waves over six years (Carlson, Jenkins, Bitterman, Keller, & National Center for Special Education Research, 2011). To measure knowledge, skills, and academic outcomes, an assessment was administered one-on-one to the students; the assessments from wave one through three were the same. However, since some of the students in the study were eight during wave four of the testing, a few of the assessments were no longer developmentally appropriate (Carlson et al., 2011). The Woodcock Johnson III Applied Problems subtest was administered to measure the mathematics concepts: adding, subtracting and counting. At the age of four, students with developmental delays, scored slightly lower (M = 381.88, SE = 2.97, effect size = 15.5) than students with Speech and Language Impairments (M = 396.68 SE = 2.80, effect size = 16.1) and students with Autism (M = 382.29, SE = 7.57, effect size = 15.5). The children with developmental delays, who received early childhood special education services, did make annual academic gains, as measured by the Woodcock Johnson III (Carlson et al., 2011). The empirical evidence points to positive learning outcomes for students who receive early intervention education services in inclusive early childhood classrooms. The findings from the PEELS study parallel researchers and theorists arguments for early intervention in the field of education being critical to closing the gap in knowledge and having long term positive outcomes.

Piaget's Theories Related to Early Learning

Piaget's work in 1977 closely aligns with the outcomes of the PEELS as he was often referred to as a developmental constructivist and believed that children are curious and have an unsatisfied urge that drives their learning. Additionally, he believed in response to novel ideas and experiences in the classroom, children construct new meaning and are influenced by maturation and are impacted by interactions with the environment through exploring, making discoveries, and being actively engaged (Piaget, 1977). Specifically in the area of mathematics concepts children gain understanding by experimenting within the environment, manipulating ordinary objects, and constructing their own meaning (Piaget, 1941/1952). Piaget believed there was a relationship between mathematics and mental structures in children, and as children develop the understanding of numbers they develop early mathematics concepts (1965). Based largely on Piaget's theory of constructivism, NAEYC defined the concept of developmentally appropriate practices for the early childhood classroom (NAEYC, 2011).

Theoretical Framework of Developmentally Appropriate Practices

In the mid-1980s, NAEYC, the largest professional organization that represents early childhood education in America, identified the need for developmentally appropriate practices (DAP) for enriching early childhood education, as NAEYC created a system to accredit programs (Cohen, 2008; Copple & Bredekamp, 2006). The DAP were developed from empirical data of how children develop and learn, and are a nationally recognized as best practice in early childhood instruction to establish guidelines that include electronic and digital media (NAEYC, 2011; Van Horn & Ramey, 2003). Bredekamp and Copple (2006), state DAPs are a method of teaching young children in a way that "meet children where they are…and help each child reach challenging and achievable goals (p. 3)". To provide educators a framework for early childhood education, DAPs were established and structured around twelve research-based principles:

> (1)belief that children's development-physical, social, emotional, and cognitive are closely related; (2) development occurs in sequence; (3) development rates differs from child to child; (4) early experiences have both a cumulative and delayed effect on development; (5) development proceeds in predictable directions toward greater complexity, organization, and internalization; (6) development is influenced by multiple social and cultural filters; (7) children are active learners; (8) development results from maturing and environment; (9) play is an important component to promote social, emotional and cognitive development; (10) development advances when students acquire new skills as well as when they are challenged beyond their current skills; (11) children demonstrate what they know and learn in different modalities; (12) children develop and learn best when they feel safe and secure in an environment (Bredekamp & Copple, 2006, p. 9-15).

Using these twelve principles, the NAEYC developed five child focused guidelines for a developmentally appropriate classroom and good teaching: "a) creating a caring environment of learners (b) teaching to enhance development and learning (c) constructing appropriate curriculum (d) assessing children's learning and development (e) establishing reciprocal relationships with families" (Bredekamp & Copple, 2006, p. 16-22). Aspects that can be observed in a developmentally appropriate classroom would be: multiple methods of teaching content, such as large group instruction, small group instruction, learning centers, and daily routines. Brumbaugh (2008) developed the acronym of RESPECT model for properly implementing DAPs: R for Relationships, E for Experiences, S for Space and Security, P for Play, E for Expectations, C for Caring, and T for Time. The acronym provides classroom instructors a framework to structure daily activities and learning opportunities.

The twelve principles of DAPs and child focused guidelines provide the structure for an early childhood classroom to create an inclusive learning environment for students with disabilities. In April 2009, the Division of Early Childhood (DEC) and the NAEYC issued a position paper in support of early childhood inclusion. The three features they identified in a highly qualified early childhood program are access, participation, and supports (National Association for the Education of Young Children, 2009). Both DEC and NAEYC define access using the universal design for learning (UDL) framework that provide multiple methods of instruction and learning, including incorporating technology. According to the Higher Education Act (2008), the term UDL means a scientifically valid framework for educational practice that:

> (A) provides flexibility in the ways information is presented, in the ways students respond or demonstrate knowledge and skills, and in the ways students are engaged; and (B) reduces barriers in instruction, provides appropriate accommodations, supports, and challenges, and maintains high achievement expectations for all students, including students with disabilities and students who are limited English proficient (p. 12).

The National Center on Universal Design for Learning illustrates this principle as a way to design curriculum that provides all individuals with equal opportunities to learn. Universal Design for Learning provides an opportunity for every child to be seen as an individual influenced by interactions and instruction (Darragh, 2007). Research illustrates, when the curriculum and learning are adjusted to meet the needs of all children, students gain knowledge and skills (Conn-Powers, Cross, Traub, & Hutter-Pishgahi, 2006). The Universal Design for Early Childhood Education (UDECE) supports an ecological approach to providing all children, including children with developmental disabilities, a high quality early childhood education (Rollins-Hines & Mau Runnells, 2009). The UDL is a framework to allow professionals an alternative delivery of instruction and gives students alternative ways of responding and engaging which lends itself to children with developmental delays in early childhood classrooms (Conn-Powers, Cross, Traub, & Hutter-Pishgahi, 2006).

Developmental Delay

According to the Centers for Disease Control and Prevention (2006), developmental disabilities affect approximately 17% of children under the age of 18 in the United States. A developmental disability or delay can originate from either environmental or biological factors (AAIDD, 2008). The IDEA amendments (2004) defined developmentally delayed as

> (B) CHILD AGED 3 THROUGH 9.—The term 'child with a disability' for a child aged 3 through 9 (or any subset of that age range, including ages 3 through 5), may, at the discretion of the State and the local educational agency, include a child—''(i) experiencing developmental delays, as defined by the State and as measured by appropriate diagnostic instruments and procedures, in 1 or more of the following areas: physical development; cognitive development; communication development; social or emotional development; or adaptive development; and ''(ii) who, by reason thereof, needs special education and related services (118 STAT. 2652)

Simeonsson (1991) defines developmental delay as a result of biological factors, environmental factors, or a combination of the two factors. Biological factors are defined as intrinsic characteristics of the child and include: prematurity, low birth weight, and complications during delivery or gestation. Whereas environmental contributions to developmental delay are defined as extrinsic and include: low socioeconomic status and lack of child-rearing skills (Simeonsson, 1991). The DEC (2009) stated that the early identification of students with DD allows a child who may have gone without early intervention access to educational services, avoiding the premature application of a traditional disability label. Access to early intervention educational services provides an opportunity for the child to respond to intervention and be dismissed from the eligibility category without a long-term inaccurate educational label of another disability (DEC, 2005). The earlier a child with a developmental delay receives intervention and education, the more likely typical development will be supported and learning difficulties will not emerge later (Coleman, Buysse, & Neitzel, 2006). In inclusive early childhood classrooms that provided appropriate language and cognitive experiences, children with developmental delays showed intellectual gains (Ramey & Ramey, 2004). Therefore, providing support in the form of early intervention educational services is critical for students with disabilities.

Early Childhood Special Education

Implementing UDL in early childhood classrooms can assist in the process of developing and maintaining successful inclusive environments for students with developmental delays by allowing students multiple modes to represent, engage, and express information (Conn-Powers, Cross, Traub, & Hutter-Pishgahi, 2006; Judge, Floyd, & Jeffs, 2008). Approximately 90% of students in early intervention in the field of education and early childhood special education are classified with two primary disabilities, developmental delay and communication disorder (Nave, Nishioka, & Burke, 2009). According to Nave, Nishioka, and Burke (2009), the students in early childhood special education classrooms have higher percentages of children with developmental delays functioning below age expected skill levels on all foundation areas, especially in phonological awareness and numbers and operations. The National Early Intervention Longitudinal Study documents the positive impact on students with special needs who receive early intervention in the field of education. The researchers' findings indicate an increase in students' communication, physical, social and cognitive abilities when entering Kindergarten after participating in early intervention in education (NEILS, 2009). According to the DEC (2007), early intervention in the field of education promotes children's learning and positively influences their outcomes. Wolery (2005) reports that children should have improved skills and developmental abilities as a result of early intervention education and early childhood special education. During a briefing, Hebbeler (2009), a developmental psychologist and a researcher with SRI International in California stated, “We know that intervening early changes their [students’ with disabilities] life trajectory” (National Early Intervention Longitudinal Study, p. 1).

Specifically Guralnick, Neville, Hammond, and Connor (2008) investigated the relationship between a child’s specific characteristics, within the group of pre-kindergarten and kindergarten age children with mild developmental delays, and their placement changes from a full-inclusion class as they transition through third grade. In a quasi-experimental study, the participant group consisted of 90 preschool and kindergarten children with mild developmental delays. The participants were recruited through 11 local school districts in a large metropolitan community in Washington State and studied for three years. Full inclusion was defined as “settings in which the child with the IEP spent the entire school day in a class in which most (more than 50%) of the children required no special educational services” (p. 239). The first 90 participants who met the criteria were included in the study. During the first two years, several assessments were administered to attain the children’s current levels in the areas of: cognition, language, adaptive behavior, behavior problems, and social competence. The Hollingshead Four-Factor Index of Social Status was used to measure the family status. At the end of year one, 78 children remained in full-inclusion settings, 5 students were being served in a specialized class, 4 students were in a partially specialized class, and 3 students were in partial inclusion. At the end of the second year, from the 78 students, 25 of them remained fully included, 33 of them were partially included, and 6 of them were moved into partially secluded classroom placements.

The authors found that one precise reason did not exist for the placement changes of any of the students. The findings were consistent with the hypothesis that starting students out early in inclusive classrooms creates a momentum for them to remain in inclusive settings (Guralnick et al., 2008). Additionally, a goal of early intervention educational services such as pre kindergarten special education classes is to reduce the duration and severity of the developmental delays (Simeonsson, 1991).

Early Childhood Mathematics Evidence Based Practices

A form of intervention required by IDEA is the use of Evidence Based Practices (EBP). An EBP can be used in any content or social area of delay. For students with DD addressing cognitive mathematics experiences using EBP as early as possible is critical (Odom & Wolery, 2003). According to the What Works Clearinghouse, early childhood mathematics EBP include: Big Math for Little Kids; Building Blocks for Math, Journeys into Early Literacy Math; Number Worlds; Pre-K Mathematics. Furthermore, some EBP curriculums such as High/Scope or Creative Curriculum, incorporate mathematics, although the focus is not restricted to just mathematics. This range of curriculum could be considered for students with DD, but further exploration for this population is needed.

Students with DD have been found to respond positively to explicit instruction (Phillips, Clancy-Menchetti, & Lonigan, 2008). Building Blocks Mathematics employs explicit mathematics instruction and the authors recommend that it should be considered for this population (Clements & Sarama, 2008; Sarama & Clements, 2004). The curriculum is structured around research based learning trajectories and is designed to include whole group and small group activities, games, free-choice learning centers, and 60 computer games appropriate for early childhood. The mathematics concepts within the curriculum build on everyday learning activities such as art, music, stories, puzzles and building blocks that occur in early childhood classrooms. Clements and Sarama (2008b), aim to "mathematize" the everyday early childhood classroom. The curriculum is based on students developmentally attaining the mathematics trajectories. Empirical evidence from two randomized studies demonstrated statistically significant findings of the effectiveness of the Building Blocks program (Clements & Sarama, 2006, 2007) for students in early childhood classrooms, to improve mathematics achievement utilizing technology.

Another EBP to consider for students with DD in an early childhood classroom is the Number Worlds curriculum (Griffin, 2004), based on five principles incorporating activities, play, and games in mathematics. The principles are as follows: the first Number Worlds is to build on the current content knowledge of the individual student, the second is to follow developmental progression in selecting new content knowledge to be taught, the third is to allow students to acquire conceptual knowledge and computational fluency simultaneously, the fourth is to provide opportunity for hands-on learning and problem solving, and the fifth is to expose students to ways other societies talk about and represent numbers (Griffin, 2004). Both the Number Worlds and Building Blocks are comprehensive mathematics curriculums that incorporate games that have an evidence-base for students in early childhood classrooms, however, neither one of the curriculums have been researched with students with DD in early childhood classrooms.

Early Childhood Mathematics

Another area students with DD in early childhood classroom need is hands on learning and play. Ginsburg, Inoue, and Seo (1999) investigated hands on learning and play with 4- and 5- year olds (N = 90) in early childhood classrooms to observe free play and record the students' spontaneous mathematical interests and questions. The students were video-taped a total of 90 times for 15 minute intervals during free play, to analyze the data. Ginsburg et al. created the following mathematical content codes: classification, magnitude, enumeration, dynamics, pattern and shape, and spatial relations. The results of the study indicated that during free play, 88% (79 out of 90) of the students engaged in at least one mathematical activity and the students on average engaged in mathematical activities 43% of the time during free play (Ginsburg et al., 1999) indicating that preschool age students engage in mathematics more frequently than realized. Ginsburg and his colleagues did not differentiate in their study students with developmental delays in mathematics. Additional researchers have concluded that mathematics in an early childhood classroom should not be limited to free time alone, rather students should engage in challenging mathematics activities (Seo & Ginsburg, 2004). Early childhood classrooms provide developmentally appropriate learning opportunities throughout the daily routine to provide mathematical learning through play and exploration.

Further investigating the concept of play and mathematics, Young-Loveridge (2004) conducted a study looking at the effects of number books and games based program on the number skills of five year olds. The participants in the study (N = 106) scored in the lower two thirds on a researcher created numeracy pre-test. The students in the treatment group (n = 23) participated in the program, while the remaining students (n = 83) continued to only receive the existing curriculum. In pairs, the students attended the intervention sessions, which consisted of number games, stories, and rhymes for thirty minutes for seven weeks. The initial effect of the program was large (effect size 1.99). Young-Loveridge concluded that when students utilize authentic materials actively through play, such as games and books, the students' mathematical concepts improve. The results of this study support the use of play and hand on learning (Ginsburg et al., 1999) for students in early childhood classrooms, but once again specific information related to students with developmental delays is missing from the research.

Early Childhood Special Education and Mathematics

Only one study focused on students with DD in early childhood classroom. In an investigation of strategies utilized in early childhood classrooms to teach mathematics McKenzie, Marchand-Martella, Moore, and Martella, (2004) described the use of *Connecting Math Concepts Level K (CMC-K)* to teach preschool students. Eleven of the participants were typical developing and five were students labeled with a DD (N=16). The study took place in an integrated university preschool where the students took part in the CMC-K curriculum for thirty lessons that included (a) rote counting, (b) numeral recognition, (c) writing numerals, (d) counting objects, (e) numeral association, (f) concepts of more and less, and (g) what number comes next. All the lessons were administered using a Direct Instruction model in small group for approximately 10-20 minutes. First the instructor demonstrated the skill, then the instructor and student practiced the skill, and then the student performed the task independently. The students were all given a pre- and post-test using the Battelle Developmental Inventory (BDI) as well as a curriculum-based placement test. The results of the study revealed the students who were considered typical developing (N = 11) had a gain score of 12.10 with an effect size of .61 in the cognitive domain, which is the overall score. Whereas, the students with developmental delays (N = 5) had gain scores of 14.60 with an effect size of .54 on the overall score. The results of the curriculum-based test revealed the mean pre-test score of the typical developing group was 4.55 and the mean posttest score was 7.90. While the pre-test score of the students with DD was 3.80 and the post-test score were 7.20. The results of this study should be interpreted with caution since this was considered a pre-experimental design without a control group, however the gains in test scores indicate the potential benefit of direct mathematics instruction for early childhood classrooms (McKenzie, Marchand-Martella, Moore, & Martella, 2004).

Technology in Early Childhood

A tool that is often used for students with DD at the upper grade levels is technology. However, for students with DD in early childhood limited research exists. Technology is a tool that allows students the ability to assist students to access content learning and the learning environment in the early childhood classroom (Clements, 1999; Floyd, Canter, Jeffs, & Judge, 2008; Sarama & Clements, 2004; Stremel, 2005). Children ages of 3 and 4, are developmentally ready to explore technology and need time to experiment (Haugland, 2000). However, in depth research on how to use the technology is limited.

In a draft position statement, NAEYC and the Fred Rogers Center stated, "technology and interactive media are learning tools that, when used in intentional and developmentally appropriate ways and in conjunction with other traditional tools and materials, can support the development and learning of young children" (2011, p. 1). In an early childhood classroom, the technology should not be an isolated activity and should be incorporated into the early childhood learning environment in a meaningful way, such as learning centers, and the content should be developmentally appropriate (Finegan & Austin, 2002). Specifically, a child, including a child with a DD should not feel forced to interact with the technology, instead, the individual student should make the choice regarding what learning centers to visit, what learning resource they utilize (i.e. technology) and the length of time the student engages in the activity (Finegan & Austin, 2002).

Approximately, 83% of children ages six months to six years use some form of screen media in a typical day, of that percentage 16% use the computer and 11% play on either a console or handheld video game (Rideout, Foehr, & Roberts, 2010; Rideout, Hamel, & Kaiser Family Foundation, 2006). Kids are attracted to digital media and enjoy using mobile technologies and playing video games (Gee, 2008; Gutnick, Robb, Takeuchi, & Kotler, 2010) that can be used to enhance their attention span as well as their learning (Gimbert & Cristol, 2004). The NAEYC highlights that technology extends learning in early childhood settings in the same way as standard classroom materials such as books, manipulatives, blocks, or toys (2011). A mobile technology, such as the iPad, has significant potential in improving individual's learning outcomes through the use of applications (Murphy, 2011) that are developmentally appropriate as well as aligned to the curriculum goals and standards (Finegan & Austin, 2002). The use of these tools in early childhood is limited for students with DD more research incorporating mobile technologies into classrooms provide structured environments for personalized learning as well as increase the student's knowledge of technologies and increase digital literacy (Gee, 2008). The way a child uses the technology is dependent by the software or content of the technology (Clements, 1999). As a result of the technology currently available, a potential reform in mathematics education for young children (Saracho & Spodek, 2009) may be needed, including an investigation of mobile technology. The NAEYC states that "technology can enhance children's cognitive and social abilities" (p. 4) when integrated into the environment, curriculum, and daily routines of the classroom in a developmentally appropriate manner. Yet, how this integration impacts students with DD in early childhood classrooms is unknown.

M-Learning

There are many forms of technology that could be utilized in a developmentally appropriate manner in early childhood classrooms for students with DD, one form of technology integration for early childhood classrooms is mobile learning devices, such as iPads. According to Johnson, Adams, and Haywood (2011), educators should be on the look out for are mobile learning devices, annually, more than 1.2 billion are produced. Mobile learning or m-learning, can be defined as the use of wireless, portable or moveable technology that runs mobile applications used for educational interactions (Educause, 2010; Naismith, Lonsdale, Vavoula, & Sharples, 2004; Park, 2011). Using mobile technologies in the classroom provides an opportunity to harness the existing engagement and interest of children, including those with DD, in the technology and assess the benefits to learning (Sharples, 2003; Shuler, 2009a). Due to the relatively low cost of m-learning devices, districts that serve economically disadvantaged communities can more easily access the technology to provide digital equity (Melhuish &

Falloon, 2010; Shuler, 2009a). However, m-learning is beginning to be utilized in studies and institution-wide implementation, currently, little empirical evidence exists in the impact of m-learning in early childhood classrooms, although, m-learning is being utilized in a variety of educational settings from kindergarten to post secondary to explore the efficacy of utilizing mobile technology to support learning (Naismith et al., 2004). Naismith et al. (2004) conducted a literature review of mobile technologies and learning and identified six themes to categorize the current utilization of mobile technologies in education: (a) behaviorist, providing reinforcement that is associated with a task or problem followed by the learner providing a solution; (b) constructivist, students constructing new ideas and concepts based on current knowledge, often times in this paradigm; (c) situated, activities that are authentic; (d) collaborative, activities that require interaction; (e) informal and lifelong, activities that are outside the learning environment; and (f) learning and teaching support, resources for learning.

iPads and Applications

An explosion of devices that could be explored in early childhood classrooms, but an appropriate device for students with developmental delays are iPads and applications. iPads and applications are specific platforms for m-learning which are receiving increased research attention due to their adoption by families and young children. Purcell, Entner, and Henderson (2010) defined applications as, "end-user software applications that are designed for cell phone operating system and which extend the phone's capabilities by enabling users to perform particular tasks" (p. 2). Chiong and Shuler (2010) investigated the use of Apple's iPhone and iPod Touch devices to support learning in a usability study and surveyed 114 children in early childhood, ages 4 to 7 and discovered two thirds of the participants had used an iPhone before with 60% of them reporting they played games on the iPhone a few times per week and ranked the iPhone as the favored mobile technology, over the Nintendo DS. Additionally, Gutnick, Robb, Takeuchi, and Kotler (2010) found that two thirds of children have an iPod or MP3 player. The Usability Study also looked at how children used the technology. Approximately 53% of the early childhood children in the study did not require an adult to assist them, while 64% of the children reported it was easy or very easy to use. The difficulties young children experienced with operating the iPhone were mostly: using their fingers to swipe across the screen, exiting the application, and holding the icon too long (Chiong & Shuler, 2010). However, despite the observed and reported difficulties with utilizing the iPhone, the young children did not give up and adapted quickly (Chiong & Shuler, 2010). The iPad was designed with an interface to promote the intuitive use by young users (Melhuish & Falloon, 2010). Nevertheless, the use by students with developmental delays has not been explored.

One tool that should be further explored in early childhood with students with DD is the iPad. The iPad, a mobile tablet, is a handheld, customized mobile computer with an abundance of software tools (Johnson et al., 2011; Murphy, 2011; Shuler, 2009b). The iPad accounts for nearly 99.8 % of all tablets used, with nearly 20 million sold in the United States (Etherington, 2011; Waters, 2010). The size of this mobile technology allows them to fit naturally into various learning environments (Chiong & Shuler, 2009, 2010). As a mobile technology iPads can be embedded into the classroom environment, and the content can be customized to meet the individual learning needs of all students, including those with DD (Johnson et al., 2011; Klopfer, 2002; Naismith, 2004; Shuler, 2009a). Johnson et al. (2011) defined the use of a mobile technology with different types of content, including games, applications, and videos as "Personal learning environments" (PLE; p. 8). A PLE allows the student to have ownership in his or her learning while the teacher sets diverse and individualized learning goals as well as individual assessment (Gee, 2008; Melhuish & Falloon, 2010; Murphy, 2011; Shuler, 2009a). Research illustrates when the curriculum and learning are adjusted to meet the needs of all children, students gain knowledge and skills (Conn-Powers, Cross, Traub, & Hutter-Pishgahi, 2006). The potential for PLE for students with DD is an essential next step for our field.

The use of iPad applications, are a specific example of a behaviorist m-learning activity utilizing a PLE (Johnson et al., 2011; Naismith, 2004). Since we know hands on learning is powerful in mathematics and important for students with DD the touchscreen of the iPad could be a potential EBP (Shuler, 2009a). Additionally the iPhone and iPod touch include desirable features such as their size, weight, ability for audio, and the ability to present text and images (Melhuish & Falloon, 2010). However, the iPad embodies all the previously indicated features as well as increased power and the large screen size (Melhuish & Falloon, 2010) which may make the devices more desirable to young children with DD. The content for an iPad is delivered in the form of an application (NPD Group, 2010).

Utilizing iPad applications allows a teacher to track student learning while giving the student feedback (Gee, 2008). There are hundreds of educational applications available in the iTunes application store and Schuler (2009) analyzed, the top 100 education applications sold and the results indicated that 35% of the applications targeted preschool aged children, 12% of the applications targeted elementary aged children and 4% targeted middle school students. Some of the developers of education applications include Nickelodeon, PBS Kids Sprout and

Disney. These companies have reported the relatively low cost of developing applications for iPhones, iTouches, and iPads make the market desirable (Rusak, 2009). In order for applications to be utilized as a part of a child's personal learning environment, the content of the application should be pedagogically sound and foster interaction (Melhuish & Falloon, 2010) these features can be individualized to meet the needs for students with DD.

Mathematics/Early Childhood/Technology

Although a thorough search of the literature was conducted to identify both conceptual and empirical articles related to Mathematics, Early Childhood, Special Education, and Technology to develop the rational for this study. The empirical studies were included in the research synthesis and the conceptual articles were used to provide background information. Articles were identified by conducting searches through several online databases such as: ERIC, PsycINFO, and Education Full Text. The three criteria used to determine the inclusion of studies were: (1) Age of subjects. The study included children ages 3-5 years. The preferred grade for inclusion in the synthesis was preschool; (2) Content. The study had to include grade or developmentally appropriate mathematics content; and (3) Intervention. The study included an intervention or some type of treatment that focused on student outcomes. The following keywords were used during these searches: numeracy OR numbers OR "number concepts" OR mathematics; "early childhood" OR "young children" OR preschool; "developmental delays" OR "developmental disabilities" OR "special education" and; technology OR "mobile technology" OR "m-learning" OR "m learning." Which yielded zero articles in all the databases. Therefore the search was modified twice, once to remove: "developmental delays" OR "developmental disabilities" which yielded 24 articles with two empirical studies in ERIC (e.g. Clements & Sarama, 2003, 2007) and six articles with one empirical study in PsycINFO (Manches, O'Malley, & Benford, 2010). The second search removed: technology OR "mobile technology" OR "m-learning" OR "m learning" which yielded 11 studies with one empirical study (e.g. McKenzie, Marchand-Martella, Moore, & Martella, 2004), in PscyhInfo yielded 12 articles with zero empirical studies.

Although there was not a plethora of research articles that met the criteria of this research study, there were a few articles. Several researchers have investigated the utilization of technology for mathematics instruction in early childhood settings. In a large group design study, Clements and Sarama (2008b) compared the Building Blocks preschool mathematics curriculum to a control condition in a randomized trial. The study included 276 students and 35 teachers within a variety of school settings. The control classes received "business as usual" instruction while the treatment group utilized the Building Blocks preschool mathematics curriculum. After 26 weeks, children in the treatment group scored significantly higher than the controls in their overall Early Math Assessment (Clements & Sarama, 2008b).

Following this study, Klein, Starkey, Clements, Sarama, and Iyer (2008) evaluated the national Pre-K Mathematics program as a part of the national Preschool Curriculum Evaluation Research program utilizing a randomized field trial. The curriculum was implemented in two public preschools serving low-income families in California and New York. A total of forty preschool programs in California and New York participated (N = 278 students) in the study. The teachers in the control group did not alter the current curriculum, which included: the Creative Curriculum, High Scope, Montessori, and locally developed materials. The teachers in the intervention group implemented components of the Pre-K Mathematics and DLM Express mathematics software according to a curriculum plan. Even though the students in both the control and treatment groups had similar pretest scores, the students in the Pre-K Mathematics intervention group had higher posttest scores measured by the researcher developed measure, Child Math Assessment (CMA; Klein et al., 2008).

Similarly, Sarama, Clements, Starkey, Klein, and Wakeley (2008) randomly selected 25 classrooms (N = 209) in Head Start and state preschool programs in California and New York. Utilizing a professional development model for the teachers to implement the Building Blocks curriculum for the experimental group (n = 13 classrooms) and the existing Pre-K Mathematics Curriculum for the control group (n = 12). As measured by the REMA, the experimental group made significant gains compared to the control group (effect size = .62). The results of the study again supported positive outcome of utilizing a technology enhanced mathematics program in an early childhood classroom.

Additionally, in a scale up study, Clements, Sarama, Spitler, Lange, and Wolfe (2011) examined the generalizability of the Building Blocks intervention. A total of 1, 375 preschool students in 42 schools in the Northeast were randomly selected and randomly assigned to three treatment groups, Building Blocks and the control group continues business as usual. The teachers implemented the intervention, Building Blocks software, with adequate fidelity (mean 0.77 in fall and 0.86 in the spring) and the results revealed the preschool students in the treatment group (n = 927) outperformed the students in the control group (n =378) on the total mathematics test score (effect size 0.72) as measured by the Research-based Elementary Math Assessment (REMA).

With regards to solving math problems, Manches, O'Malley, and Benford (2010) conducted an exploration evaluation of 12 students (using manipulative (blocks) versus the use of pencil versus paper and pencil only, without manipulatives. Students answered significantly more problems correctly with the use manipulatives than without them (Manches, O'Malley, & Benford, 2010). The researchers went on to evaluate the use virtual manipulatives representing block manipulatives versus physically using manupulatives with 65 students in one school (students ranged in age from 4 years 9 months to 8 years 8 months). There was no statistically significant difference between the groups, even when the data were disaggregated by age group, when measured by rate of number correct. One observation made by the researchers was the speed students used the mouse to interface with the virtual manipulatives might have impacted their performance (Manches, O'Malley, & Benford, 2010). The findings from this study support the use of technology as a tool, to increase engagement and promote 21st century learning skills, although the findings were not statistically significant.

Conclusion

With such limited research, Kazdin (2008) recommends researchers focus on simply improving outcomes for children by focusing on a few important questions such as: What are the desired outcomes for a child in ECSE; What practices have been effective in accomplishing those outcomes; What can be done to assist practitioners and parents to use the EBP with fidelity? In order to improve outcomes for students with DD in EC, students need to receive services in high quality early childhood settings (Campbell & Ramey, 1994; Ramey & Ramey, 1998a, 1998b, 2004; Rollins-Hines & Mau Runnells, 2009). However, the field lacks research studies that address the main constructs: mathematics, technology, early childhood, and students with DD warranting further investigation in this area. Therefore, the purpose of this study was to explore the developmentally appropriate use iPad applications in mathematics for educational use for children with disabilities in a voluntary pre-kindergarten classroom.

CHAPTER THREE: METHODS

Purpose of the Study

In this study the researcher explored the developmentally appropriate use of mathematics iPad applications for children with disabilities in a voluntary pre-kindergarten classroom using a qualitative multiple case study research design. The chapter opens with a statement of the research question guiding the study followed by a description and characteristics of case study research design. Next, the instruments utilized in the study are presented: (a) records review, (b) Test of Early Mathematics Ability-3, (c) parent questionnaire, (d) field notes, (e) observation protocol, (d) interviews, (e) iPads, and (f) Atlas.ti software. Then, a discussion of the methodology is provided that includes: (a) the role of the researcher, (b) setting, (c) participants, (d) research timeline, (e) data collection procedures, (f) internal validity, (g) reliability, and (h) data analysis. Finally, the chapter concludes with a discussion of the potential limitations of the study.

Research Questions

1. How do students with developmental delay in an inclusive Pre-Kindergarten class use mathematical applications on the iPad?
2. How do students with developmental delay in an inclusive Pre-Kindergarten class change their engagement with mathematical applications on the iPad over time?

Research Design

A case study design was employed utilizing qualitative data to build theories and generate hypotheses on utilizing iPads in the bounded system of a pre-kindergarten inclusive classroom to increase pre-kindergarten mathematical concepts (Gast, 2010; Merriam, 1988; Yin, 2009). A bounded system is defined as a circumstance that is bound by the setting, time, and each individual case that is being studied (Creswell, 2007). Further, case study research can be used to study a phenomenon systematically by conducting research to improve, inform, or understand (Yin, 2009). Case study research is predominately used in educational research (Gast, 2010) and seen as the best method of research to understand practice and extend understanding within the field of education (Merriam, 1998) specifically to answer the "how" and "why" question in research (Yin, 2009). Additionally, the researcher was interested in insight, discovery, achievement, and interpretation as a result of the use of iPads in an early childhood classroom, which included students with developmental delays. The findings from interviews, questionnaires, observations, and the TEMA-3 were analyzed.

Rationale

"Qualitative research is not done for the purposes of generalizability but rather to produce evidence based on the exploration of specific contexts and particular individuals" (Brantlinger, Jimenez, Klinger, Pugach, & Richardson, 2005, p.203). The purpose of this study was an exploratory analysis of the engagement of four case studies conducted with prekindergarten students who are labeled developmentally delayed, while using the mathematics applications on an iPad over time and to determine if the use of the iPads has an impact on mathematics achievement. Yin (2009) defines case study methodology as ". . . an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident" (p. 13). Case studies are emergent studies that occur in natural settings using multiple methods of data collection, appropriate to the methods of this study. Additionally, case study methodology is an appropriate design for this study, which sought to develop an "in-depth understanding of the situation and meaning for those involved" (Merriam, 1998, p. 19). One strength of case study methodology is that it relies on data and descriptions from multiple sources followed by member checking to ensure the interpretations are accurate (Merriam, 1998; Yin, 2009).

Method

Role of the Researcher

I am a mother, a wife, a teacher, an immigrant; I come from a multicultural upbringing from a low, middle class family. I immigrated to Orlando, Florida in 1980 with my father, mother and older sister. My father is Turkish, raised a Muslim while my mother is Austrian, raised Roman Catholic. My parents tell us they came to the United States of America to "invent themselves." Education was highly valued in my household as a child. I attended college and received a Bachelor's in Special Education with the coursework to qualify for certification in elementary education; I was highly qualified before it was mandated. Seeking answers, I returned to the university two years later to earn my Master's in Varying Exceptionalities. Currently, I am a mother to two young girls, a six year old and a four year old. Twenty-five short months ago, I switched roles from being a full time stay at home mother to becoming a full time Ph.D. student. I married my college sweetheart and have been happily married for 12 years.

My degree in special education led me through the “traditional” certification methods to becoming a teacher. I sought out additional coursework (thus becoming certified in Elementary Education as well) to broaden my studies. I graduated with honors from the University of South Florida. My first teaching experience made me quickly realize how little I knew and I had remaining questions, even after four years of teacher preparation in college. Since I graduated from a teacher preparation honors program, I did not have to complete the beginning teacher “notebook” nor did I qualify for a mentor teacher. It was very difficult to ask people to mentor me when they were not receiving compensation, and I worked at a high needs Title I elementary school. So, I felt like I should return to the university to get a master’s degree to answer some of my own questions. I earned my master’s in a degree program that was structured for working teachers and was built around action research projects to implement within the classroom during the 18 months required to finish my degree.

At my elementary school, I became a lead teacher after my 3rd year teaching. I was the department chairperson as well. I had interns in my classrooms. I conducted many classroom observations on students and teachers as a part of my role as the department chairperson. When I moved to Seminole County Public Schools, I was a staffing resource specialist and had the opportunity to work with and mentor many special education teachers within my designated schools. I have 9 years of teaching experiences in a variety of settings in two very different school districts. I have worked in and observed teachers in PK-12 grade settings. During my doctoral program, my focus has been on early intervention with extensive work in a new inclusive partnership school that began during the start of my program and continues to evolve related to using EBP in early childhood.

Setting

The case study research took place in one inclusive voluntary pre-kindergarten classroom in a large urban school district in Southeastern United States. The school has a commitment to integrating technology, with large interactive whiteboards in each classroom as well as one laptop. A requirement for the study is that the voluntary pre-kindergarten classroom teacher was a highly qualified special education teacher. The voluntary pre-kindergarten classroom had 14 students, 4 females and 10 males. Three female adults, one teacher and two assistants, were assigned to the classroom. However, there frequently was a third assistant that worked in the classroom as well. The inclusive voluntary pre-kindergarten teacher was a highly qualified special education teacher. Throughout the day, occupational, physical, speech and language therapists, worked in the classroom with a child or small groups. Sometimes the therapists removed a student to work in the therapy room on the second floor of the school building. The class schedule (see Appendix A) was followed daily with as much consistency as possible. Every other Wednesday morning the students participated in Arts Integration with an Arts Integration coach. Within the established voluntary pre-kindergarten classroom developmentally appropriate centers were in place, including a mathematics center. During the established center time, from 9 to 10 am students had the opportunity to choose centers to explore. Throughout the week, students were encouraged to go to all the centers, versus only choosing the same center everyday. The focus of the research study was on the mathematics center, which occurred with students removing manipulatives from the mathematics shelves and sitting down at the designated table. Although each classroom in the school was equipped with 360 degree ceiling mounted cameras, unfortunately, the camera in the classroom observed did not function. The researcher set up a camera on the cubbies for the first two weeks; however the quality of the video was mediocre. Therefore, the video recorder was changed to a flip cam and the location of the camera was moved to the top of the desk at the writing center to capture a different angle.

Participants

A purposive sample from the voluntary prekindergarten classroom within the school was utilized (see Table 1). The researcher focused observations on the student(s) with the labels of DD with a preferred sample size of three to four students. Criteria for inclusion in the study was: (a) confirmation of a developmental delay from environmental factors and (b) full time voluntary pre-kindergarten enrollment in an inclusive classroom. To find the participants that meet the criteria, first the researcher inquired with a school administrator to identify a highly qualified teacher in an inclusive voluntary pre-kindergarten classroom. Next, the highly qualified teacher was asked to recommend five participants that had Individual Education Programs for an identified developmental delay. Finally, a records review was conducted on the recommended children to confirm they met the inclusion criteria. However, based on the criteria of having the label of developmental delay from environmental factors, one suggested participant was excluded because he had an existing diagnosis of Pervasive Developmental Delay. All the students from the inclusive pre-kindergarten class were divided into groups for center rotations (see Table 2).

Table 1 Participant Profile

	Participant 1	Participant 2	Participant 3	Participant 4
Birthdate	11/3/06	11/30/06	4/20/07	1/12/07
Gender	Male	Male	Female	Male
Ethnicity	Hispanic	Asian/Hispanic	Caucasian	Hispanic
Disability	DD; Sp/L	DD; Sp/L	DD; Sp/L	DD; Sp/L; OT

Participant One. The first participant, who will be referred to as Participant One (see Table 2), is a Hispanic male. At the start of the study, his chronological age was 5 years 3 months. According to his individual education program, his educational diagnosis was developmental delay and speech/language sp/l for speech. According to his social history, his mother indicated he resided with his mother because there was an injunction against his father. His mother reported that at birth his umbilical cord was wrapped around his neck two times and he required oxygen. He had respiratory distress, "chest retractions" at 3 months old, at which point he was hospitalized for one week. At the age of three, he required surgery for a dog bite. Additionally, his mother reported he has asthma and she suspects that he has ADHD because she feels he is hyper and impulsive. He has received behavioral therapy in the past. The Batelle Inventory 2 was administered when he was four at which time his score in the Cognitive domain was 62.

Participant two. The second participant, who will be referred to as Participant Two (see Table 2), is an Asian/Hispanic male. At the start of the study, his chronological age was 5 years 2 months. According to his individual education program his educational diagnosis is developmental delay. In his social history, his mother reported a healthy pregnancy that resulted in a cesarean at 38 weeks gestation. Participant Two has had one febrile seizure last year (1/26/10). According to the Batelle Inventory 2 his score in the Cognitive domain was an 84.

Participant Three. The third participant, who will be referred to as Participant Three (see Table 2), was a Caucasian female. At the start of the study, her chronological age was 4 years 10 months. According to her individual education program her educational diagnosis is developmental delay and sp/l for language. Her social history indicates she was born prematurely in Russia and weighed 2 lbs. 8 oz at birth at 30 weeks gestation. She required oxygen at birth and was in the NICU for 3 months. She has had an eye surgery for strabismus and currently wears glasses. She has hypotonia and did not walk until 28 months. According to the Batelle Inventory 2 her score in the Cognitive domain was a 77.

Participant Four. The fourth participant, who will be referred to as Participant Four (see Table 2), was a Hispanic male. At the start of the study, his chronological age was 5 years 0 months. According to his individual education program his educational diagnoses are: speech and language (sp/l) impaired for language, occupationally therapy, and developmental delay for fine motor. According to his social history, his mother reported a healthy pregnancy, delivery without complications and attaining his developmental milestones as follows: (1) crawling at 6 months, (2) grabbing toys at 4 months, (3) holding up his head at 3 months, (4) rolling over at 2 months, and (5) walking at 12 months. The social history also indicated ongoing health issues of asthmas, chronic ear infections, ear tubes, and allergies to nuts, bugs, and seasonal allergies which he currently takes medication for. Participant Four's strengths were described as affectionate, easy to engage, persistent, and playful. Participant Four was the only participant with a mathematics goal on his individual education plan that stated, "He knows how to rote count to 29, he can identify numbers 1-10, and he counts objects to15." According to the Batelle Inventory 2 his score in the Cognitive domain was an 80.

Table 2 Groups for center rotation

Group 1	Group 2	Group 3	Group 4
PARTICIPANT 1	**PARTICIPANT 2**	**PARTICIPANT 3**	**PARTICIPANT 4**
G1S2	G2S2	G3S2	G4S2
G1S3	G2S3	G3S3	G4S3
G1S4	G2S4	G3S4	G4S4

Note. G=Group, S=Student

Teacher. The teacher of the voluntary prekindergarten classroom is a twenty-five year old Caucasian female. The 2011-2012 school year was her first year teaching pre-kindergarten at her current school. Prior to having her own classroom, she was a Lead Teacher Assistant for pre-kindergarten classroom at the same school. She is considered a highly qualified pre-kindergarten special education teacher although she obtained a bachelor's degree in elementary education K-6 along with the ESOL endorsement in 2009. She recently became certified in ESE K-12 and Pre-K through third grade by taking the additional certification exams.

Research Timeline

The overall timeline of the study is provided. First, a permission letter was received from an administrator at the school where the research was conducted and then the Institutional Review Board (IRB) by the University of Central Florida was approved. The researcher visited the school and met with the school campus administrators to identify a highly qualified early childhood pre-kindergarten teacher. When the research study began, the elementary grades administrator was on maternity leave, and there was an acting administrator as well as the early childhood administrator, who identified the participating teacher. Then the researcher scheduled an appointment with the teacher, for the next day to gather the names of the participants recommended by the teacher for the study. The researcher conducted a records review on the five students recommended, as stated earlier only four of the recommended students met the criteria to participate in the study.

Then, the researcher prepared two copies of the permission forms for the parents to review (see Appendix B). The researcher met three of the four parents in the classroom during dismissal to introduce herself and provide a brief overview of the research study. She then presented the parents with two copies of the parent permission letter for them to review at home. The researcher called the fourth participant's parents and left a message to briefly explain the research project and notified the parents of the two parent permission forms that were sent home. The classroom teacher assisted the researcher in attaining all the completed parent permission forms. Then, the researcher sent home a parent letter and questionnaire to the four participants (see Appendix C). To prepare for the study, a recorded interview was conducted with the teacher on January 23, 2012 to gather information about the classroom routines, characteristics of her students, and her background in teaching and mathematics.

Additionally, the researcher came to the classroom prior to data collection to watch the center time routine, assess the participants using the TEMA-3, and to desensitize the students to the researcher. Throughout the data collection, when the students attempted to engage the researcher in conversation, she would simply state, "I am a researcher in your class, I cannot talk to you or help you at this time." Every day, the iPads were located on the top shelf of the mathematics center manipulatives, the study was set to begin February 1, 2012 through February 29, 2012, however the actual study dates were February 6, 2012 through March 2, 2012 to provide the researcher with prolonged field engagement.

Data Collection Procedures

The researcher received approval from the University of Central Florida IRB to conduct Case Study research. Then the researcher provided the early childhood administrator at the data collection site with written permission for research from UCF as well as from the school administrator, and he referred the researcher to a teacher who the met the characteristics required by the study. The researcher met with the teacher and discussed the criteria required of the students to participate in the study. She was given the name of five students, of which she conducted a formal records review and identified four students who met the research criteria. Then, the researcher sent out permission forms to the students identified to gain permission from their parents or guardians to allow the administration of the TEMA-3. Detailed notes were made of the records review to identify the participants that met the study criteria. Based on records review and the TEMA-3 scores, the researcher identified four students to explore as the bounded system for the case study research. The researcher had to send out an additional permission form to one parent, made phone calls to the same parent, and met the three other mothers at the time of dismissal to obtain permission for their child to participate in the research study.

Prior to collecting the data, the researcher provided the parents a survey assessing the students' exposure and existing comfort with technology, specifically the iPad; three out of four of the surveys were sent back immediately. The fourth survey was not sent back immediately and an additional survey was sent home and the researcher talked to the mother at dismissal, however the final survey was never obtained. Additionally, the researcher utilized a semi structured interview with the teacher regarding her current mathematics instruction and her comfort with technology, specifically the iPad, prior to implementing use in the class. Multiple methods of data collection were utilized to triangulate the data to verify the consistency of the information gathered (Brantlinger et al., 2005). Prior to data collection, for three days, the research was in the classroom, for short observations to put the students at ease (Creswell, 2007). Observations focused on the natural learning environments of the inclusive voluntary pre-kindergarten classroom to observe the setting, activities and interactions (routines, current mathematics instruction, student interactions with peers as well as the teacher), participants, frequency and duration of behaviors and activities (i.e. student engagement), and other subtle factors (Merriam, 1998). After the initial few days, the researcher determined, with the input of the classroom teacher, where the iPads would be located on the shelf (a shelf marker was brought in by the researcher to match all the other shelf markers at the mathematics center), and where the iPads would be used during the established center time. The existing 360 degree camera in the classroom was not functioning, so a tripod and video camera were brought in to record the participants because video taping permission was obtained. Additionally, after the research study was completed, the researcher interviewed the students on their perception of utilizing the iPads for mathematics enhancement based on the usability study protocol (Chiong & Shuler, 2010). A pre- and post- test of the TEMA-3 was administered to assess whether or not there was an impact on the participant's mathematics achievement.

Instrumentation

Instruments for data collection procedures began with a review of student cumulative records to identify participants followed by an academic assessment of mathematical concepts as measured by the Test of Early Mathematics Ability-Third Edition (TEMA-3). The selected participants' parents or guardians received a questionnaire inquiring about home usage of technology, specifically the use of handheld gaming devices and applications, as it related to the participant based on a Usability Study (Chiong & Shuler, 2010). The researcher collected field notes as well as video recorded the use of the iPads during center time. At the completion of the study, the participants retook the TEMA-3 to measure mathematical concept knowledge. Interviews were conducted with the student participants as it related to the use of the iPads based on a usability study (Chiong & Shuler, 2010). Additionally, a semi-structured interview was conducted with the teacher prior to implementing the iPads and at the conclusion of the study to inventory her current practice for mathematics instruction, her comfort with technology as well as her perceptions on the use of iPads in the classroom. The transcripts, from the teacher and participant interviews, as well as the field notes, were analyzed utilizing the ATLAS.ti software.

Records Review

A records review consisted of the cumulative educational and health records found at the research site. Specifically, the researcher reviewed paperwork as it related to the educational label (i.e. psychological testing, behavioral testing, health records) as well as the Individual Education Program (IEP). The researcher took notes while conducting the records review.

Test of Early Mathematics Ability-Third Edition (TEMA-3)

The TEMA-3 is a norm referenced mathematics performance measure for children ages 3-0 and 8-11. The TEMA-3 measures the following concepts: academic numbering skills, number-comparison facility, numeral literacy, mastery of number facts, calculation skills, and understanding of concepts. The test contains two parallel forms of 72 questions each that was utilized as one piece of data for a pre and post-test analysis within the study.

Parent Questionnaire

A questionnaire (Appendix C) was sent home for the participants' parents or guardians. It was completed and identified the experiences and opportunities for the use of technology in the home as it related to iTouches, iPhones, iPads, or handheld gaming devices and applications and was adapted from the Usability Study (Chiong & Shuler, 2010). The responses on the questionnaire allowed the researcher to describe each individual child's preexisting knowledge and interactions with technology.

iPads

The iPad is a tablet computer, with a touch-controlled interface by Apple, designed for audio and visual media such as books, movies, music, and games, as well as web content (Apple, 2011). The focus for this project was on the use of applications (also known as Apps) for children to practice and learn mathematics concepts. For the research study, the researcher provided the class with five iPads with three mathematics applications installed on the home screen. Originally, at the bottom of the screen there was a tool bar, on the toolbar on all screens, three applications were visible: Safari, Mail, and iPod. The screen to the right of the home screen had fourteen additional preinstalled applications which were: Calendar, Contacts, Notes, Maps, Videos, Youtube, iTunes, application Store, Game Center, FaceTime, Camera, Photo Booth, Settings, and Photos. Each iPad was loaded with the same mathematics applications: 123 Numbers, MonkeyMath, and Park Math HD. The wallpaper for both the Lock Screen and the

Home Screen was set with the first option, which is gray with water drops. As a result of the participants taking videos, photos, and using the Photo Booth during the iPad center, for the second week of data collection, the researcher put further restrictions on the iPads. The researcher enabled restrictions by entering a password in the settings. The restrictions included discontinuing the use of: Safari, YouTube, Camera, FaceTime, iTunes, Ping, Installing applications, and Deleting applications. Additional restrictions included applying the "Don't Allow Changes" for the Location feature and Accounts. The researcher turned off the "In-application Purchases" feature. For the movies and TV Shows restriction, the option to "Don't Allow Movies/TV Shows" was chosen. The researcher also switched the "Allow Applications Rated" to the age of 4+. Additionally the Multiplayer Games and Adding Friends feature was turned off. All the modifications in restrictions changed the number of applications visible on the second page to 10 applications which now included: calendar, contacts, notes, maps, videos, game center, settings, mail, Photos, iPod. Additionally, the researcher also moved the Mail application from the tool bar that was visible on the bottom of the page on the home screen to the second page. Finally, all the remaining applications were placed into one folder on the second screen. Additional modifications to the iPad throughout the study included the researcher "emptying" the aquarium on the Monkey Math application because with multiple users the aquarium became full and would not allow the students to earn rewards for their work within the application. The iPads had black silicon covers for protection.

Analysis of Applications

The applications used on the iPads in the study were chosen by the researcher based on a content analysis of the Pre-Kindergarten Focal Points and Voluntary Pre-Kindergarten Standards. Originally, 14 applications were analyzed (see Appendix D): (1) Photo Touch Numbers, (2) Kids…Game, (3) Toddler Puzzle Shapes, (4) 123 Lite, (5) Monkey Math, (6) Park Math, (7) Balloon Academy, (8) Kids Counting, (9) Oscar's 1-10 Balloons, (10) Colors & Shapes, (11) Numbers…Kids, (12) Kidimedia, (13) Monkey Rows, and (14) Patterns. Then the applications that comprehensively addressed the Pre-Kindergarten Focal Points and Voluntary Pre-Kindergarten Standards were selected for further analysis with the Common Core Kindergarten Standards. The three applications analyzed were (see Appendix E): 123 Numbers, MonkeyMath, and Park Math HD. Two experts in mathematics and EC were identified to review the three applications for inter-rater reliability regarding which standards were covered in the application. The first expert was an early childhood special education (ECSE) faculty member with extensive knowledge in children with developmental delays, children in early childhood prekindergarten classrooms and developmentally appropriate practices in mathematics. The second expert was a mathematics education faculty member with extensive knowledge in mathematics content and national standards for Mathematics, specifically Common Core and NCTM standards. The experts evaluated the three applications: 123 Numbers, Monkey Math, and Park Math with the same standards. The standards were: Florida's Voluntary Prekindergarten (VPK) Mathematics Standards, NCTM's Focal Points for Prekindergarten Mathematics, and the Common Core Mathematics Standards for Kindergarten. After the researcher and the experts evaluated each application, the three analyses were compiled to determine agreement (detailed analysis in Appendix F). Agreement between the researcher and two experts, across standards, for the: 123 Numbers application ranged from 79%-87% with an average of 84% agreement; Monkey Math application ranged from 80%-88% with an average of 85% agreement; and Park Math ranged from 84%-91% with an average of 88%.

For the VPK standards, agreement ranged from 84%-90% for the 123 Numbers application with an overall agreement of 87%; agreement for the Monkey Math application ranged from 87%-88% with an overall agreement of 88%; and agreement for the Park Math application ranged from 90%-88% with an overall agreement of 89%. When evaluating the applications using the VPK standards, the researcher had a higher percentage of alignment with the mathematics content and standards expert across all three applications (see Table 3).

Table 3 Agreement of VPK Standards

Application	ECSE Expert	Mathematics Content & Standards Expert	Overall Agreement
123 Numbers	84%	90%	87%
Monkey Math	87%	88%	88%
Park Math	90%	88%	89%

For the Focal Points standards, agreement ranged from 75%-83% for the 123 Numbers application with an overall agreement of 79%; agreement for the Monkey Math application ranged from 75%-100% with an overall agreement of 88%; and agreement for the Park Math application ranged from 92%-83% with an overall agreement of 85%. When evaluating the applications using the Focal Point standards, the researcher had stronger alignment with the mathematics content and standards expert for the 123 Numbers and Monkey Math application, but had a higher percentage of alignment with the ECSE expert for the Park Math application (see Table 4).

Table 4 Agreement of Focal Points Standards

Application	ECSE Expert	Mathematics Content & Standards Expert	Overall Agreement
123 Numbers	75%	83%	79%
Monkey Math	75%	100%	88%
Park Math	92%	83%	85%

Lastly, for the Common Core standards, agreement ranged from 82%-91% for the 123 Numbers application with an overall agreement of 87%; agreement for the Monkey Math application ranged from 73%-86% with an overall agreement of 80%; and agreement for the Park Math application ranged from 73%-95% with an overall agreement of 91%. When evaluating the applications using the Common Core standards, the researcher had a higher percentage of alignment with the mathematics content and standards across all three applications (see Table 5).

Table 5 Agreement of Common Core Standards

Application	ECSE Expert	Mathematics Content & Standards Expert	Overall Agreement
123 Numbers	82%	91%	87%
Monkey Math	73%	86%	80%
Park Math	73%	95%	91%

Field Notes

Using a laptop, the researcher collected field notes of the participants' use of mathematics applications on the iPad during center time. The iPads were located at the mathematics center and all the activity within the center was video recorded. A calendar was maintained to represent the frequency of attendance, use of the iPad, and interest of the iPad for each participant (Table 6).

Table 6 Participation Calendar

Date	PARTICIPANT 1	PARTICIPANT 2	PARTICIPANT 3	PARTICIPANT 4
2-1-2012 2-2-2012	Data collection did not begin as scheduled			
2-6-2012	✓	✓	✓	✓
2-7-2012	||✖	✓	✓	|| Legos
2-8-2012	||★	✓	✓	10 minutes late
2-9-2012	✓	✓	✓	✓
2-10-2012	✓	✖	✓	✓
2-13-2012	||★	✓	✓	✓
2-14-2012	Valentine's Day-teacher requested no center time			
2-15-2012	✓	✓	✓	||Building
2-16-2012	✓	✓	✓	||Building
2-17-2012	✓	✓	✓	✓
2-20-2012	||★	||✖	||✖	||★
2-21-2012	✓	✓	✓	✓
2-22-2012	||★	✓	||★	✓
2-23-2012	||★	✓	||★	✓
2-24-2012	||★	|| ||✓	||★	|| Play dough
2-27-2012	||✖	✓	||★	✓
2-28-2012	||✓	✓	||✓	✓
2-29-2012	Therapy	||✖	||✓	✓
3-1-2012	✓	✓	✓	✓
3-2-2012	||✖	✓	||✖	✓

Note. ✓*=used the iPad during mathematics center time,* ✖*=absent,*⃠*=did not want to use the iPad,* ★*=Came to iPads but left OR did not want to come but was directed to OR asked to leave; Shaded area represents Arts Integration and center time was only 30 minute.*

Interviews

Before the data collection, the researcher conducted a semi-structured interview with the teacher regarding her current practices as related to mathematics instruction and attitude toward technology. Additionally, semi-structured interviews with the teacher and the students were conducted at the conclusion of the study related to their perceptions of using the iPads in the classroom during center time. The student interview with each student was adapted from the

Usability Study (Chiong & Shuler 2010). The interviews were recorded for later transcription and inter observer agreement was conducted to determine the accuracy of the transcribed notes.

Data Analysis Software

ATLAS.ti

One method used to analyze the qualitative data was through a software program, AtTLAS.ti. This computer-based qualitative software allowed the researcher to theme transcripts and video for further analysis. The variety of analysis tools within ATLAS.ti allowed the researcher the opportunity to view the data, visually theme the data, and compile themes both from the transcripts and the videos. Furthermore, the data of the transcripts and videos was combined to create themes represented in video clips.

Internal Validity of Data

The following strategies were utilized to support internal validity: triangulation, member checks, long-term observation, peer examination, participatory modes of research, and researcher's bias (Brantlinger et al., 2005; Merriam, 1988). The method of triangulation employed was collecting data from multiple sources (observation, interviews with teacher, interview with the students, parent questionnaires, the TEMA pre and post test data, and the calendar of use) and finding themes across the data sets. During the study the researcher provided the transcripts of the interviews with the teacher as a means of conducting a member check (Brantlinger et al., 2005). At the end of the study, the researcher shared research results with the classroom teacher. When the researcher observed the iPad use of the students, detailed field notes were kept using date and time stamping for each observation to create an audit trail (Brantlinger et al., 2005).

The researcher worked collaboratively by utilizing peers, colleagues, and experts in the field of case study design to discuss findings as they occurred and shaped the data collection procedures and research design (Brantlinger et al., 2005). A university faculty with expertise in the area of qualitative research was utilized prior to conducting the study, as an external auditor to discuss research design, data collection instruments, as well as data analysis. After the data were collected and analyzed, additional consolations with an external auditor occurred to discuss the data analysis to confirm the findings as logical and grounded (Brantlinger et al., 2005). All the data analysis of themes were evaluated by a mathematics education faculty member with experience conducting qualitative research. Additionally, the classroom teacher, as the expert of her classroom, was consulted for conceptualization of the iPad implementation, as well as when reporting the research results. Lastly, to address researcher reflexivity, the researcher wrote a personal biography to clarify assumptions, biases, values, and views prior to conducting the research, and contributed to the document throughout and following the study (Brantlinger et al., 2005; Gast, 2010).

Reliability of Data

Interobserver Agreement (IOA) with a research assistant was obtained on scoring of the TEMA-3 pre and post exam as well as the agreement between the researcher and two expert evaluators for the standard alignment with the applications. Additionally, for at least 25% of the field notes, the research assistant reviewed and validated the themes from the observation sessions. Additionally, all of the transcribed notes from teacher interviews and student interviews were checked for accuracy by the researcher because the notes were transcribed by an outside company.

Data Analysis

The observations and interviews were transcribed and checked for accuracy. The videos were watched by the researcher and were used to enhance the observation field notes. The final observation notes were typed during the observation, and all the observation notes were checked by the researcher for accuracy using the video recordings. Then the observation notes, transcribed notes from the teacher pre and post interviews, and the student interviews were coded utilizing the ATLAS-ti software to look at individual themes for each case as well as overall themes of the study. The researcher used a transcription company for the audio recordings of the interviews with the teacher and the students, and the tapes were checked by the researcher for 100% reliability. The teacher interview notes were given to the teacher for member checking. The scoring of the TEMA-3 and the accuracy of the tables were checked for accuracy by an undergraduate research assistant studying special education and were found to be 95% accurate and were corrected to 100% accuracy. The accuracy of the transfer of data from the pencil paper evaluations completed by the evaluators, to the typed tables of the Content Analysis of the applications were checked for accuracy as well, and was found to be at 100%. Additionally, the researcher utilized the ATLAS-ti software for theming analysis of the transcription notes and the same Mathematics faculty member who had evaluated the applications conducted IOA on 25% of the themed data for 85% or greater agreement. Since the students are so young in the study, themes were not member-checked with students, but will be triangulated with parent, teacher, and student interviews. The results were presented utilizing direct quotes and detailed descriptions of the students and setting to influence the particularizabiltiy of the findings (Branlinger et al., 2005).

Limitations

Multiple data collection procedures as well as application selection procedures were utilized to increase the credibility of the research findings (Gast, 2010). The access of technology for young children and the need for quality early mathematics instruction increases, the researcher desired to conduct an exploratory qualitative research to provide a basis for future quantitative studies that are grounded in experience (Branlinger et al., 2005). Finally, data collection was dependent on observation, field notes, and interview themes, which can be subjective.

Logistical limitations also occurred. Working around the existing class schedule was a logistical limitation since VPK hours are from 9am-12am and opportunity for iPad usage was limited to center time, approximately two hours per day. The students within the pre-kindergarten classroom had the choice of what center to explore during the established center time, therefore the researcher and teacher had to schedule the center time to strategically place the participants at the mathematics center using the iPads for the purposes of the research study.

Also, conducting research in the public schools can be difficult since the researcher had to work around the public school calendar and student attendance.

Another variable that contributed to the findings included the individual participants prior experiences utilizing handheld technology. The range in previous experiences impacted how quickly the students became comfortable with the technology, those with more experience became less frustrated with the iPads. An additional contributing factor was the impact of the individual student's developmental delay. The factors that affected the use of the iPad included fine motor skills and student's attention span.

The data collected in this study enabled the researcher to contribute to the literature base by developing theories used to inform further design research studies, measuring academic growth as it relates to the use of iPad mathematics applications, based on the findings from this study (Giangreco & Taylor, 2003).

CHAPTER FOUR: RESULTS

The researcher in this study used multiple case studies to explore the developmentally appropriate use of mathematics iPad applications for children with developmental disabilities in a voluntary pre-kindergarten classroom. This chapter opens with a statement of the research question followed by a discussion of the themes that emerged for each of the four individual cases is provided. Next, a discussion of how the data were analyzed and triangulated is provided. Then, a rich description of the two overarching themes that emerged from the data analysis and triangulation of multiple sources are presented: (a) records review, (b) test results of Early Mathematics Ability-3, (c) parent questionnaire, (d) field notes, (d) interviews, and (e) iPad use calendar. The chapter concludes with a summary of the findings of the qualitative iPad study.

Research Questions

1. How do students with developmental delay in an inclusive Pre-Kindergarten class use mathematical applications on the iPad?
2. How do students with developmental delay in an inclusive Pre-Kindergarten class change their engagement with mathematical applications on the iPad over time?

Participant Themes

A purposive sample from one voluntary prekindergarten classroom within the school was utilized. In order to bind the case to a reasonable scope (Creswell, 2007), the inclusion criteria for the study were: (a) confirmation of a developmental delay; (b) full time voluntary pre-kindergarten enrollment in the inclusive classroom; and (c) a highly qualified pre-kindergarten special education teacher. The criteria matched four students in the classroom. Prior to the data collection, each student was administered a TEMA-3 pre test and a parent questionnaire was sent home. Then, for 19 days, the researcher observed in the voluntary prekindergarten classroom for 2 hours during the existing center time block. During this time, the researcher focused her observations on four identified participants, which will be referred to as: Participant One, Participant Two, Participant Three, and Participant Four. For each individual case, multiple sources of data were analyzed including a records review, the parent questionnaire, TEMA-3 test scores, the observation field notes, and the transcripts from the exit interviews. From the multiple sources of information, the data were analyzed and two unique themes related to each individual case emerged that are discussed in the following sections.

Participant One. The first participant, a Hispanic male, was 5 years 3 months old at the start of the study. He received special education services for his developmental delay and speech. In his social history, his mother reported health related events from his early years including his umbilical cord wrapped around his neck requiring oxygen at birth and respiratory distress at 3 months old that required a one week hospitalization. Additionally, the mother reported existing health and behavior concerns including asthma, hyperactivity, and impulsivity. On the Batelle Inventory 2 his score in the Cognitive domain was 62. After analyzing the data in the study, investigating the use of iPads in the voluntary prekindergarten class, two themes emerged specific to Participant One. The sources of information for his data analysis were: records review, the parent questionnaire, TEMA-3 tests, researcher's observation field notes, and the transcripts from his exit interview. The first theme was difficulty as it related to both the technology and the mathematics content. The second theme was distractibility from the mathematics applications when using the iPads. The responses on the parent questionnaire, filled out by Participant One's mother, was a precursor to both the themes. On the questionnaire she indicated that that although Participant One had prior knowledge of what an iPhone and an iPad were, he thought that an iPhone was used as a phone and to play music while an iPad was for the internet, games, and music. Participant One had limited prior access to either piece of technology, both were owned by family members not in his home and Participant One believed an iPhone was only for adults, and he had never touched an iPad prior to the study. During the data collection, the researcher observed when Participant One became frustrated with the technology and content he left the mathematics applications and became distracted with other features of the iPad as well as other events within the classroom environment.

Theme one. The theme of difficulty was observed by the researcher the first day the iPads were in the classroom. When Participant One came to the mathematics center and played with the iPads he said, "I want to do monkey game. How do you do this?" The researcher observed he was having difficulty turning on the Monkey Math application.

The second day, when Participant One came to the mathematics center and played with the iPads, another student stood next to him and helped him play the Park Math application. The researcher observed yet another student that sat next to Participant One and told him how to answer questions in the Park Math application; however when he had to answer the question 20-5= the researcher observed him pressing all the answers from top to bottom until he got the right answer. On the sixth day of data collection, the researcher observed Participant One playing the

Park Math application, where he had to feed the hippo seven green hot peppers, however Participant One did not discriminate between the red and green peppers. Even when the directions within the application stated, "Feed the hippo 4 green peppers." On the same day, similar errors related to the mathematics content in the Park Math application occurred when Participant One had to complete patterns including an ABAB pattern. The researcher observed on the sixth day, Participant One answered seven problems by choosing the incorrect answer first, but then would choose the correct response in his second attempt.

Then, the researcher observed that Participant One switched to the Monkey Math application. Within this application one of the tasks was to trace the numbers in the sand. The researcher noticed when Participant One had to trace the number two, he became frustrated and said, "I can't do it." The next task within the Monkey Math application required him to fill in the blank (e.g. 2, 3, __, __, 6). The researcher observed in order for him to complete the number sequence correctly, he made three errors. Other instances observed day one through four of data collection included Participant One choosing all the numbers in the answer bank from top to bottom or left to right to get the correct answer versus calculating the answer and choosing the correct number. Additionally, within the Monkey Math application, one task required Participant One to pop the bubbles with the correct number or correct picture representation of a number. Participant One was observed choosing the correct responses in this activity. On the seventh day of data collection, the researcher observed Participant One leaning his head with his ear directly over the iPad on the table to listen versus increasing the volume on the ipad. During the exit interview, Participant One's difficulty with comprehension was documented when the researcher asked him, “Did you like using the iPad?” and Participant One answered “Yes” so the researcher asked, “What did you like?” and Participant One responded, “Red.”

Theme two. The second consistent theme the researcher observed for Participant One was his distractibility from the mathematics application when using the iPads. Over the 19 days of data collection, it was coded that he was distracted from the mathematics applications over 20 times or approximately once per day. Examples of his distractions that the researcher observed included leaving the mathematics applications to use other applications on the iPad such as the camera and Photo Booth (before those applications were restricted), changing the wallpaper, and going to the interactive white board at the front of the classroom during his time at the mathematics center.

Findings from his records review indicated Participant One’s mother’s concerns with his attention span. The first time the distractibility was observed by the researcher was on the third day of the iPad use, at the end of his mathematics center rotation. At this point in the class, Participant One turned on the camera application on the iPad and played with the camera, then he left the camera application and turned on the iTunes application, and next he left the iTunes application and turned on the Photo Booth application. On the fourth day of data collection, the researcher observed Participant One sitting down at an iPad in the mathematics center, the image on the iPad screen was upside down and the researcher observed Participant One looking at the screen with a look of confusion. Participant One’s fellow student took the iPad and turned the image right side up and handed it back to Participant One. At which time Participant One said, “Thank you.” Briefly he played on the Monkey Math and Park Math application, but within two minutes he swiped the screen and turned on the typewriter and held up both his right and left hands in a typing motion. He then turned on the camera application and watched himself and then he left the camera application.

On the fifth day of data collection, the researcher observed Participant One open the Photo Booth application and take pictures of himself. He spent several minutes opening and closing the Photo Booth application. Then, Participant One left the Photo Booth application and opened the photo album and looked through the pictures he had taken. It was interesting to note that he did know how to make a pinching motion on the screen to make the images smaller and larger. On five occasions, the researcher observed when Participant One became frustrated with the mathematics task, he would open the non-mathematics Applications such as: the mail application, the Photo Booth application, the typewriter, or the settings application. The researcher observed Participant One on the sixth day swiping the screen all the way to the right so that the typewriter appeared and he would hold up both his hands and use his pointer fingers on both hands to mimic he was typing. The researcher documented that when he typed he did not spell words, he just typed random letters. The researcher observed on the sixth day the method he used to open the typewriter was after leaving an application, he would hit the home button two times which would pull up the typewriter. When the typewriter came up, he would vigorously move his fingers as if he was typing. On the seventh day of data collection, a student G1S4 (see Table 6) wanted to show Participant One how to change the wallpaper and the lock screen, Participant One did not want G1S4 to touch his iPad nor did Participant One want to learn how to change the background. However, once he did learn how to change the wallpaper and lock screen he changed both every day during the data collection through the Settings application. The researcher noted on the fifth day of data collection, Participant One used one of the pictures he had taken of himself and made it the wallpaper and lock screen for his iPad. However, on that day he became frustrated with the iPad and made a fist and motioned like he was going to punch the iPad, although he never did. Additionally, the researcher noted, on the same day he used his fist to pop the bubbles in the Monkey Math application.

By the sixth day, when Participant One sat down at the table with the iPads, he immediately went to the Settings application, but before he changed the wallpaper and lock screen he looked over his shoulder at the researcher and closed the Settings application. When he was timed by the researcher on the sixth day, it was recorded that he spent over 4 minutes out of the possible 15 minute iPad rotation altering the wallpaper and lock screen picture.

Additionally, Participant One was often distracted by the interactive whiteboard at the front of the room. The interactive whiteboard center was often one of the choices during center rotations. On six days of data collection, the researcher observed Participant One leaving the mathematics center and going to the front of the room to play on the interactive whiteboard. On the 10th day of data collection the researcher noted Participant One again went to the interactive whiteboard to play StarFall instead of going to the mathematics center with the iPads and the teacher had to redirect him to the iPads. The researcher observed the assistant taking the pointer from him and telling him to go to the iPads, when he screamed out, “NOOOOOOO!” The assistant than walked him to the iPads. Participant One proceeded to flip the iPad up off the table and said, “my pooder [my computer]” as he pointed to the interactive whiteboard. He then opened the Monkey Math application and started to use the iPad, however when the teacher stated, it was time to switch, he immediately jumped up and he went to the interactive whiteboard.

Additionally, the researcher observed on day 10 that in the midst of using the iPads, Participant One turned to the teacher and asked, “My turn?” as he pointed to the interactive whiteboard. The researcher documented Participant One asking the teacher an additional three times during the 30 minute center rotation to go to the front to play on the interactive whiteboard. The researcher observed Participant One watching the students use the interactive whiteboard versus playing on his iPad for the majority of his center rotation.

Another type of distraction the researcher observed was non-academic activity within the mathematics applications. Participant One would get distracted from completing the mathematics and would spend time on non-academic activities. For example, in the Monkey Math application, Participant One would spend time moving all the sea life decorations (i.e. fish, castles, mermaids, coral) out of the aquarium. Then, he would systematically place them back in the aquarium.

Additionally, in the Park Math application, when the application is initially launched, there is a square in the top right corner with the words “Level:” and a number from 1-3. This number represents the level of the game. On the sixth day of data collection the researcher observed Participant One pressing the square vigorously to hear the ding and change the level from 1-3. He would do this repeatedly or he would press a beach ball or pinwheel on the screen which made them spin around and around instead of launching the mathematics content of the application.

The researcher noted that Participant One got distracted by the other boys in his group during the iPad center. On the 16^{th} day of data collection, the researcher documented a specific incident where Participant One was asked by his neighbor, G4S4, to replay a puzzle within the

Park Math application. The neighbor, G4S4, touched Participant One's screen and Participant One said, "What the heck." As the boys continued to play their iPads next to each other, Participant One repeated, "What the heck" and then G4S4 said, "What the poop." Then Participant One said, "What the hell." The teacher stated, "That is not what you say in school." The researcher observed that within the mathematics center, the conversation continued to escalate and Participant One said, "What the hell, what the hell, what the hell" and G4S4 echoed the same back to him. The teacher announced, "It is time to switch." and the students stood up and left the center. On the 17th day of data collection, it was noted by the researcher that an additional distraction for Participant One was speech and language therapy during center time which resulted in him not having time at the mathematics center to use the iPads.

The researcher also observed Participant One's distractibility and impulsivity during the exit interviews. The iPad displayed pictures of the mathematics applications versus the applications themselves, however, Participant One continued to press on the screen of the iPad and switch to the next picture. The interviewer explained to him, "…you're just looking, don't touch it because then the picture changes. I just want you to be looking…These are just pictures, this is not the iPad working…I want to show you pictures and ask you questions," the researcher had to continue to repeat, "you are just looking" throughout the exit interview.

Participant Two. The second participant, an Asian and Hispanic male, was 5 years 2 months old at the start of the study. He received special education services for his developmental delay. In his social history, his mother reported a healthy pregnancy that resulted in a cesarean at 38 weeks gestation. Within the last two years, Participant Two (1/26/10) had one febrile seizure. According to the Batelle Inventory 2 his score in the Cognitive domain was an 84. After analyzing the data in the study, investigating the use of iPads in the voluntary prekindergarten class, there were two themes that emerged specific to Participant Two. The sources of information for his data analysis were: records review, TEMA-3 tests, researcher's observation field notes, and the transcripts from his exit interview. The first theme was Participant Two's use of digital vocabulary as it related to the iPads. The second theme was his proficiency with the iPad technology.

Theme one. The first theme, digital vocabulary was observed by the researcher the first day the iPads were in the classroom. Participant Two came over to the mathematics center table and sat down with an iPad and said, "What happened to my file? Did someone take my file?" The researcher noted on three different days (the first, second, and thirteenth day), Participant Two looked at his classmates' iPad screens and told them, "You are not on the file." Additionally, the researcher noted the first day of data collection Participant Two used technology vocabulary when he was typing in the search bar, and he was observed saying, "…both of them went on mail."

The researcher documented on the fifth day of data collection Participant Two stated to his group, "I want to download a game." It was also noted on the fifth day of data collection, when Participant Two saw that an application was removed from the iPad he stated, "They erased it." Participant Two continued to talk without having a designated audience and said, "Someone downloaded an App yesterday. I am doing Park Math. If you download Apps, you need money. I will bring in my wallet. I have twenty-nine cents in there."

On the sixth day of data collection, the researcher noted during the mathematics center a student asked Participant Two to help him find a particular application on his iPad. Participant

Two looked at his classmate's iPad and the mathematics application was gone and Participant Two said to him, "You deleted it." Participant Two was correct in his observation that the application had been deleted, the researcher had to reinstall the application prior to the seventh day of data collection.

On the ninth day of data collection, on one of the iPads, a student moved two of the applications into one folder by dragging the application on top of each other. This made the applications look different. When Participant Two saw the new application folder with multiple applications inside he asked, "Who downloaded this thing?" The researcher noted that he had an understanding of the process for how the applications needed to be downloaded to an iPad and that the applications require a payment.

The researcher observed on the 15th day of data collection Participant Two came to the mathematics center and played with the iPad, then he looked at the researcher and asked, "How do you download?" The researcher noted on the same day Participant Two also used the settings application to change the wallpaper on an iPad to the Earth and said, "I changed the wallpaper." And then at the end of the session, he changed the wallpaper back to the original wallpaper and told the researcher, "I made it normal."

Additionally, the researcher's notes indicated on the 18th day of data collection when Participant Two came to use the iPads, he turned on the iPad and opened the settings application. Participant Two then proceeded to turn the airport mode to OFF and then he said, "I know there is WiFi at Barnes and Nobles. I turned the airplane mode OFF. I know what it's going to do."

Based on a conversation he overheard the researcher having on the 18th day of data collection, he told his friends, "On the last day she [the researcher] is going to download all kinds of different Apps."

Theme two. The second theme for Participant Two that emerged was his proficiency of the iPad technology, which was first observed by the researcher on the second day the iPads were in the classroom. On that day Participant Two discovered how to turn the power off on the iPad. He promptly stated, "I turned off the iPad." He stood up to show an adult and then he turned to the researcher and stated, "I know how to turn an iPad off." The researcher documented that Participant Two spent time powering the iPad on and off during the center time on the second day of data collection. When it was time to clean up the center, he turned off the power to all four of the iPads. For the third and fourth day of data collection, the first thing Participant Two said when he came to the mathematics center was, "I know how to turn off this iPad" and Participant Two powered the iPad off and then powered it back on.

Sometimes when the students used the iPads, the image on the screen would flip and then the image would be upside down. If the screen flipped when Participant Two was using it, he would flick his wrists slightly to have the image turn right side up. Throughout the use of the iPads Participant Two would swipe the screen to the right and access the typewriter and he would type the name of the game he was looking for versus pressing on the picture of the application. He also used the typewriter to access the applications by typing out the name of the specific application. Participant Two was also observed deleting existing texts in the search bar. Additionally, the researcher noted that on day two Participant Two was the first one to know how to change the levels between 1-3 in the Park Math application.

All the mathematics applications had to be played in landscape orientation, therefore the iPad had to be held parallel to the table. All of the students held the iPad in landscape, however the researcher noted that on the fourth day of data collection Participant Two held the iPad to portrait view and said, “I can use the iPad like this” and then on the sixth day of data collection the researcher noted that he held the iPad in portrait view and turned to ask the researcher, “Can I use it like this?” On the sixth day of data collection, Participant Two walked over to the iPad center and told a classmate, “I am getting my own iPad tomorrow.”

Another non mathematics application that Participant Two used was the calendar application, which he accessed on five occasions. On the 8th day of data collection was the first time he opened the calendar application, at which time he said, “We have to write down an event. Today is [his sister’s] social studies event I forgot.” The researcher found when resetting the iPads, Participant Two inserted his birthday with “my birthday” into two of the calendars on November 11th. The researcher observed on the eight day of data collection that he repeatedly held the screen up at a 90 degree angle with the top cover laying flat in front of him and he would say, “I’m going to use it like a computer like this” or “I am pretending this is a computer.”

On the ninth day of data collection, Participant Two propped the iPad up on his left arm so that the screen was at a 45 degree angle while he played on it. The iPads had black silcon covers that could be latched to prop the screen up at an angle. By the fourteenth day of the iPads in the classroom, Participant Two tried to prop up the iPad at an angle with the cover. By the fifteenth day he figured out how to prop up his iPad and other students were asking him to prop up their iPads. He also engaged in using the settings application to change the wallpaper. During the exit interviews he mentioned again, that he would be getting an iPad. The researcher asked him, “Did you like using the iPad?” To which Participant Two stated, “…but I am going to get one soon.” The researcher clarified, “You’re going to get an iPad soon?” Then Participant Two said, “Yes. Because I’m so smart. I’m really smart because I do my homework; I can tell what’s 15-1, even all the mathematics problem, I just know pluses, minuses—I know minus and times, I can—I can tell what’s two times one…two.” When the researcher asked him if it was “…hard to use the iPads?” He responded, “No, it was very easy.”

Lastly, during the exit interviews in contrast to the other students who had a difficult time understanding that the iPad was just displaying pictures and was not able to be used during the interview, with just one explanation, Participant Two realized that he could not press the screen. Therefore, he answered each question and described what he would have done. When the screen displayed a seesaw that the child had to move up mice to balance the seesaw, Participant Two described to the researcher what he would have done. The researcher asked, “..what did you do with this game, help the mice balance their seesaw [the researcher read the direction on the screen]?” Participant Two said, “Press—three on here and here [pointing to both sides of the seesaw].” The student’s response illustrated the concept of balancing the seesaw on the left and right by placing a few mice on one side of the fulcrum. Which was interesting because during the data collection he had a disinterest with the seesaw game and would leave the task quickly.

Participant Three. The third participant, a Caucasian female, was 4 years 10 months old at the start of the study. She received special education services for her developmental delay and language needs. In her social history, her mother reported Participant Three was born prematurely, at 30 weeks gestation, in Russia and weighed 2lbs. 8 oz at birth. At birth, she required oxygen and was in the NICU for three months. She had an eye surgery for strabismus and currently she wears glasses. She has hypotonia and reportedly did not walk until 28 months and currently wears braces on her feet. According to the Batelle Inventory 2 her score in the Cognitive domain was a 77. After analyzing the data from the study, two themes emerged specific to Participant Four. The sources of information for her data analysis were: records review, the parent questionnaire, TEMA-3 tests, researcher's observation field notes, and the transcripts from his exit interview. The first theme was her need to work collaboratively with one member of her group. The second theme was her distractibility when using the iPads, although the two themes overlap because Participant Three was distracted with G3S2's actions with the iPad, versus using her iPad to play mathematics applications.

Theme one. The theme of working collaboratively with one specific member of her group was frequently observed as Participant Three had a desire to sit next to and watch G3S2 play on the iPad. The researcher noted Participant Three sat next to G3S2 every day. On day three of data collection, the researcher documented Participant Three saying to G3S2, "I want to play like you" and on day four she told him "I want to do that too." The researcher observed that on five of the data collection days, when Participant Three came to the mathematics center there was not an iPad in front of the empty seat next to G3S2, so Participant Three picked up an iPad and moved it around the table, so that she could sit in a seat next to G3S2. Additionally, the researcher noted on one of the days there was not an empty chair next to where G3S2 was sitting, so Participant Three picked up a chair and moved it next to him.

Additionally, the researcher observed other behaviors such as Participant Three looking at G3S2's iPad and attempting to find the application he was playing on her iPad. It was also noted by the researcher that Participant Three spent time daily watching what G3S2 play on his iPad. The student G3S2 was always playing the mathematics applications. On the fifth day of data collection, the researcher observed Participant Three say to G3S2, “I want to do it like you” or “I want to do what [G3S2] is doing.” When her peer did not help her, she turned to the researcher and said, “I want to tell you something, I want what [G3S2] has.” In response, He leaned over to her iPad and helped Participant Three go to where he was in the Monkey Math application and he watched her play and told her “There you go” when she got the answer correct.

Also, the researcher observed that Participant Three would play some of the mathematics games, particularly the Monkey Math. When Participant Three came to the reward aquarium screen, she would look over to G3S2’s iPad and say, “I want to play like [G3S2] did.” On the eighth day of data collection, the researcher observed that when Participant Three was off task in other applications (e.g. playing in the mail application), she would look over at G3S2’s iPad. When G3S2 changed the wallpaper on his iPad, Participant Three said, “I want it like yours [G3S2]. I cannot do it.” The researcher observed G3S2, take Participant Three’s iPad and change the wallpaper for her.

On the 16th day of data collection, the researcher noted that when Participant Three’s view was blocked from G3S2’s iPad because he propped up the iPad, she stood up to see what he was playing and she asked him questions like, “How do you get to that one?” When G3S2 was playing a mathematics application Participant Three also wanted to play that application too. When G3S2 did not respond to Participant Three, she would touch his screen and he get upset with her because she accidently exited him from his game. He said, “Look what you have done.” Participant Three, however, did help G3S2 to get back to the game that they were both playing on their individual iPads. But then when G3S2 was on the number two and Participant Three could not figure out how to get her screen to look like his screen she asked him, “How do I get to the number two?” She told him that she has to do the number that he was doing. Later in the game she got frustrated when she was hitting the back arrow and the screen would not change, G3S2 leaned over and said, “That’s because you are at zero.” As they both worked on a tracing application G3S2 announced, “I chose red” so Participant Three would change her color to red too. She said to him, “I want to do the same thing” or “I want to do it like you.” Overall, if Participant Three played the mathematics applications, she played the same application as G3S2, however within the application (i.e. Monkey Math, Puppy Math, 123) both students would play different games but if Participant Three noticed what he was playing and she would attempt to change what she was playing to match what he was screen.

Theme two. The second theme that emerged for Participant Three was her distractibility when using the iPads throughout the study. According to Participant Three’s parent questionnaire results, she had prior experiences with iPhones, iTouches, and iPads. Both of her parents own an iPad that she uses by herself to watch movies and play games. The researcher observed on the first day Participant Three came to the mathematics center to use the iPads, she opened iTunes, the video application, and all the other non mathematics applications on the iPad. On the second day of having the iPads in the classroom when Participant Three came to the mathematics center, she sat down with the iPads and flipped the cover back and forth for a period of time and then she said to the teacher, “I want to play with something else.” Then she was pressing the applications on the screen, she pressed it so long that the application started to shake and could have been deleted, but she knew to press the home button so that the applications were not deleted. Then she scrolled through all the non mathematics applications and said two more times to the teacher, “I want something else.” The researcher observed on the fourth day, Participant Three opened Face time application and the Photo Booth application and took videos and pictures of herself and the classroom. She sat and watched herself on the camera and was posing for pictures. She tried to balance the iPad with her chin as she took video of the classroom. When a group member told the teacher what she was doing, she immediately put the iPad down and the camera unintentionally turned off. The teacher redirected her to “play math games” but as soon as the teacher left the mathematics center, Participant Three opened the setting application. Then she turned the Photo Booth application back on until a student told the teacher again, promptly, Participant Three hid the iPad under the table. The researcher noted on three other incidents that she opened the Photos application and looked for the pictures she had taken in earlier days. On the 7th day of data collection the researcher noted that when another group member changed the wallpaper on his iPad she asked him, “How do you do that G4S4?” He showed her how to change the wallpaper. She spent time in the mail application and pressed all the buttons within the mail application.

The researcher documented that Participant Three often fidgeted with the iPad. For example, on the third and fourteenth day of data collection, Participant Three held the iPad up off the table with the short end of the iPad toward the table, she was instructed by an assistant to put the iPad down so Participant Three released the iPad and dropped it forcefully on the table. The researcher documented 20 incidents where Participant Three played the applications upside down for an extended period of time and on the 8th day of data collection she looked at the researcher and stated that the iPad “…[was] not loud enough.” One of the days she played the entire game upside down and with her left hand even though she was right hand dominant. Often during the center time, one of the centers was the interactive whiteboard at the front of the class and on two of those occasions the researcher noted, Participant Three became more engaged in watching the interactive whiteboard versus the iPad at the mathematics center. On the fifteenth day of data collection, Participant Three spent the majority of her center time biting the glue off of her fingers as well as picking her nose.

The researcher observed on the tenth day of data collection, Participant Three left the iPads and walked over to the teacher and said, “I’m all done.” The teacher told her she had five minutes left and to go back to the center. By the thirteenth day of data collection the researcher documented that Participant Three had left the iPad center four days in a row and walked around the room. The researcher noted on the thirteenth day Participant Three wanted to join the art center with the teacher and was redirected to go back to the Mathematics center. On the fourteenth day the researcher observed Participant Three walk back to the table with the iPads and move her iPad to another table to sit by herself.

During the second administration of the TEMA-3 on March 3, 2012, Participant Three could hear her classroom through the door and repeatedly told the researcher that she had to get back to her class. This behavior may have impacted her post iPad scores. She answered 20 questions on the pre-test and only answered 10 questions on the post test, and of those 10 the last 6 answers were incorrect responses. On the pretest she was able to answer the question to represent nonverbal production questions 1-4 correctly, where on the post test she only answered one of the three answers correctly. Additionally, on the pretest she was able to produce sets: up to 5 items correctly for all three of the questions and on the post test she only answered one of the two questions correctly. Therefore, her raw score went from a 9 on the pretest to 4 on the post test resulting in a 10 point difference in her Mathematics Ability Score (pretest = 85 and posttest = 75).

During the exit interview, her distractibility was also observed…she told the interviewer a few times, “Time to switch.” Because she could hear inside the classroom and she knew they were switching centers. When the researcher told Participant Three that she was going to put additional applications on the iPads for the last day of data collection, “I’m not going to be here tomorrow. I’m going to Busch Gardens. With my buddy, my two boy buddy.” From that point on the researcher could not get Participant Three to refocus on questions regarding the iPad, therefore she was sent back to the classroom to join center time.

Participant Four. The fourth participant, a Hispanic male, was a 5 year 0 months old at the start of the research study. He received special education services at school for language therapy, occupationally therapy, and developmental delay. According to the records in his records review, his mother had a healthy pregnancy and he met his developmental milestones within the normal range. Although he has had multiple health issues including asthmas, chronic ear infections, ear tubes, in addition to nut, bug, and seasonal allergies he was of general good health. During the time spent in the classroom, the researcher never observed any health related issues. On his Individual Education Program he was described as affectionate, easy to engage, persistent, and playful. After analyzing the data in the study, two themes that emerged specific to Participant Four. The same multiple sources of data were utilized for his data analysis as well. The first theme was Participant Four’s ability to use the iPad, which will be referred to as usability. The term usability refers to Participant Four’s ability to perform basic functions on an iPad including: swiping the unlock tab on the home screen and using the touchscreen with one finger. The second theme was the enrichment of his mathematics content knowledge as related to the use of the iPad.

Theme one. The first theme, usability, was first addressed in the data from the parent questionnaire, Participant Four, had prior experience with a hand held device, since his mother had an iPhone. However, his mother indicated he had never used an iPad prior to the study and that he only used the iPhone with her assistance and that he required help pressing the home button and swiping his finger across the screen. This observation was consistent with his use with the iPads in the classroom. Even though his mother indicated he had never used an iPad prior to the study, on the first day of data collection he told his classmates, "I own an iPad." The researcher observed Participant Four use the iPad with another participant the first day. The iPads were available during center time. During the observation the researcher noticed Participant One was sitting at the iPad table with the iPad on the table in front of him and Participant Four was leaning on the table over the iPad. When Participant One called out "I want to do monkey game. How do you do this?" Participant Four came over to assist but had a difficult time swiping the screen and literally held Participant One's hands off the screen to try to use the iPad. Then Participant Four sat down at the iPad table with an iPad in front of him, but did not use it. Instead he watched what his neighbor was doing on another iPad. When Participant Four did pick up the iPad to play, he opened and closed the silicon cover repeatedly and then turned the iPad on and off repeatedly.

The researcher's notes indicated on the second day that the iPads were in the classroom, Participant Four did not want to leave the Lego center for the iPads (see Table 5). The researcher observed the teacher prompting Participant Four to go to the iPads, but he chose not to attend that center. Three instances were observed that Participant Four did not leave his current center to go to the iPads at the mathematics center: One instance he stayed at Legos (day three), two instances he stayed at the building center (day seven and eight), and the third instance he stayed at the play dough center (day fourteen). On the tenth day of data collection, the researcher observed the fourth instance where Participant Four did not want to come to the iPad center from building, but the assistant allowed him to transition with blue teddy bear counters, therefore he did come to the iPad center that day. Due to an absence and a non-desire to go to the mathematics center, the fourth day of the study was Participant Four's first day going to the mathematics center to use the iPads.

Participant Four qualified for developmental delay under the fine motor domain and qualifies for occupationally therapy. Therefore, the difficulty Participant Four had using the iPad that was observed may be a result of his fine motor deficiency. For instance, the researcher observed the first day (day four) when he actually came to the mathematics center the iPads were on the shelf at Mathematics centers. Participant Four got an iPad and brought to the table and opened the silicon cover but the home screen on the iPad was locked. He asked, "How do you turn this on?" and repeated it aloud three times. Then he said, "What do you do here? Come on?" The researcher then observed him hit the iPad with his fist. He began to rub his eyes and his face and then used his right pointer finger and pressed all around the screen. He pressed his finger on the tip of his nose and asks, "My do it?" Then he closed and opened the cover and he hit the iPad with his fist again. He did press the home button but did not swipe the arrow (which is what is required to turn it on). He then swiped the arrow from the left to the right and turned on the iPad. Then he swiped the iPad screen to the right and by-passed the mathematics applications and opened a typewriter. The researcher observed his neighbor reach over in an attempt to help him, and Participant Four pulled the iPad away from his neighbor closer to his chest. He did finally open the Park Math application and began to play.

Additionally, the researcher observed on five incidents throughout the study when Participant Four had to perform a task that required him to slide his finger across the screen he always had a difficult time. When Participant Four used his finger to move an object, the touchscreen did not respond to his touch (e.g. placing fish in the aquarium or connecting the dots to count in the Monkey Math application). When this occurred he became vigorous with his motions and clenched his fists and left the screen. One of the reasons the touchscreen did not react to the touch of his finger was because the side of his right hand was resting on the touchscreen, throughout the study he continued to have difficulty with the sliding motion, but began coping with it much better as time passed. For example, the researcher observed on the tenth day of data collection, when Participant Four was playing the Monkey Math application, he attempted to connect the dots using one finger and pressing vigorously on the screen in an up and down motion to get the line to move from number to number. He also used both his right and left pointer fingers to make a vigorous up and down motion on the touch screen. Participant Four would also alternate between his right middle finger and his thumb, versus his pointer finger. Throughout the study, the researcher documented instances where Participant Four had to trace the number in the sand in the Monkey Math application, and Participant Four said, “This is too long” and left that activity. He appeared to have trouble with the tracing activity and therefore chose another application. On the eighth day of data collection, the researcher observed

Participant Four's reaction when he came to the mathematics center and opened the silicon cover of the iPad, but there was an error screen. To deal with the error, Participant Four should have pressed "cancel" to begin using the iPad. However instead, he attempted to swipe the unlock bar like usual. When the iPad did not turn on, he put it down and picked up another iPad that was sitting to his left. With the new iPad, he slid the screen to the right and it would not slide. The researcher documented him saying, "I cannot do this." By the last week of the study (data collection days 15-19), Participant Four was having an easier time tracing the letters in the sand and connecting the dots in the Monkey Math application, however when he thought he finished tracing or connecting the dots and the iPad did not register his actions, he would go back to his earlier habit of vigorously pressing up and down with his fingers in a dotting motion. In addition, during the exit interview, the researcher showed Participant Four an iPad that displayed screen shots of each of the mathematics applications as well as the activities within the applications. When asked, "What did you tell your mom about using the iPad?" Participant Four responded, "I don't play iPad." Then the researcher asked, "You didn't play with the iPad?" and Participant Four stated, "I like the other iPad." The researcher clarified, "You like the other iPad? You like it when you can press it and play the game? Not the pictures?" To which Participant Four responded by nodding his head yes. Once again this was a demonstration of how Participant Four did not completely understand the usability of the iPad.

Theme two. The second theme for Participant Four was how the iPad engaged and enriched his abilities as it related to his mathematics content knowledge. In his prekindergarten class, Participant Four was the only student who had a mathematics goal on his IEP. His goal written 12/8/11 stated: "He knows how to rote count to 29, he can identify numbers 1-10, and he counts objects to15." However, on his TEMA-3 pre-test, he scored in the above average range (standard score = 119) which reflects a more advanced mathematics knowledge than what is currently defined on his IEP from three months earlier (see Table 7). Specifically, questions on the TEMA-3 he answered correct, reflected his ability to: (a) rote count to at least 42; (b) read numerals 10, 13, 16, 28, 47, and 90; and (c) answer what number comes next after 29, 49, and 69. After the use of the iPads, his TEMA-3 post-test that was administered on March 2, 2012, revealed he scored in the above average range (standard score = 120). He showed improvement in: (a) writing single-digit numbers and (b) Identifying what number comes next after 25, 34, 59 and 6. The researcher observed throughout the study, within the Monkey Math game, he always had high rates of accuracy on the academic content tasks. He was able to accurately answer addition problems (e.g. 4+3=7), pattern completion (e.g. ABABA___), and fill in the blank (e.g. 1 ___ 3 ___ 5). Sometimes when he was asked to choose the shape with a particular number of sides he made errors only when the shape was an octagon. Additionally, in the Monkey Math application, the reward screen was an aquarium with a variety of fish, coral, and sea life decorations that could be added. He systematically removed all the items that were in the aquarium and would first place back the clown fish and sometimes, underwater decorations. However, in the last week of the study, Participant Four began to answer the questions incorrectly so that he the monkey would shake his head no, Participant Four would shake his head no as well and say, "ooo ooo" just like the monkey. Participant Four exhibited that behavior for every question and told the other students in the group to do it as well. As soon as he chose the wrong answer one time and mocked the monkey, he chose the correct answer the second time. Lastly, during the exit interviews, as the screen shots showed an example of the activities within the applications, Participant Four would answer the question that was displayed. For instance, there was a screen shot that had an addition problem of “2+2” and Participant Four stated, “2+2=2.”

Table 7 provides a summary of the students pre and post test scores on the TEMA-3. As noted in the narrative of the themes that emerged for each students in the study, all students but one had scores increase. The decrease in scores for Participant Three in the researcher’s opinion was not due to a loss of skills in mathematics but due to not wanting to complete the assessment due to distractions from her classroom.

Table 7 Pre and Post Mathematics Ability Score as measured on the TEMA-3

Name	Pre Mathematics Ability Score Form A	Post Mathematics Ability Score Form B	Difference
PARTICIPANT 1	66	75	9
PARTICIPANT 2	124	132	8
PARTICIPANT 3	85	75	-10
PARTICIPANT 4	119	120	1

Overall Themes

Building on the themes that emerged for the individual cases, the researcher utilized the software Atlas.ti to analyze the multiple sources of data to discover what overall themes emerged. The sources of data included a records review, the parent questionnaire, TEMA-3 test scores, the observation field notes, the transcripts from the exit interviews of both the teacher and the students, and transcripts of the interview with the teacher prior to data collection. When using Atlas.ti, the researcher typed all the data gathered to have it in an electronic format. To represent the data of the records review, the researcher typed up the notes she had collected during the review. Additionally, the researcher created a table representing the parent questionnaires which was also analyzed. All of the field notes were typed, as were all the transcripts from the pre and post interviews. The data consisted of 120 pages of raw data that the researcher analyzed with Atlas.ti. During the coding process, the researcher assigned a specific code to every word or phrase within the raw data. The codes were: Mathematics Content, iPad Prior Knowledge, technology confidence, nonmathematics application use, technology misuse, fine motor skills, frustration, misuse of Mathematics applications, distractibility, absence, engagement of the iPad, Puppy Math, Monkey Math, 123 Math application, nonengagement, and peer interactions. After the data were coded, the researcher ran an analysis using Atlas.ti that grouped together the codes. Thirty percent of the data were checked for inter-observer agreement an independent rater. After these data were checked, the researcher and the inter observer had 98% agreement on the data. The researcher removed the 2% of the data that did not meet agreement after consensus and review. Therefore, the data that were used in the study had 100% agreement. The codes that supported technology literacy were: iPad prior knowledge and technology confidence, which happened to be 10% of the data. The initial codes that supported academic improvement were: Mathematics Content Puppy Math, Monkey Math, 123 Math application, and peer interactions.

Overarching Themes

The researcher verified that at least three data sources were represented within each of the broader themes of technology literacy and academic improvement. The first theme that emerged across all the cases, was the concept of technology literacy, defined by the U.S. Department of

Education (1996) as "computer skills and the ability to use computers and other technology to improve learning, productivity, and performance." The second theme that emerged across all the cases was academic improvement related to both mathematical content and cooperative learning interactions with peers.

Theme One

Technology literacy was based in the students' prior experiences with touchscreen technology. The teacher explained in the pre-interview, technology was a normal part of the day for the students with the use of the interactive whiteboard in the classroom. During the teacher interview she stated,

> Everyday I use technology, we use it for music, and movement activities. I put songs on there and then kids can see like -- for example like a song. You can see kids doing it, in circle time. We use it for months, of the year days of the week, alphabet, shapes, colors, so they can see a visual like when they are singing January, February, March. They actually see the words.

It was also noted in the parent questionnaires, all three of the participants who returned the survey had prior knowledge using handheld touchscreen technology with the iTouch, iPad, or iPhone. When the iPad was introduced one of the participant's stated, "My dad has one of these." Another student proclaimed, "I own an iPad." The introduction of the iPads was a novelty to the students in the pre-kindergarten classroom. However, prior to the study the students had not used iPads in the classroom. The first day of data collection was chaotic and disorganized as all the students wanted to come to the Mathematics center to use the iPads. On that day, students did not equally distribute themselves among the typical choice of centers ("listening center, music center, blocks, dramatic play, mathematics, science, art" teacher reported at the pre data collection interview). The teacher reported in the post study interview that after the first day, she had to reorganize the students and assign them to groups for centers. The teacher described the group organization:

> Yeah there were four students being studied. So we put each one of those students into a group along w/three others students. So there were four students in a group. We would start them off at one center, and then in 15 minutes we would rotate. So they had four centers they would rotate 2 in 15 minute increments.

The students became very accustomed to the iPads in the classroom and began referring to the center as, the "iPad center" instead of the mathematics center. The teacher stated,

> I think it went real well. I loved how all the children were very eager to want to get on the iPads, and they were really excited about getting on them. To get on them that we had to split them up into groups and rotate simply because they all wanted to go on all the time.

Although the daily access and use of iPads was a novel concept for the students, technology was not, which may have contributed to their technology literacy. The participants demonstrated iPad literacy skills at different degrees of proficiency when using the iPad. The different skills that were observed that enhanced the use of the mathematics applications included: Using the finger swipe to access the applications' screen on the iPad, knowing that they needed to press the home button when the applications began to shake so that the application would not be deleted, having the ability to adjust the volume, using two finger pinching skills to increase the size of the image, and having prior knowledge that when the picture flips on the screen turning the screen will have the picture flip back the right direction. As the data collection continued, the participants identified the power button and proudly stated, "I turned off iPad…Now I know how to turn an iPad off." Another technology literacy skill the researcher observed was the students' acquisition of how to physically set up the iPad using the iPad case. The participants discovered how to prop up the iPad in the case so that the iPad sat on the desk at a 45 degree angle to ease the use of the device. The first student that acquired this skill stated, “I’m going to use it like a computer like this.” An advanced skill the researcher observed was the students swiping the screen all the way to the right or pressing the home button twice to bring up a blank screen with the search bar stating “Search iPad,” and then typing in the name of the mathematics application and tapping on the picture of the application when it appeared. When one participant (or another student in the classroom) demonstrated an iPad skill, the other students would either observe how to do the skill (i.e. turning off the iPad or propping it up) or would ask the peer for assistance to acquire the skill which increased their performance and proficiency of using an iPad for all the participants. Some additional skills that were observed were knowledge of tilting the screen from left to right to move the beads in the abacus as well as immediately putting one’s fingers in position to type when the keyboard was displayed on the screen.

Additionally, the participants demonstrated different skills that distracted from the use of the mathematics applications that included adding events and birthdays to the calendar application. One participant stated, “We have to write down an event. Today is Kelly’s social studies event I forgot. I will write down events. Like Kelly’s social studies event.” On another day the same student stated, “I will remember President’s Day.” When the researcher was “clearing” the iPads post data collection she discovered students had inputted their individual birthdays accurately in the calendar. On another instance, a student turned the airport mode OFF and stated, “I know there is Wi-Fi at Barnes and Nobles. I turned the airplane mode to off. I know what it’s going to do.” Prior to the researcher increasing the restriction on the iPad, the participants were utilizing other features of the iPads such as: using the camera to take pictures and video, looking through the album of pictures other students had taken, opening iTunes, opening the mail application, and utilizing FaceTime application to watch themselves,

The feature of changing the wallpaper and home screen could not be restricted on the iPads and throughout the data collection on a daily basis participants spent time changing the wallpaper and home screen. On one instance the participant proudly stated, "I changed the wallpaper." Some students were satisfied with just making the change and then would re-engage with the mathematics applications; however, it was noted other participants would engage for 2-3 minutes just changing the wallpaper and home screen. One of the participants chose an Earth as the picture for the wallpaper and stated, "Look the Earth. I can see the Earth."

Technology literacy. Technology literacy was also observed in the vocabulary the students demonstrated regarding an iPad and technology. Specific phrases that were recorded were: "Did someone take my file?" or "What happened to my file?" or "You deleted it." or "I want to download a game." For the last day of data collection, the researcher put additional mathematics games on the iPad and the participants were heard saying, "She downloaded new games on here." One of the participants stated, "You want to download Angry Birds? Then you go to the game center and download." The technology literacy that was observed was a result of prior use with other mobile technologies such as the iTouch, iPhone, or iPad.

Theme Two

The second overall theme that emerged was academic improvement related to both mathematical content and cooperative learning interactions with peers. The three applications that were placed on the iPads were: Monkey Math, Park Math, 123 Numbers. The data coding revealed that the Monkey Math game was launched 67 times during data collection, the Park Math game was launched 52 times and the 123 Math application launched 18 times. During this data collection period, the researcher recorded the students' preference for the Monkey Math application. During the exit interviews each of the students reported liking all the applications. The mathematical skills explored through play in the Monkey Math application included: finding the shape with the given amount of sides, completing patterns, identifying written numbers, identifying numbers represented by pictures, tracing numerals, filling in missing numbers, using simple addition, identifying the smallest numerals, and counting. The mathematical skills explored through play in the Park Math application: adding, subtracting, counting, balancing, ordering sorting, matching patterns, and using one to one correspondence. The mathematical skills explored through play in the 123 Math application included: tracing numbers, counting, identifying how many, and filling in missing numbers. The researcher administered a pre and post test of the TEMA 3 to provide a quantitative measure to assess the participants' mathematics content knowledge. Three out of four of the participants standard scores increased on the TEMA 3 on their post test as compared to the pre test. Table 8 provides a detailed account of the participants' pre and post TEMA 3 scores. The basal scores are highlighted in light grey and the ceiling items are highlighted in dark grey.

Table 8 TEMA 3 Pre and Post Test Comparisons

Entry Point	Item #	Item Name	PARTICIPANT 4	PARTICIPANT 4	PARTICIPANT 2	PARTICIPANT 2	PARTICIPANT 3	PARTICIPANT 3	PARTICIPANT 1	PARTICIPANT 1
			A	B	A	B	A	B	A	B
Age 3	1	Perception of Small Number	1	N/A	N/A	N/A	1	N/A	N/A	N/A
	2	Produce Finger Displays: 1, 2, Many	1	N/A	N/A	N/A	1	1	1	N/A
	3	Verbal Counting by Ones: 1 to 5	1	N/A	N/A	N/A	1	1	0	N/A
	4	Perceptions of More: Up to 10 Items	1	N/A	N/A	N/A	1	1	0	N/A
	5	Nonverbal Production: 1 to 4 Items	1	N/A	N/A	N/A	1	0	0	1
	6	Enumeration: 1 to 5 Items	1	N/A	N/A	N/A	0	0	0	0
Age 4	7	Cardinality Rule	1	N/A	N/A	N/A	0	0	0	0
	8	Nonverbal (Concrete) + & -	1	N/A	N/A	N/A	0	0		
	9	Number Constancy	1	N/A	N/A	N/A	0	0		
	10	Produce Sets: Up to 5 Items	1	N/A	N/A	N/A	1			
	11	Produce Finger Displays to 5	1	N/A	N/A	N/A	1			
	12	Verbal Counting by Ones: 1 to 10	1	N/A	N/A	N/A	1			
	13	Number After: 1 to 9	1	N/A	N/A	N/A	0			
	14	Reading Numerals: Single-Digit #	1	N/A	N/A	N/A	1			
Age 5	15	Writing Numerals: Single-Digit #s	0	1	1	1	0			
	16	Concretely Modeling + Word Problems: Sums up to 9	1	1	1	1	0			
	17	Part-Whole Concept	0	0	0	0	0			
	18	Written Representation of Sets up to 5	1	1	1	1	0			
	19	Choosing the Larger Number: Number Comparisons 1 to 5	1	1	1	1	0			

Table 8 TEMA 3 Pre and Post Test Comparisons										
	20	Choosing the Larger Number: Number Comparisons 5 to 10	1	1	1	1				
	21	Verbal Counting by Ones: to 21	1	1	1	1				
Age 6	22	Number After: 2-Digit Numbers to 40	0	1	1	0				
	23	Enumeration: 6 to 10 items	1	0	0	1				
	24	Verbally Count Back from 10	1	1	1	1				
	25	Equal-Partitioning: Fair-Sharing of Discrete Quantities	0	0	0	0				
	26	Mental Addition: Sums 5 to 9	0	0	1	1				
	27	Mental Number Line: 1-Digit #s	1	1	0	0				
	28	Produce Sets: Up to 19 Items	1	1	0	1				
	29	Reading Numerals: Teen Numbers	1	1	1	1				
	30	Writing Numerals: 2-Digit Numbers	0	0	1	1				
	31	Verbal Counting by Ones: Up to 42	1	1	1	1				
Age 7	32	Counting on from the Larger Addend	1	0	0	1				
	33	Verbal Counting by 10s: Up to 90	1	1	1	1				
	34	Symbolic Additive Commutativity	0	0	0	0				
	35	Reading Numerals: 2-Digit Numbers	1	1	1	1				
	36	Number After: Decades	1	1	1	0				
	37	Mental Number Line: 2 Digit #s	0	0	0	0				
	38	Enumeration: 11 to 20 items	1	0	0	0				
	39	Number After: 2 Digit Numbers to 90	0	1	0	1				
	40	Verbally Count Back from 20	1	0	1	1				
	41	Subtraction Facts: N-N & N-1	0	0	0	1				

	42	Verbally Counting by 10s: 100 to 190	0	0	1	1				
Age 8	43	Addition Facts: Sums up to 9	0	0	0	0				
	44	Reading Numerals: 3-Digit Numbers	0	0	1	1				
	45	Writing Numerals: 3-Digit Numbers	0		0	0				
	46	Addition Facts: Sums of 10 & Small Doubles			0	0				
	47	Tens in One Hundred			0	1				
	48	Number After: 100 Terms			1	1				
	49	Written Addition Accuracy: 2-Digit Addends & No Carrying			0	0				
	50	Subtraction Facts: M-N=N			0	0				
	51	Addition Facts: Large Doubles			0	0				
	52	Mental + / - : Decade +- 10			0	1				
	53	Hundreds in 1000			0	0				
	54	Multiplication Facts: Nx0 & Nx1				0				
	55	Written Subtraction Procedure: Alignment				0				
	56	Subtraction Facts: 10 - N				0				
	57	Adding Multiples of 10				0				
Raw Score			31	31	34	42	9	4	2	5
Mathematics Ability Score			119	120	124	132	85	75	66	68

Mathematical content. The first element of the overall theme of academic improvement that was observed was mathematical content; the academic observations made during the iPad use included students using their fingers to count the sums for addition problems, pointing to objects or the sides of shapes on the screen, and using one on one correspondence to solve problems. The participants' accuracy rates did improve over time. At the outset of the study, participants were observed needing more than one attempt to answer the questions correctly, while at the conclusion, many were able to answer the questions correctly the first time. Within the first week of data collection one of the participants stated, “I can’t do it” when he had to trace the number two in the Monkey Math application. Another student required all four attempts to answer an ABAB pattern and stated, “Oh my god” after getting the answer correct in the final attempt. When Participant Two had to put the animals from smallest to largest in the Park Math application, he turned to me and stated, “It is VERY hard.” The teacher also felt that the use of iPads was beneficial, “I really think it enhanced their learning because they were that excited, and they were having fun while they used the iPads.”

Overall, the participants’ confidence seemed improved over time with such statements as, “It is so easy to trace the nine.”; another student stated, “I can do it.”; “WOW!”; one student shouted out “Yeah Baby!” after he popped all the bubbles correctly in the Monkey Math application. During the third week of data collection, Participant Two turned to the researcher and said, “I know a lot of math”; another student was very proud when he popped 10 of the bubbles correctly in the Monkey Math application and stated, “I win.” On one of the data collection days, Participant One had to trace then number five in the sand, and when he successfully completed the task he stated, “I’m 5”. During the exit interview, Participant Four stated, “I really like those numbers [referring to the 123 Math application] and you have zero, one, two, and three…”

One of the more difficult tasks within the Park Math application was balancing the seesaw on the left and right side with an equal amount of mice. At the beginning of data collection, when all of the participants chose the task, they would make a quick unsuccessful attempt at balancing the seesaw, and then quickly change tasks within the application or leave the application all together. However, during the third week, two of the participants (Participant Four and Two) were successful in balancing the seesaw, they both had the same strategy of taking all the mice off the seesaw and then placing them back one by one. Overall the participants' confidence in solving the problems improved over the course of the study, for example Participant Two stated, "I know 5-3" when he solved a problem correctly in the Park Math application. Therefore as the students used the iPads over the four weeks and became more comfortable with the technology, they became more successful with the more difficult content within the three mathematics applications over time.

Cooperative learning interactions. The second overall theme that emerged was cooperative learning interactions with positive peer interactions. During the exit interview, the teacher stated that the all the students enjoyed working together in the center and got along well while using the iPads. Additionally, during the participants' exit interviews, the researcher presented the iPad with screen shots to prompt the discussion about the applications with the participants. When the researcher asked the participants about the applications, they all responded favorably and stated that using the iPads was "easy." When referring to the Park Math game Participant Three stated, "I like the paint. I like the ducky game." The researcher observed peer interactions throughout the data collection period. Students often assisted each other as it related to the use of the iPad (i.e. turning it on, increasing or decreasing the volume, changing the wallpaper, navigating the applications, and answering the questions). The participants were heard saying, "I want to play like you" and were observed giving each other a "thumbs up" for encouragement. When the iPads were new and novel items the students had a difficult time sharing. For example, if a student attempted to touch the iPad a participant was using, the participant would pull the iPad away or physically removed the student's hands off the iPad. As the weeks of data collection continued, the participants would lean over to each other's iPads and help answer questions or navigate the iPad. Or they handed their iPads to each other to get assistance, Participant Three stated, "How do you do that?" and pushed her iPad to him to have him get to the same activity he was playing. Also, the participants would show their iPads to each other to display their accomplishments, "Look what I am doing." The group member responded, "Oh I want to try that." Additionally, the participants began to talk about the content as well, "I fed the hippo three watermelons too" or "Now I am coloring the number one." They would encourage each other to play the application that they were playing. Participant Three told a group member, "Press Park Math with me. Do the same thing I am doing." When the peer interaction increased and the dialogue related to the use of the iPads and the mathematics applications, the participants began to explore all three applications in depth.

Conclusion

The exploration of the developmentally appropriate use of mathematics iPad applications for children with developmental disabilities in a voluntary pre-kindergarten classroom for educational purposes, revealed both individual and overall themes aligned to the twelve research-based principals from Bredekamp and Copple (2006). Specifically, themes that emerged from the participants using the mathematics applications on the iPads, aligned to,

> …belief that children's development-physical, social, emotional, and cognitive are closely related; development is influenced by multiple social and cultural filters; children are active learners; play is an important component to promote social, emotional and

> cognitive development; development advances when students acquire new skills as well as when they are challenged beyond their current skills; (Bredekamp & Copple, 2006, p. 9-15).

The multiple sources of data: (a) records review, (b) test results of Early Mathematics Ability-3, (c) parent questionnaire, (d) field notes, (d) interviews, and (e) iPad use calendar were analyzed to identify the themes. Eight individual themes emerged that were specific to the participants: difficulty with the content, difficulty with the technology, distractibility, collaboration, digital vocabulary, iPad proficiency, usability, and mathematics content. Additionally, two overall themes emerged that encompassed all the participants; technology literacy and academic improvement related to both mathematical content and cooperative learning interactions with peers. The TEMA-3 was given as a baseline measurement to explore if there was an impact from using mathematics applications on an iPad on mathematics achievement. For three out of the four participants, the quantitative evidence collected with the TEMA-3, "…bolsters findings…[because] it corroborates those findings from qualitative evidence" (Eisenhardt, 1989, p. 538) that the iPads influenced the mathematics achievement scores of the TEMA-3. The themes revealed both strengths and weaknesses of providing iPads to students with developmental delays in the voluntary pre-kindergarten classroom. The findings from this initial investigation will enable researchers to develop hypothesis based on these four cases to design future quantitative and qualitative research studies.

CHAPTER FIVE: DISCUSSION

This study explored the developmentally appropriate educational use of mathematics iPad applications for children with developmental delays in a voluntary pre-kindergarten classroom. This research utilized a case study research design to systematically investigate a phenomenon to improve, inform, or understand (Yin, 2009) how students with developmental delays utilized the iPads with mathematics applications. Data collection and analyses were dependent on multiple sources of information including: (a) records review, (b) pre and post Test of Early Mathematics Ability-3, (c) parent questionnaire, (d) field notes, (e) observations, (d) teacher interviews, and (e) student interviews. The data were analyzed and triangulated for themes across sources utilizing the Atlas.ti software. The results of data analyses revealed individual themes for each case as well as overall themes for all the cases. This chapter opens with a discussion of the demands and challenges of utilizing iPads in the voluntary pre-kindergarten classroom and includes a discussion of expected and unexpected findings of this study, underscored by a summary of themes that emerged during the data collection. Next, the researcher provides a discussion of the findings of the study as they relate to existing research and a description of the limitations of the findings. Implications for future research based on findings of the study are discussed, followed by a conclusion of the findings of this study that explored the developmentally appropriate educational use of mathematics iPad applications for children with developmental delays in a voluntary pre-kindergarten classroom.

Demands and Challenges

Although the site for data collection was a school that has a commitment to integrating technology across the grade levels the only access to technology the students had, in the voluntary pre-kindergarten classroom, was one large touchscreen interactive whiteboard. Therefore, when the iPads were introduced in the mathematics center the first day every student wanted to use the iPads and did not want to leave the mathematics center. In addition, on the first day multiple students attempted to use one iPad simultaneously and the participants became upset. After the first day of data collection, the classroom teacher proposed dividing the students into four groups of approximately five students (see Table 2) to make the iPad implementation more manageable and less chaotic. To facilitate the data collection, one participant was assigned per group, therefore the researcher only had to focus observations on one participant in the group per rotation. Implementing the center rotation provided a structure to insure that all the participants had access to the iPads, however since the rotation schedule lasted thirty minutes per rotation, the participants were forced to leave the center when the teacher called out “time to switch” and the students were redirected to stay in the center they were assigned for each rotation. The students could not choose their own activities within the classroom due to the implementation of the study. The decision to have students stay was one made by the classroom teacher and not the result of a request by the researcher. This lack of choice, in the opinion of the researcher, caused the rotation schedule to be less developmentally appropriate. If the classroom center time schedule included an adult who facilitated the mathematics center and the iPads, the schedule could have been less structured and more developmentally appropriate. The participants who wanted to leave the center out of frustration or boredom then could have asked the adult for assistance or could have received prompting to re-engage with the mathematics applications on the iPad. Additionally, if more students, than the amount of iPads wanted to come to the center, the teacher could have facilitated a turn taking or sharing of the five available iPads.

One environment challenge was the distracting stimuli from other center choices during the center rotations including: play dough, art, housekeeping, building, writing, and interactive whiteboards. The use of the iPads was affected when the participants and other students in the voluntary pre-kindergarten classroom did not want to come to the mathematics center or use the iPad, causing the use of the iPads to be inconsistent (see Table 6). On a number of instances, the researcher observed the participants at the mathematics center distracted by the students using the interactive whiteboards. An additional environmental challenge related to the other centers, was the physical proximity of the adults in the classroom. In the room were three adults stationed at particular centers (i.e. play dough, art, the interactive whiteboard). Therefore no adult was available to assist the students who required help with the iPads at the mathematics center. The students and participant in the iPad center attempted to engage the researcher for directions, confirmation, and/or reinforcement. The researcher repeated to the students and participants, “I am a researcher, I cannot help you with the iPads. I am just watching.” The researcher made an attempt to reengage the students with the iPads with non verbal prompts. The participants, as well as the other students could have benefited from an adult at the table or at least a level of monitoring the center by asking questions and getting assistance when the students were frustrated by features of the mathematics applications. The support of an adult would be particularly beneficial for students with developmental delays that affect their ability to use the iPads independently or by students who were easily distracted from the mathematics applications.

In an attempt to have the implementation of the iPads be developmentally appropriate and maintain the role as the researcher, there was no prior instruction provided to the teacher on how to implement the iPads. Prior to the study, the teacher was asked about her comfort level with handheld technology and she stated that she had experience. The teacher was asked by the researcher to introduce the iPads as she would any new item to her classroom. However, the teacher did not initiate providing instructions to the students and participants on how to use the iPad,. The teacher expressed concerns during data collection that the students might break the iPads. Once again, this was not from a lack of experience with mobile technology. The teacher stated she had personal experience with mobile touchscreen technology, however she had not had opportunities to utilize mobile technology in her classroom prior to the study. Therefore, she was apprehensive on the use of the iPads as a sense of responsibility to the safety of the iPads. Although the researcher continued to reassure the teacher prior to data collection that the iPads were durable with the silicone covers, when the study was implemented, the teacher requested that the iPads not be laid out on the iPad table at the mathematics center, like the other mathematics manipulatives. Instead, the iPads were on the center of the table next to the mathematics center bookshelf. The students were very respectful of the iPads and had very few incidents in which they handled the iPads too roughly or inappropriately. The location of the iPads may have contributed to the monopolized use of the iPads over any other mathematics manipulative at the center. In the future, the researcher would design and implement a protocol of how to handle the iPads for the participants as well as an age-appropriate user guide for simple operations of the iPad. This protocol would be developed based on the observations and findings from the participants, with developmental delays, in this study which confirmed the findings from Chiong and Shuler (2010) approximately 47% of the early childhood children in the study required an adult to assist them when using touchscreen technology. The protocol for the lesson would include a broad over view of how to handle an iPad,including how to carry it and place it on the table. Additionally, the lesson would introduce the iPad’s features, such as the power button, the home button, and the volume. The lesson would also address usability of the iPad such as how to use the touchscreen with one finger, the pinch motion to increase and decrease the image on the screen, how to slide you finger to drag objects on the touchscreen, and how to lock the screen. Chiong and Shuler (2010) findings aligned with the observations of this study that the difficulties young children experienced with operating the iPad included using their fingers to swipe across the screen. More advanced instruction would include how to prop up the iPad on the case.

Initially, teachers should introduce the iPads in a group setting, perhaps during circle time. The teacher will need to model how to handle and use the iPad. Then, when the iPads are introduced to the class, an adult needs to be present at the center to monitor the usability and to reteach students as needed. Having an adult present at the center may decrease the frustration of the users as well as decrease the distractibility. Additionally, prior to introducing any new applications, the teacher should explore and learn the features of the games within the applications to model how to navigate the application and teach any new functions.

Expected and Unexpected Findings

Based on prior experience with using handheld held technology with the early childhood population, the researcher expected the participants with developmental delays would be highly engaged with the iPads. However, the fact that the novelty of the mathematics iPads applications decreased, over the 19 days of data collection, was an unexpected finding. The themes from the data collection revealed that the participants with developmental delays became distracted from the iPads and became engaged and interested in the more common centers within the classroom such as the play dough and the interactive whiteboard in the classroom. The interactive whiteboard may have been more engaging to two of the participants due to the teacher support at that center as well as the nature of that center with students working collaboratively. The participants were distracted from the mathematics applications and spent time exploring the iPad's other features and functions. Additionally, there were instances when the participants did not want to come to the mathematics center to use the iPad or when participants wanted to leave the center early to go to another center. Once again, if the centers were designed following purely developmentally appropriate practices, then the participants would have come and gone from the centers as they chose, versus under the direction of the teacher and based on a rotation schedule. Also, if the iPads were available in the classroom consistently, the teacher should add new academic, developmentally appropriate applications frequently to keep the level of engagement high as well as utilize other features of the iPads for content enhancement (e.g. the camera, video camera, and the calendar). Additionally, the iPad applications need to match the skills of the individual students versus using the same applications for all the students. Educators who choose to utilize applications for content enhancement should align the games within the applications to the grade level standards and the students abilities to work independently at a certain skill level.

An additional unexpected finding was that some of the functions within the game, that seemed natural or easy, were quite difficult for the participants. The researcher observed difficulty with participants' dragging their finger to move images across the screen. Once again, implementing a protocol on how to use the iPad would include instruction on which fingers to use and how to manipulate the screen to have success prior to introducing the iPads and prior to the introduction of any new application. In addition, Participant Four who received OT could have benefitted from working with his support team of specialists on the iPad to ensure less frustration with the physical expectations of using this tool.

In an attempt to structure the post study interviews, the researcher interviewed the participants to obtain their perceptions of utilizing the iPads for mathematics enhancement based on the usability study protocol (Chiong & Shuler, 2010). Based on the observations over the 19 days of data collection and the participants consistently attempted to communicate with the researcher, the researcher expected rich interviews with the participants describing their time with the iPads. However, the post data collection interviews with the participants were difficult to transcribe because the participants were unintelligible due to articulation and overall they were not very descriptive when discussing their time using the iPads.

Summary of the Themes

As a result of the data collection and the uniqueness of the individual participant, the researcher initially analyzed the data as it related to each participant. The participants all met the inclusion criteria of the study: they had a developmental delay from an environmental factor and they attended a full time voluntary pre-kindergarten enrollment in an inclusive classroom with a highly qualified teacher. However, the unique personalities, skills, and interest levels of the participants individualized the findings of the study. Remembering that technology is a tool, not the answer, the iPad is a mobile technology tool, that could be utilized to individualize instruction to a student. However, the nature of this study was specific to three mathematics applications, that were aligned to three sets of standards, so the iPads were all configured the same versus being individualized.

During the data analysis, the researcher determined the individuality of the participants necessitated individual themes for each participant and allowed the researcher to answer the research questions: How do students with developmental delay in an inclusive Pre-Kindergarten class use mathematical applications on the iPad? and How do students with developmental delay in an inclusive Pre-Kindergarten class change their engagement with mathematical applications on the iPad over time? Interestingly, after data analysis, the researcher realized the two themes for each participant were unique to the individual but related to both questions.

Participant One. The two themes that emerged for Participant One were: (a) difficulty as it related to both the technology and the mathematics content and (b) distractibility from the mathematics applications. Both of Participant One's themes were similar and were most likely a representation of his personality as well as his skills. Within his social history, his mother identified concerns with Participant One's attention and activity levels. However, when an adult was available to work with him on the iPad he was more focused on the iPad and mathematics content. Gimbert and Cristol (2004) found that mobile technologies, such as the iPad, can be used to enhance attention span as well as learning. Additionally, if the iPads were available in the classroom consistently, Participant One could come and go from the iPad at his will without having a feeling of missing other centers (e.g. the interactive whiteboard). Finegan and Austin (2002) reported that a student should make the choice of which learning centers to visit, what learning resource they utilize (i.e. technology) and the length of time the student engages in the activity. Therefore, to utilize technology in the future for Participant One, a variety of content (i.e. Mathematics, Science, Language Arts, Reading) applications should be utilized to maintain his attention. Additionally, Participant Two was drawn to a specific program on the interactive whiteboard, the teacher could researcher if they are available for the iPads (i.e. BrainPop Jr.).

Participant Two. The two themes that emerged for Participant two were: (a) his use of digital vocabulary as it related to the iPads and (b) proficiency with the iPad technology. Once again, both of Participant Two's themes were related. Both themes also support the findings of Haugland (2000) that students in pre-kindergarten are developmentally ready to explore technology and need time to experiment. Amongst all the participants he was the user who was most interested in the iPad as a form of technology, he was attracted to digital media and enjoyed using the iPad (Gee, 2008; Gutnick, Robb, Takeuchi, & Kotler, 2010). Participant Two was representative of the approximately 83% of children ages six months to six years who use some form of screen media in a typical day (Rideout, Foehr, & Roberts, 2010; Rideout, Hamel, &

Kaiser Family Foundation, 2006). The theme of proficiency with the iPad was representative of Participant Two's prior use of the iPad, just as Chiong and Shuler (2010) found that two thirds of the students ages 4 to 7 surveyed had used an iPhone. Unfortunately, Participant Two did not return his parent questionnaire, therefore his prior home use was unknown. His interest in technology should continue to be nurtured and technology should be utilized within his academic learning. When choosing applications for Participant Two, the teacher should be conscientious to allow the mathematics applications to continue to challenge him academically to continue to foster his interest with the technology and enhance his learning.

Participant Three. The two themes that emerged for Participant Three were: (a) her need to work collaboratively with one of her peers and (b) her distractibility when using the iPads. Once again, the two themes that related to Participant Three overlapped because she was distracted with her peer's actions with the iPad instead of using her iPad individually to play mathematics applications. The need to work collaboratively aligned to NAEYC statement that "technology can enhance children's cognitive and social abilities" (p. 4) as the iPads were integrated into the environment. To foster Participant Three's desire to interact with her peers, choosing applications that allow multiple players so she could take turns learning, playing, and interacting with her peers. The technology should be incorporated into the environment in a meaningful way, such as learning centers, and the content should be developmentally appropriate (Finegan & Austin, 2002) which would reduce the distractibility of the user. Additionally, a student like Participant Three would benefit from an adult at the iPad center to help keep her focused on her iPad versus on her peer's iPad. Additionally, Participant Three was very interested in the video camera and taking pictures, the iPad camera could be utilized in content instruction as well (e.g. take pictures of 4 red items around the room).

Participant Four. The two themes that emerged for Participant Four were: (a) his ability to use the iPad, which will be referred to as his usability and (b) mathematics content knowledge. The themes for Participant Four were related in that he initially experienced difficulty with the iPad that continued, but improved throughout the study, regardless, his mathematics content knowledge improved during the time of the data collection which aligns to Ginsburg, Inoue, and Seo's (1999) findings in their investigation of the impact of hands on learning and play on mathematics content knowledge. Additionally, these findings support the findings from Young-Loveridge (2004) concluding that when students utilize content through play, such as games, the students' mathematical concepts improve. In the case of Participant Four, the iPad, impacted his individual learning outcomes through the use of the mathematics applications (Murphy, 2011). Over the length of the study, Participant Four's accuracy in answering the mathematics content questions correctly within the application improved. The teacher should provide him with teacher or therapist supported use of learning with technology as a tool.

Summary of Findings and Current Literature

The literature contained limited existing empirical studies that focus on early childhood, mathematics (Fox & Diezmann, 2007), technology, and children with developmental delays. However, Kazdin (2008) recommended researchers focus on improving outcomes for children by limiting the research focus to investigate the desired outcomes for children in ECSE and evaluating what practices have been effective. The following section aligns the current literature to the findings of this research study that explored the developmentally appropriate educational use of mathematics iPad applications for children with developmental delays in a voluntary pre-kindergarten classroom with mathematics applications.

Clements and Sarama (2008a & 2008b) designed the Building Blocks Mathematics software utilizing puzzles and art. The three applications, 123 Numbers, MonkeyMath, and Park Math HD, from the iPad study provided opportunities for the students to demonstrate mathematics concept knowledge utilizing puzzles and art. Additionally, the empirical evidence from two randomized studies with the Building Blocks program demonstrated improved mathematics achievement utilizing technology as did the achievement data for three out of four of the participants within this qualitative research study.

The Number Worlds curriculum (Griffin, 2004) was based on five principles that incorporated activities, play and games in mathematics, similarly, the three selected iPad applications included four of the five principles. The first principle, builds on current content knowledge, was represented for all the students because the first five questions, which every student answered most of them correctly, on the TEMA 3 evaluated: numbering and numbering comparisons. Similarly, all three of the applications had activities that practiced and reviewed numbering and numbering comparisons. The second principle, follows a developmental progression to select new content, was demonstrated by the researcher when choosing the three applications since they were all selected based on the alignment to national and state pre-kindergarten standards. The third principle, allows students to acquire conceptual knowledge and computational fluency simultaneously, was easily accomplished by the applications since they all provided multiple opportunities to practice the mathematic concepts in a variety of ways. The fourth principle that paralleled the iPad research, provides hands-on learning and problem solving, was a natural feature of the iPad since the games all required using the touchscreen to answer the questions. The final principle from the Number Worlds curriculum was to expose students to ways other societies talk about and represent numbers (Griffin, 2004). This principle was not demonstrated in this particular research study, but could be incorporated into future research utilizing iPads by using some of the applications on the market that allow the user to change the language in which the content is presented.

Many lessons were learned when the researcher implemented iPad use in the inclusive pre-kindergarten classroom. The first day of the iPad investigation, the iPads were an option during the center time (i.e. free choice time) and multiple students attempted to use one iPad simultaneously. Therefore, after the first day of having the iPads available in the classroom, the researcher and teacher redesigned the class schedule to a rotation schedule with the iPads as an option during the mathematics center and every student had the opportunity to go to the mathematics center during the center time. Out of the nineteen days of data collection, three out of four participants came to the mathematics center each day, where one of four came sixteen out of the nineteen days. When the participants came to the mathematics center, they only chose to use the iPads at that center. This finding aligned to the findings of Ginsburg, Inoue, and Seo (1999) in their investigation of 4 and 5 year olds. They found that during free play, 88% (79 out of 90) of the students engaged in at least one mathematical activity and the students on average engaged in mathematical activities 43% of the time during free play (Ginsburg, Inoue, & Seo, 1999).

One of the emerging themes of the study was the concept of what perceived to be some level of academic improvement in mathematics with the iPad. Young-Loveridge concluded when students utilize authentic materials actively through game play the students' mathematical concepts improve. Although there was additional mathematics instruction in the class, many of the activities within the three applications in the iPads, were game based. Specifically, the application the participants played the most was the Monkey Math Application. The monkey within the application cheered and made noises to encourage the participant as they engaged in mathematical activities. Additionally, the participants earned rewards for correct mathematical responses by being given the option to place items into an aquarium at the end of the game. These findings were similar to Young-Loveridge's (2004) findings of play and mathematics achievement.

Lastly, another theme that emerged with Participant Four was his improvement with mathematical concepts. During the data collection, the researcher observed the participant answering questions correctly on the iPad within the applications and with the use of virtual manipulatives which appeared to have translated into improved Post TEMA-3 scores for this particular participant. Similiarly, Manches, O'Malley, and Benford (2010) conducted an exploration study to evaluate how students use virtual manipulatives versus physically manipulatives with 65 students in one school. Their findings revealed no statistically significant difference occurred between the use of virtual and physical manipulatives. Even though there was not a statistically significant difference in students increased outcomes in mathematics, these findings and the findings from the research study support the use of technology as a tool, to increase engagement and promote 21st century learning skills in mathematics.

Limitations

Multiple data collection procedures as well as applications selection procedures were utilized to increase the credibility of the research findings (Gast, 2010). One limitation of the study relates to the available personnel within the classroom. For many of the students, including the participants, their experience using iPads was limited, therefore they required an adult's assistance. The results of not having an adult at the table with them during center time, was that the participants were often distracted by non mathematics applications on the iPad instead of using the designated mathematics applications. Additionally students were distracted by each other and made inappropriate choices in their language as well as using the iPads inappropriately. Finally, since the data collection was heavily dependent on observation, field notes, and interview themes, the data and data analyses were subjective.

Additionally, another limitation was working around the existing class schedule which included an arts integration teacher coming to the class twice a month at 9:30 am, which only allowed 30 minutes of center time. To assist the researcher with data collection, the teacher rearranged the schedule during those two instances to insure the four identified participants used the iPads for the day. The school calendar also proved to be a limitation with Valentine's Day occurring during the month of data collection and the teacher requested not to have center rotations to accommodate her scheduled holiday activities. Finally, since the center time rotations became longer than the scheduled time circle time was decreased. This decrease may have impacted the mathematics instruction of the students since the voluntary pre-kindergarten teacher utilized circle time to introduce and review mathematics concepts through the calendar, literature, and activities using the interactive whiteboards. In the same vein, the students all used the iPads if they came to the mathematics center, therefore during the 19 days of data collection, the students did not play with the traditional mathematics manipulatives that were available in the classroom.

Additionally, the students' attendance, as well as therapy sessions, were limitations in this study (see Table 2). Three out of the four participants were absent at least two of the days during data collection. Frequently the therapist sat with the participant while the participant was using the iPad, however one of the days of data collection a participant had to leave the room to receive therapy.

Lastly, the Participants might have been impacted by the specific category that qualified them for special education, developmental delay. The one participant with fine motor needs who received occupational therapy had difficulty with the touchscreen at times and would have benefited from explicit user instructions by a teacher or a therapist. Just as the student with attention deficits lost focus and became distracted would have benefited from adult guidance and instruction when using the iPad mathematics applications. Overall, adult support and instruction could help bridge some of the delays the students displayed by providing explicit instruction, error correction, and positive feedback.

Implications of the Study

As the need for quality early mathematics instruction increases (NCTM, 2000), coupled with the increased access to technology for many pre-kindergarten students (Chiong & Shuler, 2010) the data collected and results of this exploratory qualitative research will enable the researcher to develop future quantitative studies are grounded in experience (Branlinger et al., 2005). The National Association for the Education of Young Children believes "Early childhood programs have an obligation to use technology to bridge the digital divide" (2011, p. 4) just as, the focus of the inclusive school utilized for data collection is on technology and project-based learning for all students, including students with disabilities. Therefore, these research findings of student interest, engagement, and improved mathematics outcomes align to the school's mission and will be shared with the administration at the school. The research study revealed the success of utilizing iPads during center time for students with developmental delay with just four iPads, which is an investment of approximately $1600 which is a relatively low cost for m-learning devices (Melhuish & Falloon, 2010; Shuler, 2009a).

Johnson et al. (2011) defined the use of a mobile technology with different types of content, including games, applications, and videos as "Personal learning environments" (PLE; p. 8). The iPad is one example of a mobile technology that lends itself to developing a PLE for individual students. As the researcher discovered in the study, the predetermined applications did not engage the four participants equally and therefore may not have been a tool that created a PLE for some students. When utilizing the iPads for classroom use, the researcher recommends individualizing the iPad applications to meet the needs of the individual students.

Shuler (2009) identified hundreds of educational applications available in the iTunes App store and discovered 35% of the top 100 education applications targeted preschool age children. However, after the researcher evaluated fourteen applications, it was uncovered that only the three applications utilized in the study comprehensively covered national and state standards. Therefore, the information from the applications analysis will be disseminated through national and state peer-reviewed journals and presentations with a focus on early numeracy as well as children with developmental delays in an inclusive classroom. In conjunction with the application analysis a parent focused article will disseminated as well to help guide parents in choosing the right apps for their children. The purpose of this dissemination activity is to provide parents with a tool to identify apps that align with quality indicators linked to state and national standards as well as addressing restrictions that can be put on an iPad beyond the traditional parental controls.

Previous empirical studies contributed to the rational of this study. Cutler (2011) recommended making mathematical moments playful, including playing with puzzles, games, patterns, and shapes, the applications that were selected provided many opportunities to practice these principles. Based on the findings from this study the researcher developed theories and concepts to further design research studies, measuring academic growth as it relates to the use of iPad mathematics applications, (Giangreco & Taylor, 2003) for students with DD. However, due to the non mathematics applications becoming highly distractible for the participants and diverting their attention from the desired mathematics applications, the researcher created a protocol for setting the security restrictions on the iPad. Additionally, Ramani and Siegler (2008) found that exposure to numerical concepts through games and play prior to entering kindergarten improves the foundation of mathematics and since there was improved academic outcomes on the TEMA-3 by three out of the four participants, the researcher recommends investigating academic outcomes for students with developmental delays utilizing a single subject research design or a large group design.

Duncan et al., 2007 found that a student's mathematics skills at the start of kindergarten are a stronger predictor for school success than reading, social skills, or attention skills. Findings from the National Mathematics Advisory Panel (2008) indicated positive effects of instruction infused with technology on mathematics achievement. Further, the Division for Early Childhood (DEC) of the Council for Exceptional Children (CEC) recommended incorporating technology into the classroom to provide instruction and for educational use (2009). Therefore, the results of the study of the developmentally appropriate educational use of mathematics iPad applications for children with developmental delays in a voluntary pre-kindergarten classroom suggest certain mathematics iPad applications can be a tool utilized to increase mathematics outcomes and technology engagement for students with developmental delays. The results of this research study will inform future investigative efforts of the researcher on the use of technology tools with content aligned to national and state standards in pre-kindergarten classrooms to increase student with and without disabilities outcomes in mathematics. Lisenbee (2009) recommended capitalizing on young children's curiosity with technology and embedding technical tools into the classroom environment, therefore utilizing technology. Tools like the iPad, coupled with teacher support and assistance, have the potential to impact many students with developmental delays in pre-kindergarten classrooms in the area of mathematics.

APPENDIX A: DAILY SCHEDULE

8:15-8:45	Arrival/Bathroom/Fine Motor Skill
8:45-9:00	Morning Snack
9:00-10:00	Centers/Small Group/Reading Readiness
10:00-10:30	Circle Time
10:30-11:00	Playground/Gross Motor Skills (Prepare Lunch)
11:00-11:05	Wash Up/Story Time
11:05-11:35	Lunch Time
11:35-11:45	Ready to Rest (child selects one book)
11:45-12:00	Bathroom
12:00-1:30	Nap/Quiet Activity/Journals
1:30-1:45	Wake Up/Bathroom
1:45-2:15	Technology Time
2:15-2:30	Centers/Music & Movement



Wednesday School Day ends at 1:30 & Arts Integration with every other Wednesday from 9:35-10:05

APPENDIX B: INFORMED CONSENT

ENRICHING STUDENTS WITH DEVELOPMENTAL DELAYS IN AN EARLY CHILDHOOD CLASSROOM USING iPADS WITH MATHEMATICS APPLICATIONS

Informed Consent

Principal Investigator(s): *Selma Powell, MA*

Faculty Supervisor: *Lisa Dieker, PhD*

Investigational Site(s): [redacted]

How to return this Consent Form: Two (2) copies of this consent form are being sent home and if you approve your child to participate in this study, please fill in the required field, sign one of the copies of the consent form and give it to your child to be submitted to Selma Powell and keep the other copy for your records. This consent form will be collected from your child in the classroom.

Introduction: Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. You are being asked to allow your child to take part in a research study that will include about 3-4 people from the voluntary pre-kindergarten class at [redacted]. Your child is being invited to take part in this research study because he or she is a student at the [redacted] Voluntary pre-Kindergarten.

The person doing this research is Ms. Selma Powell of the Exceptional Education Department at UCF. Ms. Powell is a doctoral student at UCF and she is supervised by Professor Dr. Lisa Dieker.

What you should know about a research study:

- Someone will explain this research study to you.
- A research study is something you volunteer for.

- Whether or not you take part is up to you.
- You should allow your child to take part in this study only because you want to.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you or your child.
- Feel free to ask all the questions you want before you decide.

Purpose of the research study: The purpose of the research is to investigate the use of iPads in the inclusive early childhood classroom related to numeracy instruction.

What your child will be asked to do in the study: Participating students will be exposed to a mathematics based applications using an iPad during center time. By participating in this research, students will be using iPads to learn mathematical concepts. An initial diagnostic test will be given to determine your child's current level in mathematics skills, those results will be shared with you and the teacher, the results from the evaluation will allow me to determine an appropriate starting point with the iPad applications. Students will be asked for feedback on the iPads and applications. The research will occur for approximately four weeks but no longer than six weeks. Your child does not have to answer every question or complete every task. You or your child will not lose any benefits if your child skips questions or tasks.

Location: At [redacted].

Time required: We expect that your child will be in this research study for twenty to thirty minutes, during free choice center time, for four to six weeks.

Audio and video taping:

Your child will be audio and video taped during this study. If you do not want your child to be audio taped, your child will *not* be able to be in the study. Discuss this with the researcher or a research team member. If your child is audio and video taped, the tape will be kept in a locked, safe place. The tape will be erased or destroyed when the researcher has completed the research project.

Risks: There are no expected risks for taking part in this study. There are no reasonably foreseeable risks or discomforts involved in taking part in this study.

Benefits: We cannot promise any benefits to you, your child, or others from your child taking part in this research. However, possible benefits include exposure to mathematics curriculum delivered through the iPads and mathematics by taking part in this research.

Compensation or payment: There is no compensation, payment or extra credit for your child's part in this study

Confidentiality: We will limit your personal data collected in this study. Efforts will be made to limit your child's personal information to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the IRB and other representatives of UCF. Your child's identity will be kept confidential. The researcher will make every effort to prevent anyone from knowing that your child gave us information, or what that information is. For example, your child's name will be kept separate from the information he or she gives, and these two things will be stored in different places.

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints, or think the research has hurt your child talk to *Selma Powell*, Exceptional Education Program, College of Education, (407) 823-2598 or by email selmapowell@knights.ucf.edu, or *Lisa Dieker*, Faculty Supervisor, at Exceptional Education Program by email at lisa.dieker@ucf.edu.

IRB contact about you and your child's rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and applicationroved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

Your signature below indicates your permission for the child named below to take part in this research.

DO NOT SIGN THIS FORM AFTER THE IRB EXPIRATION DATE BELOW: 12/19/2012

____

Name of participant

____ ____________________

Signature of parent or guardian Date

❑ Parent
❑ Guardian (See note below)

____

Printed name of parent or guardian

Assent

❑ Obtained

____

Note on permission by guardians: An individual may provide permission for a child only if that individual can provide a written document indicating that he or she is legally authorized to consent to the child's general medical care. Attach the documentation to the signed document.

APPENDIX C: PARENT LETTER AND QUESTIONNAIRE

University of Central Florida

ENRICHING STUDENTS WITH DEVELOPMENTAL DELAYS IN AN EARLY CHILDHOOD CLASSROOM USING iPADS WITH MATHEMATICS APPLICATIONS

To the Parents of:

Thank you for signing permission for your child to participate in the study. Please take a moment to complete the attached questionnaire regarding your child's prior use of handheld technologies. This information will give me a starting point of your child's ability and understanding of using an iPad.

I look forward to spending the next month in your child's classroom and observing the evolution of the use of the iPads in the classroom.

Regards,

Selma Powell

ENRICHING STUDENTS WITH DEVELOPMENTAL DELAYS IN AN EARLY CHILDHOOD CLASSROOM USING iPADS WITH MATHEMATICS APPLICATIONS

Children's Prior Knowledge of Mobile Devices & Other Technologies

1. Does your child know what an iPhone is: YES NO
   a. If YES:
      What does your child say it does?
      Has your child ever seen one? Where?
      Has your child ever used one?
      Does your child usually use it by himself or herself, or with someone else? Who?
      Do you have one in your house? Whose is it?
      Does your child think this is for someone his or her age, or is it for grown-ups, or is it for both?
      Does your child need help pressing the home button?
      Does your child need help swiping his or her finger over the screen?

2. Does your child know what an iTouch is: YES NO
   a. If YES:
      What does your child say it does?
      Has your child ever seen one? Where?
      Has your child ever used one?
      Does your child usually use it by himself or herself, or with someone else? Who?
      Do you have one in your house? Whose is it?
      Does your child think this is for someone his or her age, or is it for grown-ups, or is it for both?

3. Does your child know what an iPad is: YES NO
   a. If YES:
      What does your child say it does?
      Has your child ever seen one? Where?
      Has your child ever used one?
      Does your child usually use it by himself or herself, or with someone else? Who?
      Do you have one in your house? Whose is it?
      Does your child think this is for someone his or her age, or is it for grown-ups, or is it for both?

Adapted from the Usability Study Protocol *Conducted by Sesame Workshop's Research Division*

APPENDIX D: TABLES FOR CONTENT ANALYSIS OF ALL APPLICATIONS

FOCAL POINTS

	Number and Operation/Algebra					Geometry					Measurement	
	Developing an understanding of whole numbers, including concepts of correspondence, counting, cardinality, and comparison					**Identifying shapes and describing spatial relationships**					**Identifying measurable attributes and comparing objects by using these attributes**	
APP	1 to 1 Correspondence	Matching Sets	Comparing Numbers	Counting objects to 10 and beyond	“more than” and “less than”	Find shapes	Describe shapes	2D and 3D shapes	Solve problems	“above” “below” and “next”	Identify object as “same” “different” and “more” or “less”	Length and weight
Photo Touch Numbers				X								
Kids…Game				X								
Toddler Puzzle Shapes						X	X	X				
123 Lite	X	X	X	X							X	
Monkey Math	X	X	X	X				X	X	X	X	
Park Math	X	X	X	X	X						X	
Balloon Academy				X								
Kids Counting	X			X								
Oscar’s 1-10 Balloons				X								
Colors & Shapes	X			X								
Numbers…Kids				X								
Kidimedia				X								
Monkey Rows									X			
Patterns									X			

	Mathematical Thinking																		
	Number Sense													**Number and Operations**					
	Demonstrates understanding of *one-to-one correspondence*		**Shows understanding of how to count and construct *sets***		**Shows understanding by participating in the comparison of quantities**				**Assigns and relates numerical representations among *numerals* (written), *sets* of objects, and number names (spoken) in the range of 5-10**	**Counts and knows the sequence of number names (spoken)**		**Shows understanding of and uses appropriate terms to describe *ordinal* positions**		**Shows understanding of how to combine *sets* and remove from a concrete *set* of objects (receptive knowledge)**		**Shows understanding of addition and subtraction using a concrete *set* of objects (expressive knowledge) or story problems found in everyday classroom activities**			**Begins to develop an understanding of separating a *set* into a maximum of four parts, with teacher support and multiple experiences over time**
APP	**Child demonstrates *one-to-one correspondence* when counting.**	**Child demonstrates *one-to-one correspondence* to determine if two *sets* are equal.**	**Child counts *sets* in the range of 10 to 15 objects.** (taking away) situations.	**Child constructs *sets* in the range of 10 to 15 objects.**	**Child compares two *sets* to determine if they are equal.**	**Child compares two *sets* to determine if one *set* has more.**	**Child compares two *sets* to determine if one *set* has less.**	**Child determines one *set* of objects is a lot more than another set of objects**		**Child counts and recognizes number names (spoken) in the**	**Child counts up through 31 by understanding the pattern of adding by one, with teacher support and multiple experiences over time**	**Child demonstrates the concept of *ordinal* position with concrete objects (e.g., children or objects).**	**Child names *ordinal* positions (e.g., first, second, third, fourth, fifth).**	**Child indicates there are more when they combine (add) *sets* of objects together.**	**Child indicates there are less when they remove (subtract) objects from a *set*.**	**Child combines *sets* of objects to equal a *set* no larger than ten.**	**Child removes objects from a *set* no larger than ten.**	**Child uses concrete objects to solve complex problems (e.g., fingers, blocks).**	
Photo Touch Numbers										X									
Kids…Game										X	X(20)								
Toddler Puzzle Shapes																			
123 Lite	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**									
Monkey Math	**X**				**X**	**X**	**X**	**X**	**X**		**X**					**X**			
Park Math	**X**				**X**	**X**	**X**	**X**			**X**				**X**	**X**	**X**	**X**	
Balloon Academy										X									

Kids Counting	X									X									
Oscar's 1-10 Balloons										X									
Colors & Shapes	X									X									
Number…Kids										X									
Kidimedia										X									

	Mathematical Thinking																				
	Patterns and Seriation						**Geometry**										**Spatial Relations**				
	Understands characteristics of patterns and non-patterns and begins to reproduce them with at least two elements (e.g., red/blue, red/blue versus a non-pattern such as rainbow)				**Sorts, orders, compares, and describes objects according characteristics or attribute(s) (*seriation*)**		**Understands various two-dimensional shapes, including *circle*, *triangle*, *square*, *rectangle*, *oval*, and other less common shapes (e.g., *trapezoid*, *rhombus*)**				**Shows understanding that two-dimensional shapes are *equivalent* (remain the same) in different *orientations***			**Understands various three-dimensional shapes, including *sphere*, *cube*, *cone*, and other less common shapes (e.g., *cylinder*, pyramid)**		***Analyzes* and constructs examples of simple *symmetry* and non-*symmetry* in two-dimensions, using concrete objects**	**Shows understanding of spatial relationships and uses position words (e.g., in front of, behind, between, over, through, under)**		**Describes *relative position from different perspectives***	**Understands and can tell the difference between *orientation* terms such as horizontal, diagonal, and vertical**	**Uses directions to move through space and find places in space**
APP	**Child recognizes patterns and non-patterns**	**Duplicates identical patterns with at least two elements**	**Recognizes *pattern units* (e.g., red/blue is the *pattern unit* of a red/blue/red/blue/red/blue pattern; dog/cat/cow is the *pattern unit***	**Child begins to independently produce patterns with at least two elements (e.g., red/blue, red/blue), with teacher support and multiple experiences over time**	**Child places objects in increasing order of size where the increasing *unit* is constant (e.g., *unit* blocks).** many objects.	**Child verbalizes why objects were placed in order (e.g., describes process of how and why), with teacher support and multiple experiences over time.**	**Child categorizes (sorts) examples of two-dimensional shapes.**	**Child names two-dimensional shapes.**	**Child constructs examples of two-dimensional shapes.**	**Child identifies the number of sides of two-dimensional shapes.**	**Child slides shapes, with teacher support and multiple experiences over time.**	**Child flips shapes, with teacher support and multiple experiences over time.**	**Child rotates shapes, with teacher support and multiple experiences over time.**	**Child categorizes (sorts) examples of three-dimensional shapes.**	**Child names three-dimensional shapes.**		**Child shows understanding of positional words (receptive knowledge).**	**Child uses the positional terms verbally (expressive knowledge) (e.g., in front of, behind, between, over, through, under), with teacher support and multiple experiences over time.**			
Toddler Puzzle Shapes							X	X			X										
Monkey Math			**X**	**X**							**X**										
Park Math			**X**	**X**	**X**																
Balloon Academy								X													
Monkey	X		X	X																	

rows																					
Patterns	X		X																		

APPENDIX E: TABLES FOR CONTENT ANALYSIS

VPK STANDARDS																			
	Mathematical Thinking																		
	Number Sense													**Number and Operations**					
	Demonstrates understanding of *one-to-one correspondence*		**Shows understanding of how to count and construct *sets***		**Shows understanding by participating in the comparison of quantities**				**Assigns and relates numerical representations among *numerals* (written), *sets* of objects, and number names (spoken) in the range of 5-10**	**Counts and knows the sequence of number names (spoken)**		**Shows understanding of and uses appropriate terms to describe *ordinal* positions**		**Shows understanding of how to combine *sets* and remove from a concrete *set* of objects (receptive knowledge)**		**Shows understanding of addition and subtraction using a concrete *set* of objects (expressive knowledge) or story problems found in everyday classroom activities**			**Begins to develop an understanding of separating a *set* into a maximum of four parts, with teacher support and multiple experiences over time**
APPLICATION	**Child demonstrates *one-to-one correspondence* when counting.**	**Child demonstrates *one-to-one correspondence* to determine if two *sets* are equal.**	**Child counts *sets* in the range of 10 to 15 objects.** (taking away) situations.	**Child constructs *sets* in the range of 10 to 15 objects.**	**Child compares two *sets* to determine if they are equal.** arranged in a line, a rectangular array, or a circle, or as many as 10 things in a scattered configuration; given a number from 1–	**Child compares two *sets* to determine if one *set* has more.**	**Child compares two *sets* to determine if one *set* has less.**	**Child determines one *set* of objects is a lot more than another *set* of objects.**		**Child counts and recognizes number names (spoken) in the range of 10 to 15.**	**Child counts up through 31 by understanding the pattern of adding by one, with teacher support and multiple experiences over time.**	**Child demonstrates the concept of *ordinal* position with concrete objects (e.g., children or objects).**	**Child names *ordinal* positions (e.g., first, second, third, fourth, fifth).**	**Child indicates there are more when they combine (add) *sets* of objects together.**	**Child indicates there are less when they remove (subtract) objects from a *set*.**	**Child combines *sets* of objects to equal a *set* no larger than ten.**	**Child removes objects from a *set* no larger than ten.**	**Child uses concrete objects to solve complex problems (e.g., fingers, blocks).**	
123	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**									
Monkey Math	**X**				**X**	**X**	**X**	**X**	**X**		**X**					**X**			
Park Math	**X**				**X**	**X**	**X**	**X**			**X**				**X**	**X**	**X**	**X**	

VPK STANDARDS																					
	Mathematical Thinking																				
	Patterns and Seriation						**Geometry**										**Spatial Relations**				
	Understands characteristics of patterns and non-patterns and begins to reproduce them with at least two elements (e.g., red/blue, red/blue versus a non-pattern such as rainbow)				**Sorts, orders, compares, and describes objects according characteristics or attribute(s) (*seriation*)**		**Understands various two-dimensional shapes, including *circle*, *triangle*, *square*, *rectangle*, *oval*, and other less common shapes (e.g., *trapezoid*, *rhombus*)**				**Shows understanding that two-dimensional shapes are *equivalent* (remain the same) in different *orientations***			**Understands various three-dimensional shapes, including *sphere*, *cube*, *cone*, and other less common shapes (e.g., *cylinder*, pyramid)**		***Analyzes* and constructs examples of simple *symmetry* and non-*symmetry* in two-dimensions, using concrete objects**	**Shows understanding of spatial relationships and uses position words (e.g., in front of, behind, between, over, through, under)**		**Describes *relative position from different perspectives***	**Understands and can tell the difference between *orientation* terms such as horizontal, diagonal, and vertical**	**Uses directions to move through space and find places in space**
APPLICATION	**Child recognizes patterns and non-patterns**	**Duplicates identical patterns with at least two elements**	**Recognizes *pattern units* (e.g., red/blue is the *pattern unit* of a red/blue/red/blue/red/blue pattern; dog/cat/cow is the *pattern unit* of a dog/cat/cow/dog/cat/cow/dog/cat/cow pattern)**	**Child begins to independently produce patterns with at least two elements (e.g., red/blue, red/blue), with teacher support and multiple experiences over time**	**Child places objects in increasing order of size where the increasing *unit* is constant (e.g., *unit* blocks).** many objects.	**Child verbalizes why objects were placed in order (e.g., describes process of how and why), with teacher support and multiple**	**Child categorizes (sorts) examples of two-dimensional shapes.**	**Child names two-dimensional shapes.**	**Child constructs examples of two-dimensional shapes.**	**Child identifies the number of sides of two-dimensional shapes.**	**Child slides shapes, with teacher support and multiple experiences over time.**	**Child flips shapes, with teacher support and multiple experiences over time.**	**Child rotates shapes, with teacher support and multiple experiences over time.**	**Child categorizes (sorts) examples of three-dimensional shapes.**	**Child names three-dimensional shapes.**		**Child shows understanding of positional words (receptive knowledge).**	**Child uses the positional terms verbally (expressive knowledge) (e.g., in front of, behind, between, over, through, under), with teacher support and multiple experiences over time.**			
123																					
Monkey Math			**X**	**X**							**X**										
Park Math			**X**	**X**	**X**																

FOCAL POINTS													
	Number and Operation/Algebra					Geometry					Measurement	
	Developing an understanding of whole numbers, including concepts of correspondence, counting, cardinality, and comparison					**Identifying shapes and describing spatial relationships**					**Identifying measurable attributes and comparing objects by using these attributes**	
APPLICATION	1 to 1 Correspondence	Matching Sets	Comparing Numbers	Counting objects to 10 and beyond	“more than” and “less than”	Find shapes	Describe shapes	2D and 3D shapes	Solve problems	“above” “below” and “next”	Identify object as “same” “different” and “more” or “less”	Length and weight
123 Lite	X	X	X	X							X	
Monkey Math	X	X	X	X				X	X	X	X	
Park Math	X	X	X	X	X						X	

COMMON CORE STANDARDS																						
	Counting & Cardinality							Operations & Algebraic Thinking					Number & Operations in Base Ten	Measurement & Data			Geometry					
	K.CC.1	K.CC.2	K.CC.3	K.CC.4	K.CC.5	K.CC.6	K.CC.7	K.OA.1	K.OA.2	K.OA.3	K.OA.4	K.OA.5	K.NBT.1	K.MD.1	K.MD.2	K.MD.3	K.G.1	K.G.2	K.G.3	K.G.4	K.G.5	K.G.6
APPLICATION	Count to 100 by ones and by tens.	Count forward beginning from a given number within the known sequence (instead of having to begin at 1).	Write numbers from 0 to 20. Represent a number of objects with a written numeral 0-20 (with 0 representing a count of no objects).	Understand the relationship between numbers and quantities; connect counting to cardinality.	Count to answer "how many?" questions about as many as 20 things arranged in a line, a rectangular array, or a circle, or as many as 10 things in a scattered configuration; given a number from 1–20, count out that many objects.	Identify whether the number of objects in one group is greater than, less than, or equal to the number of objects in another group, e.g., by using matching and counting strategies	Compare two numbers between 1 and 10 presented as written numerals.too much, or more.	Represent addition and subtraction with objects, fingers, mental images, drawings[1], sounds (e.g., claps), acting out situations, verbal explanations, expressions, or equations.	Solve addition and subtraction word problems, and add and subtract within 10, e.g., by using objects or drawings to represent the problem.	Decompose numbers less than or equal to 10 into pairs in more than one way, e.g., by using objects or drawings, and record each decomposition by a drawing or equation (e.g., 5 = 2 + 3 and 5 = 4 + 1).	For any number from 1 to 9, find the number that makes 10 when added to the given number, e.g., by using objects or drawings, and record the answer with a drawing or equation.	Fluently add and subtract within 5.	Compose and decompose numbers from 11 to 19 into ten ones and some further ones, e.g., by using objects or drawings, and record each composition or decomposition by a drawing or equation (such as 18 = 10 + 8); understand that these numbers are composed of ten ones and one, two, three, four, five, six, seven, eight, or nine ones.	Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object.	Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference. *For example, directly compare the heights of two children and describe one child as taller/shorter.*	Classify objects into given categories; count the numbers of objects in each category and sort the categories by count	Describe objects in the environment using names of shapes, and describe the relative positions of these objects using terms such as *above*, *below*, *beside*, *in front of*, *behind*, and *next to*.	Correctly name shapes regardless of their orientations or overall size.	Identify shapes as two-dimensional (lying in a plane, "flat") or three-dimensional ("solid").	Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/" corners") and other attributes (e.g., having sides of equal length).	Model shapes in the world by building shapes from components (e.g., sticks and clay balls) and drawing shapes.short.	Compose simple shapes to form larger shapes. *For example, "Can you join these two triangles with full sides touching to make a rectangle?"*
123		X	X	X																		
Monkey Math	X	X	X	X	X	X	X	X	X		X	X				X	X					
Park Math	X	X	X	X	X	X	X	X	X		X	X			X							

APPENDIX F: STANDARD ANALYSIS AGREEMENT

VPK STANDARDS AGREEMENT																				
	Mathematical Thinking																			**Agreement**
	Number Sense													**Number and Operations**						
	Demonstrates understanding of *one-to-one correspondence*		**Shows understanding of how to count and construct *sets***		**Shows understanding by participating in the comparison of quantities**				**Assigns and relates numerical representations among *numerals* (written), *sets* of objects, and number names (spoken) in the range of 5-10**	**Counts and knows the sequence of number names (spoken)**		**Shows understanding of and uses appropriate terms to describe *ordinal* positions**		**Shows understanding of how to combine *sets* and remove from a concrete *set* of objects (receptive knowledge)**		**Shows understanding of addition and subtraction using a concrete *set* of objects (expressive knowledge) or story problems found in everyday classroom activities**			**Begins to develop an understanding of separating a *set* into a maximum of four parts, with teacher support and multiple experiences over time**	
APP	**Child demonstrates *one-to-one correspondence* when counting**	**Child demonstrates *one-to-one correspondence* to determine if two *sets* are equal.**	**Child counts *sets* in the range of 10 to 15 objects.** (taking away) situations.	**Child constructs *sets* in the range of 10 to 15 objects.**	**Child compares two *sets* to determine if they are equal.** arranged in a line, a rectangular array, or a circle, or as many as 10 things in a scattered configuration; given a number from 1–20, count out that many objects.	**Child compares two *sets* to determine if one *set* has more**	**Child compares two *sets* to determine if one *set* has less.**	**Child determines one *set* of objects is a lot more than another *set* of objects.**		**Child counts and recognizes number names (spoken) in the range of 10 to 15.**	**Child counts up through 31 by understanding the pattern of adding by one, with teacher support and multiple experiences over time**	**Child demonstrates the concept of *ordinal* position with concrete objects (e.g., children or objects).**	**Child names *ordinal* positions (e.g., first, second, third, fourth, fifth).**	**Child indicates there are more when they combine (add) *sets* of objects together.**	**Child indicates there are less when they remove (subtract) objects from a *set*.**	**Child combines *sets* of objects to equal a *set* no larger than ten.**	**Child removes objects from a *set* no larger than ten.**	**Child uses concrete objects to solve complex problems (e.g., fingers, blocks).**		
123	-+ 0% 100%	-+ 0% 100%	++ 100% 100%	++ 100% 100%	+- 100% 0%	+- 100% 0%	+- 100% 0%	++ 100% 100%	-+ 0% 100%	+- 100% 0%	-+ 0% 100%	++ 100% 100%	++ 100% 100%	-+ 0% 100%	-+ 0% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	68% 79%
Monkey Math	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	+- 100% 0%	-+ 0% 100%	++ 100% 100%	-+ 0% 100%	++ 100% 100%	++ 100% 100%	-+ 0% 100%	-+ 0% 100%	++ 100% 100%	-+ 0% 100%	++ 100% 100%	++ 100% 100%	74% 95%
Park Math	++ 100% 100%	-+ 0% 100%	++ 100% 100%	+- 100% 0%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	+- 0% 100%	++ 100% 100%	-+ 0% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	-+ 0% 100%	++ 100% 100%	79% 95%
Agreement	67% 100%	33% 100%	100% 100%	100% 67%	100% 67%	100% 67%	100% 67%	100% 67%	0% 100%	100% 67%	0% 100%	100% 100%	100% 100%	33% 100%	33% 100%	100% 100%	67% 100%	67% 100%	100% 100%	74% 90%

	Mathematical Thinking																						
	Patterns and Seriation						Geometry										Spatial Relations						
	Understands characteristics of patterns and non-patterns and begins to reproduce them with at least two elements (e.g., red/blue, red/blue versus a non-pattern such as rainbow)				**Sorts, orders, compares, and describes objects according characteristics or attribute(s) (*seriation*)**		**Understands various two-dimensional shapes, including *circle*, *triangle*, *square*, *rectangle*, *oval*, and other less common shapes (e.g., *trapezoid*, *rhombus*)**				**Shows understanding that two-dimensional shapes are *equivalent* (remain the same) in different *orientations***			**Understands various three-dimensional shapes, including *sphere*, *cube*, *cone*, and other less common shapes (e.g., *cylinder*, pyramid)**		***Analyzes* and constructs examples of simple *symmetry* and non-*symmetry* in two-dimensions, using concrete objects**	**Shows understanding of spatial relationships and uses position words (e.g., in front of, behind, between, over, through, under)**		**Describes *relative position from different perspectives***	**Understands and can tell the difference between *orientation* terms such as horizontal, diagonal, and vertical**	**Uses directions to move through space and find places in space**	**Agreement**	**Overall Agreement**
APP	**Child recognizes patterns and non-patterns**	**Duplicates identical patterns with at least two elements**	**Recognizes *pattern units* (e.g., red/blue is the *pattern unit* of a red/blue/red/blue/red/blue pattern; dog/cat/cow is the *pattern unit* of a dog/cat/cow/dog/cat/cow pattern)**	**Child begins to independently produce patterns with at least two elements (e.g., red/blue, red/blue), with teacher support and multiple**	**Child places objects in increasing order of size where the increasing *unit* is constant (e.g., *unit* blocks)**, many objects.	**Child verbalizes why objects were placed in order (e.g., describes process of how and why), with teacher support and multiple experiences over time.**	**Child categorizes (sorts) examples of two-dimensional shapes.**	**Child names two-dimensional shapes.**	**Child constructs examples of two-dimensional shapes.**	**Child identifies the number of sides of two-dimensional shapes.**	**Child slides shapes, with teacher support and multiple experiences over time.**	**Child flips shapes, with teacher support and multiple experiences over time.**	**Child rotates shapes, with teacher support and multiple experiences over time.**	**Child categorizes (sorts) examples of three-dimensional shapes.**	**Child names three-dimensional shapes.**		**Child shows understanding of positional words (receptive knowledge).**	**Child uses the positional terms verbally (expressive knowledge) (e.g., in front of, behind, between, over, through, under), with teacher support and multiple experiences over time.**					
123	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	100% 100%	87%
Monkey Math	++ 100% 100%	++ 100% 100%	++ 100% 100%	+- 100% 0%	+- 100% 0%	++ 100% 100%	+- 100% 0%	+- 100% 0%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	100% 81%	88%
Park Math	++ 100% 100%	++ 100% 100%	+- 100% 0%	+- 100% 0%	++ 100% 100%	+- 100% 0%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	100% 86%	91%
Agreement	100% 100%	100% 100%	100% 67%	100% 33%	100% 67%	100% 67%	100% 67%	100% 67%	100% 100%	100% 100%	100% 100%	100% 100%	100% 100%	100% 100%	100% 100%	100% 100%	100% 100%	100% 100%	100% 100%	100% 100%	100% 100%	100% 89%	95%

FOCAL POINTS

	Number and Operation/Algebra					Geometry					Measurement		Overall Agreement
	Developing an understanding of whole numbers, including concepts of correspondence, counting, cardinality, and comparison					**Identifying shapes and describing spatial relationships**					**Identifying measurable attributes and comparing objects by using these attributes**		
APP	1 to 1 Correspondence	Matching Sets	Comparing Numbers	Counting objects to 10 and beyond	“more than” and “less than”	Find shapes	Describe shapes	2D and 3D shapes	Solve problems	“above” “below” and “next”	Identify object as “same” “different” and “more” or “less”	Length and weight	
123 Lite	++ 100% 100%	-+ 0% 100%	+- 100% 0%	++ 100% 100%	-+ 0% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	-- 0% 0%	++ 100% 100%	++ 100% 100%	++ 100% 100%	75% 83% = 79%
Monkey Math	++100% 100%	++ 100% 100%	++100% 100%	++ 100% 100%	++ 100% 100%	-+ 0% 100%	++ 100% 100%	-+ 0% 100%	++ 100% 100%	-+ 0% 100%	++ 100% 100%	++ 100% 100%	75% 100% = 88%
Park Math	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	-- 0% 0%	++ 100% 100%	+- 100% 0%	++ 100% 100%	92% 83% = 88%
Agreement	100% 100%	67% 100%	100% 67%	100% 100%	67% 100%	67% 100%	100% 100%	67% 100%	33% 33%	67% 100%	100% 67%	100% 100%	80% 89% = 85%

COMMON CORE STANDARDS AGREEMENTS

	Counting & Cardinality							Operations & Algebraic Thinking					Number & Operations in Base Ten	Measurement & Data			Geometry						Agreement
	K.CC.1	K.CC.2	K.CC.3	K.CC.4	K.CC.5	K.CC.6	K.CC.7	K.OA.1	K.OA.2	K.OA.3	K.OA.4	K.OA.5	K.NBT.1	K.MD.1	K.MD.2	K.MD.3	K.G.1	K.G.2	K.G.3	K.G.4	K.G.5	K.G.6	
APP	Count to 100 by ones and by tens.	Count forward beginning from a given number within the known sequence (instead of having to begin at 1).	Write numbers from 0 to 20. Represent a number of objects with a written numeral 0-20 (with 0 representing a count of no objects).	Understand the relationship between numbers and quantities; connect counting to cardinality.	Count to answer "how many?" questions about as many as 20 things arranged in a line, a rectangular array, or a circle, or as many as 10 things in a scattered	Identify whether the number of objects in one group is greater than, less than, or equal to the number of objects in another group, e.g., by using matching and counting strategies	Compare two numbers between 1 and 10 presented as written numerals.too much, or more.	Represent addition and subtraction with objects, fingers, mental images, drawings[1], sounds (e.g., claps), acting out situations, verbal explanations, expressions, or equations.	Solve addition and subtraction word problems, and add and subtract within 10, e.g., by using objects or drawings to represent the problem.	Decompose numbers less than or equal to 10 into pairs in more than one way, e.g., by using objects or drawings, and record each decomposition by a drawing or equation (e.g., 5 = 2 + 3 and 5 = 4 + 1).	For any number from 1 to 9, find the number that makes 10 when added to the given number, e.g., by using objects or drawings, and record the answer with a drawing or equation.	Fluently add and subtract within 5.	Compose and decompose numbers from 11 to 19 into ten ones and some further ones, e.g., by using objects or drawings, and record each composition or decomposition by a drawing or equation (such as 18 = 10 + 8); understand that these numbers are composed of ten ones and one, two, three, four, five, six, seven, eight, or nine ones.	Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object.	Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference. *For example, directly compare the heights of two children and describe one child as taller/shorter.*	Classify objects into given categories; count the numbers of objects in each category and sort the categories by count	Describe objects in the environment using names of shapes, and describe the relative positions of these objects using terms such as *above, below, beside, in front of, behind,* and *next to.*	Correctly name shapes regardless of their orientations or overall size.	Identify shapes as two-dimensional (lying in a plane, "flat") or three-dimensional ("solid").	Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/" corners") and other attributes (e.g., having sides of equal length).	Model shapes in the world by building shapes from components (e.g., sticks and clay balls) and drawing shapes.short.	Compose simple shapes to form larger shapes. *For example, "Can you join these two triangles with full sides touching to make a rectangle?"*	
123	++ 100% 100%	-+ 0% 100%	-+ 0% 100%	-+ 0% 100%	-- 0% 0%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	+- 100% 0%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	82% = 87% 91%
Monkey Math	-+ 0% 100%	++ 100% 100%	-+ 0% 100%	-+ 0% 100%	-- 0% 0%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	+- 100% 0%	++ 100% 100%	++ 100% 100%	++ 100% 100%	+- 100% 0%	++ 100% 100%	-+ 0% 100%	-+ 0% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	73% = 80% 86%
Park Math	++ 100% 100%	-+ 0% 100%	-+ 0% 100%	-+ 0% 100%	++ 100% 100%	-+ 0% 100%	-+ 0% 100%	++ 100% 100%	++ 100% 100%	+- 100% 0%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	-+ 0% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	++ 100% 100%	73% = 84% 95%
Agreement	67% 100%	33% 100%	0% 100%	0% 100%	0% 33%	67% 100%	67% 100%	100% 100%	100% 100%	100% 33%	100% 67%	100% 100%	100% 100%	100% 67%	67% 100%	67% 100%	67% 100%	100% 100%	100% 100%	100% 100%	100% 100%	100% 100%	74% = 83% 91%

Black=Early childhood special education expert Blue= Math content expert

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