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Creature Counting: The Effects of Augmented Reality on Perseverance and Early Numeracy Skills

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Creature Counting: The Effects of Augmented Reality on Perseverance and Early Numeracy Skills

by

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DEDICATION

"Families are the compass that guides us. They are the inspiration to reach great heights, and our comfort when we occasionally falter."

-Brad Henry

Thank you, George and Carolyn, for being my everything on this journey.

"My father gave me the greatest gift anyone could give another person: he believed in me."

—Jim Valvano

Thank you, Dad, for always being in my corner.

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ABSTRACT

Augmented reality (AR) and mobile devices show promise for promoting mathematics practices and an increase in perseverance. Using an experimental pre-/posttest comparable condition group design, this study investigated (a) whether differences exist in students' number sense outcome scores based upon the type of board game they played with (augmented reality version versus traditional) and (b) find whether students' perseverance levels based upon the type of board game they played were different. Using a classroom observation protocol designed to measure perseverance and a pre-/posttest on subitizing and approximate number system, the study used a 2x2 mixed repeated measures ANOVA, one-way ANOVA, and linear regression models to analyze these assessments. The early number sense scores of students playing an AR version of the researcher designed game called *Creature Counting* (n=30) was compared with students who played a traditional board game version of the same game (n=26).

Results of this empirical study show students who participated in the AR version of *Creature Counting* had growth in number sense scores. Findings from the study showed that students in both groups improved between the pre-/posttest on the subitizing assessment, with the AR group making greater improvement. The findings also showed that students in both groups improved between the pre-/posttest on the approximate number systems assessment. However, there was no statistically significant difference in improvement when comparing children in the intervention group to children in the comparison group. Additionally, for children in the intervention group, perseverance scores collected did not predict number sense scores after playing *Creature Counting*. Implications for these findings are discussed.

CHAPTER 1: INTRODUCTION

The issue of quality in early elementary mathematics education has been the focus of several noteworthy educational initiatives (Clements, Fuson, & Sarama, 2017; National Association for the Education of Young Children, 2009; Obama, 2013b). The Educate to Innovate initiative, for example, sought to "move American students from the middle to the top of the pack in science and math achievement over the next decade" (Obama, 2013b, para. 2). The push for improving mathematics has climbed to the top of the national agenda in response to the new demands of international competition in the 21st century, which requires a workforce that is competent in mathematics. Specifically, there is a concern about the frequently low mathematics performance of economically disadvantaged students (Fleer, 2011; Ottmar, Decker, Cameron, Curby, & Rimm-Kaufman, 2013; Zigler & Bishop-Josef, 2006). Particularly alarming is that these disparities are present in the earliest years of schooling and even before school entry (Anders et al., 2012; Clements & Sarama, 2014; Halle et al., 2009).

The Mathematical Sciences Education Board found that, while virtually all young children have the capability to learn and become competent in mathematics, for many students, the potential to learn mathematics in the early years of school is not currently achieved (Cross, Woods, & Schweingruber, 2009). This disconnect is concerning because, as Duncan et al. (2007) found, "mastery of mathematics concepts in preschool is the *most* powerful predictor of later learning" (p. 1443). Providing children with basic mathematical foundations, however, presents early elementary educators with considerable challenges and frustrations, especially in the context of authentic learning situations (Gasteiger, 2012).

To address this issue, two prominent education associations—the National Association of Educating Young Children's (NAEYC) and National Council of Teachers of Mathematics

(NCTM)—published a joint position statement, titled *Early Childhood Mathematics: Promoting Good Beginnings* (Clements, Copple, & Hyson, 2002). This joint position statement proposed 10 essential recommendations teachers and other key professionals should implement in mathematics instruction (see Figure 1).

In high-quality mathematics education for 3- to 6-year-old children, teachers and other key professionals should:

1. Enhance children's natural interest in mathematics and their disposition to use it to make sense of their physical and social worlds
2. Build on children's experience and knowledge, including their family, linguistic, cultural, and community backgrounds; their individual approaches to learning; and their informal knowledge
3. Base mathematics curriculum and teaching practices on knowledge of young children's cognitive, linguistic, physical, and social-emotional development
4. Use curriculum and teaching practices that strengthen children's problem-solving and reasoning processes as well as representing, communicating, and connecting mathematical ideas
5. Ensure that the curriculum is coherent and compatible with known relationships and sequences of important mathematical ideas
6. Provide for children deep and sustained interaction with key mathematical ideas
7. Integrate mathematics with other activities and other activities with mathematics
8. Provide ample time, materials, and teacher support for children to engage in play, a context in which they explore and manipulate mathematical ideas with keen interest
9. Actively introduce mathematical concepts, methods, and language through a range of appropriate experiences and teaching strategies
10. Support children's learning by thoughtfully and continually assessing all children's mathematical knowledge, skills, and strategies.

Figure 1. Recommendations to guide classroom practice. Adapted from "Early Child Mathematics: Promoting Good Beginnings. A Joint Position Statement of the National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (NCTM)," by D. H. Clements, C. Copple, and M. Hyson, 2002, p. 3. Copyright 2002 by the National Association for the Education of Young Children.

These recommendations coincide with other research findings, which suggest that, even though children are naturally curious about mathematics (Charlesworth & Lind, 2011), their learning experiences must still involve explicit, intentional, and strategic interactions with other young children. These interactions tend to use rich language which support children's development of knowledge, and involve active participation (Alexander & Judy, 1988; Gasteiger, 2012; Shumway, 2011). This same seminal position statement from the NAEYC and

NCTM also specifically indicates what must be done for effective change to occur in early mathematics education. One recommendation (see Figure 1) is that stakeholders should "provide ample time, materials, and teacher support for children to engage in play, a context in which they explore and manipulate mathematical ideas with keen interest" (Clements et al., 2002, p. 3).

Overwhelming evidence shows mathematics programs that incorporate play activities can promote myriad positive attributes, such as long-term academic achievements, increased inventiveness, curiosity, social skills, and perseverance beyond traditional curriculum programs (Alfieri, Brooks, Aldrich & Tenenbaum 2011; Bodrova, 2001; Leong, 1996; Leong & Bodrova, 2007; Marcon, 1993, 1999, 2002; Zosh, Fisher, Golinkoff, & Hirsh-Pasek, 2013). Programs that include play activities may demonstrate these results because there is an emphasis on collaboration and a partnership between teachers and students. This form of collaboration represents co-constructive elements of learning, but reviews of most curriculum programs revealed an instructive perspective on learning (Gasteiger, 2014). Programs that adhere to an instructive perspective rely on teacher-led activities and offer minimal opportunities for children to share their voice in learning and provide less time that incorporates play (Downey & Garzoli, 2007).

Despite evidence of the effectiveness of this strategy, this key component is still conspicuously absent from most programs. For instance, technology has played an instrumental part by incorporating natural, playful contexts when learning mathematics (Sollervall, 2012), but most elementary schools have failed to implement these tools (Plowman, McPake, & Stephen, 2010) or train teachers on how to apply technology with authentic learning experiences (Burden, Hopkins, Martin, and Trala, 2012).

Another perspective of learning that informs the educational field is the push for less focus on academic ability and more on children's ability to apply perseverance when learning. A report released by the U.S. Department of Education Office of Technology ([USDOE-OT]; Shechtman, DeBarger, Dornsife, Rosier, & Yarnall, 2013) strongly urges educators to integrate perseverance into their teaching practice. Debating the cognitive development theories, Shechtman et al. (2013) believed what matters most in a child's development is not the amount of information educators can cram in their brains, but how students should react to learning. As Shechtman et al. (2013) noted,

> The test score accountability movement and conventional educational approaches tend to focus on intellectual aspects of success, such as content knowledge. However, this is not sufficient. . . . If students are to achieve their full potential, they must have opportunities to engage and develop a much richer set of skills. (Shechtman et al., 2013, p. v)

Perseverance is the cornerstone of many successful endeavors, in school or out. Perseverance allows students to control their impulses, stay focused on the task at hand, avoid distractions, and control their emotions (Tough, 2013). The ability to persevere is the primary distinction between becoming successful learners and unsuccessful learners. Students who have perseverance were found to spend a longer amount of time working through difficult problems (Tough, 2013) than those who lacked this trait.

The recent spotlight on improving early mathematics instruction has forced elementary schools to examine and make modifications to their Kindergarten programs to prepare students for the challenges of elementary school (Stanberry, 2014). Yet, schools are still struggling to make effective modifications to prepare their students (Santagata, Yeh, & Mercado, 2018). The question still remains, what can realistically be done now to balance out and advance success in early elementary mathematics? The first step is to merge the instructional ideas researchers have proven are effective in mathematics, play, technology, and character traits. The next step is to synthesize these concepts and apply them in a way that can educate young students in mathematics, which is what this study suggests.

Promoting Number Sense and Perseverance in a Technological Play-Based Context

The data paints a clear picture: the active, engaged, and motivated student is the one who is best prepared for the future (Chi, 2009). If children are to make the gains in mathematics that are expected of them, then our elementary schools need to offer a 21st-century learning environment that promotes (a) learning opportunities where students are able to persevere when tackling problems, and (b) work in systematic and explicit mathematics teaching. Developmentally appropriate educational play via technology has the possibility to achieve the proposed objective.

A Key Concept in Early Numeracy: Subitizing and Approximate Number Systems

While a summary of the final report on the Early Numeracy Research Project (ENRP) conducted in Australia between 1999 and 2001 revealed there is no agreed-upon continuum for learning early mathematics, the researchers identified areas of mathematical learning with specific "growth points" (Clarke et al., 2017, p. 3). One specific mathematical growth points young children should follow along the path to mathematical understanding involves understanding number sense. Neergaard (2013) reported in a study conducted by the University of Missouri that of 180 seventh-graders who lagged behind their peers in a test of core math skills needed to function as adults were the same kids who had the least number sense ability reporting all the way back to when they started first grade. Ensuring students have a strong foundation with number sense skills is vital for long term achievement in mathematics. Two essential areas in the development of understanding early numeracy is known as *subitizing* and *approximate number sense*. Having a strong foundation with these number sense skills encourages students to think flexibly and promotes confidence with numbers.

Sarama and Clements (2009), primary researchers of early mathematics education and subitizing, proclaimed this early numeracy skill "appears to form a foundation for all learning of numbers" (p. 50). Subitizing is defined as the rapid and accurate perceptions of a small number of items. This early numeracy mathematics skill introduces basic ideas of cardinality, parts and wholes, and the beginning relationships in arithmetic (Shumway, 2011). Subitizing is critical for young children to understand because the associated skills learned form a web that connects the foundational ideas about mathematics, which in turn, progress from elementary school up to high school and beyond. Students from low-resource communities often lag behind their more advanced peers in their subitizing ability, thus hampering their mathematical development (Clements & Sarama, 2014). When students are able to rapidly subitize, they can reserve their mental energy for higher order, multistep mathematical problems, thus closing part of the mathematics gap experienced by too many students.

Another number sense ability that is important for foundational learning is the capability to accurately estimate the differences between quantities. This skill is referred to approximate number systems (ANS) and is the mental ability that allows individuals to detect differences in magnitude between groups without relying on language or symbols. The ability to estimate between numbers correlates strongly with mathematics achievement (Dowker, 1997; Halberda et al., 2008). This ability to abstractly process quantities is an important skill for several reasons. First and foremost, students should be able to determine the reasonableness of their answer. Without ANS skills, students have difficulty determining if their answer is within a reasonable range. Secondly, students who struggle with ANS also struggle to use mental math to more quickly arrive at a reasonable estimated solution for their answer (Hoffman, 2015).

Due to the fact subitizing is a skill learned through experience rather than direct instruction, Van de Walle, Karp, & Bay-Williams (2012) suggests the use of play-based experiences to help students understand this concept. Tucker (2014) also agrees that play is a natural partner in mathematics education because, first, it allows children to apply skills, and second, play allows students to have a heightened awareness that mathematics can be useful and enjoyable in the real world.

Play in Mathematics Instruction

A prominent contributor in the area of play, Bruce (2011), found the purest form of play allows a child to visualize, which aids in making decisions and predictions, experiment with strategies, show curiosity, and repeat, rehearse, and refine observed social behaviors and skills. All of these vital developments of play are also essential for mathematical thinking and problem solving.

Zosh et al. (2013) asserted,

> Play is imperative if children are to thrive in a 21st-century world. As the world has changed, so to have the knowledge and competences needed to succeed—such as creativity, critical thinking, collaboration, communication, confidence, and content—all of which begin in the sandbox during play. (Zosh, et al., 2013, p. 96)

Essentially, play fosters problem solving. Tucker (2014) bolstered Zosh et al.'s statement, noting that "problem solving for young children . . . does not mean reaching for commercial mathematical investigation packs and worksheets, with their abstract symbols and de-contextualized subject matter" (p. 5); instead, young children can best achieve problem solving by incorporating play in their lessons. As such, educators should offer opportunities that permits student to make connections and see a purpose to solving problems.

Clements and Sarama (2014) concurred that academic learning combined with play is not an either/or choice for teachers of young children; the behaviors are mutually reinforcing. They argued, “Combining play with intentional teaching, and promoting play with mathematical objects and mathematical ideas is pedagogically powerful” (Clements & Sarama, 2017, para. 11). One way to merge play in mathematics is through board games.

Playing board games in mathematics have been reported to help raise the math skills of disadvantaged pre-kindergarten students (Siegler & Ramani, 2008). Additionally, playing board games encourages children to persevere (Hromek, & Roffey, 2009). The combination of play and mathematics, according to Tickell (2011), creates connections in their learning that helps them to make sense and refine their thinking and encourages students’ curiosity, which drives them to persevere, regardless of difficulty.

The Importance of Having Perseverance in Education

As imperative as scholastic preparation is, cognitive ability is only a fragment of what students truly need to succeed in life. Gardner's (2011) multiple intelligences, Goleman's (2006) emotional intelligence, and Dweck's (2006) growth mindsets all reflect the fact that our mindsets are even more important than our skills (Hoerr, 2012). Teaching students of any age means educating the whole student.

Brophy (2013) suggested that students who possess perseverance enjoy discovering new skills, techniques, and new ways of gathering knowledge. They often feel excited when completing an activity because they are deeply involved and motivated to learn something new. Dweck (2007) emphasized this point by stating that the most motivated and successful students are those who believe in their own skills and talents and embrace perseverance through learning. In simpler terms, when students are motivated, they are more likely to persevere.

The USDOE-OT proposed the next steps in understanding perseverance and learning require researchers to develop empirically based models that will lead the exploration on how to develop perseverance over time, within disciplinary contexts, such "as part of how they become proficient in mathematics" (Shechtman et al., 2013, p. 88). Perseverance is the ability to dig deep and persist when working through difficult situations. Duckworth and Eskreis-Winkler (2013) asserted perseverance is actually a better predictor of success than IQ. While there is debate as to if this statement is true, perseverance may have the potential to change how we teach and assess students. However, there is not a sufficient amount of data collected yet to make this case.

Researchers have been called to action to examine how perseverance influences learning. Beginning with the youngest learner is the ideal place to start. Moreover, Shecthman et al. (2013) recommends beginning with the use of new and emerging advances in technology to help promote perseverance in students. Technology has been linked with an increase in student engagement, which makes them more likely to persevere in difficult situations (Liu, Horton, Olmanson, & Toprac, 2011).

Technology as a Learning Tool

It is difficult to find a classroom without some type of technology component incorporated in the instruction and learning process. Mobile devices such as iPhones and iPads have become ubiquitous in classrooms around the country. Children are using technology such as iPads and other devices more than ever before (Blagojevic, Brumer, O'Clair, & Thomes, 2012). Yet even with the presence of this technology in school, each year more struggling students are falling further behind in mathematics classrooms across the country. Understanding how educational technology can be integrated to improve the mathematics skills of struggling learners is something all teachers should know and be able to apply in their own classrooms (Cheung &

Slavin, 2013). Educators are seeking ways to actively engage students in the learning process through technology, but they need support (Herrington, Reeves, & Oliver, 2014). Anderson, Reder, and Simon (1996) concurred and opined that "greater emphasis should be given to the relationship between what is learn[ed] in the classroom and what is needed outside of the classroom" (p. 5) and suggested the use of more situated learning opportunities. Papert (1996), a pioneer in artificial intelligence, also agreed that learning is most effective when students willingly participate in the process.

Research has shown augmented reality (AR) is an effective way to engage learners through situated learning (Dunleavy & Dede, 2014). According to Dunleavy and Dede (2014), AR offers guidance through scaffolding and enables hands-on learning processes through metacognitive and authentic inquiry. These findings also reflect current research in play. AR has been found to also increase student engagement because it motivates students, which makes them more likely to persevere in difficult situations and willingly approach challenging tasks more than their less motivated peers (Liu, Horton, Olmanson, & Toprac, 2011). In other words, students tend to activate perseverance to a greater extent when they are learning with this type of technology.

While there are many benefits to using technology such as AR and mobile devices in education. There are also downsides to consider and plan for. Schools, teachers, and principals have the difficult challenge of finding balance with technology in the classroom. It should be a priority to decide how and when technology can and should be used to enhance students' learning (Palfrey & Gasser, 2008). Regardless of what is generally agreed is important, the question remains, how do educators effectively incorporate mobile devices into their curriculum? Shelton (2002) asserted that AR with mobile devices has not been widely adopted into early elementary settings because of the lack of awareness of how to incorporate these technologies in school. Thus, more research must be conducted to build the case for the use of these learning tools.

Statement of Purpose

By merging the benefits of AR technology and play-based learning may have the potential to increase critical early math skills such as subitizing and ANS. Therefore, the primary purpose of this study was, first, to examine whether differences exist in students' number sense scores based upon the type of board game intervention they received. This was investigated using a sample of Kindergarten students in two groups: those playing a traditional board game version of a subitizing task versus those playing an AR-enhanced version of the same board game. Previous research findings on AR indicated promise in formal educational settings (Dunleavy & Dede, 2014), but few have empirically studied AR in the formal learning environment of young children (Peirce, 2013). To address this gap in the knowledge base, this study was conducted in kindergarten classrooms, during regular class hours in the school building. For this study, the use of an AR-enhanced mathematics board game with a mobile device was introduced and implemented in randomly assigned groups. The board game was called *Creature Counting*.

The secondary purpose of this research study was to empirically test (a) whether students who exhibit the characteristics of perseverance experienced greater learning gains on number sense skills and (b) if perseverance was a predictor for student success. As advised by Clements (2004), all aspects of the mathematics curriculum need to be considered in a high-quality early elementary mathematics program. Such a program includes mathematical content, processes, and habits of the mind, such as persistence. AR researchers have endorsed that use of this technology which promotes students' ability to persevere when problem solving (Di Serio, Ibáñez, & Kloos, 2013), but such research has not yet been documented successfully with a younger student population.

Summary of Methodology

This study used an experimental pre-/posttest comparable condition group design (Campbell & Stanley, 1963; Shadish, Cook, & Campbell, 2002). This study was conducted in five kindergarten classrooms, with a sample size of 62 students. The school in which the study was conducted is located in a heavily populated, diverse, urban school district in Pennsylvania.

A 2x2 mixed repeated measures ANOVA, one-way ANOVA, and linear regression models were used in this study to investigate kindergarten students' number sense ability in the areas of subitizing and approximate number system (ANS). Additionally, perseverance levels were compared with those playing the AR-enhanced board game versus participants in a similar version of board game without technology. Students' mathematical learning as a result of the intervention and comparison were assessed with a proximal measure using a subitizing assessment of the FastBridge Learning *earlyMath* measurement (SU-K) as a pre-/posttest and a distal measure that assesses ANS aptitude via the Psychological Assessment of Numerical Ability, also known as Panamath. Perseverance levels were assessed during the students' actual demonstration of perseverance when playing either the AR-enhanced board game or the traditional board game based on a researcher-created observation form, called the Classroom Observation Protocol for Perseverance (COP-P). The COP-P was adapted from the scale of determining persistence created by Lufi and Cohen (1987) and from the Overall Short Grit Scale (Grit-O), created by Duckworth, Peterson, Matthews, and Kelly (2007).

Research Questions

This experiment was conducted with two different groups and incorporated three continuous outcome variables: SU-K, Panamath, and COP-P, which measure mathematical practices and students' observed perseverance on task.

The study investigated the following research questions:

1. Do children in the intervention group make greater gains than children in the comparison group on tasks of number sense?
   A. Do children in the intervention group make greater gains than children in the comparison group on the subitizing assessment?
   B. Do children in the intervention group make greater gains than children in the comparison group on approximate number systems?
2. Do perseverance scores differ between children in the intervention group and children in the comparison group?
3. Do perseverance scores predict number sense scores?
   A. Do perseverance scores predict subitizing scores?
   B. Do perseverance scores predict approximate number systems scores?

Significance of Study

Vygotsky (as cited in Albert, 2012) asserted, "The only good kind of instruction is that which marches ahead of development and leads it . . . instruction must be oriented toward the future, not the past" (p. 16). Early elementary mathematics programs need to apply Vygotsky's advice by linking existing research on best practices in a way that can benefit our future learners. This research tested innovative ideas that can enhance student learning, not stagnate it.

By designing and analyzing the effects of an AR-enhanced board game and perseverance levels, it might be possible to inform future mathematics instruction. Therefore, the goals of this investigation were to (a) add to the limited knowledge base of number sense, AR, and perseverance in kindergartens; and (b) create supplemental mathematics interventions that incorporate play and technology, while also promoting perseverance, in ways educators can easily integrate into existing mathematics curricula. The materials designed and tested in this study are intended to be integrated in mathematics classrooms. They can be used to help increase the number sense skills of subitizing and ANS in early elementary students.

Definition of Terms

Approximate number system (ANS): a cognitive system that supports the estimation of the magnitude of a group without relying on language or symbols.

Augmented reality (AR): a technology that superimposes a computer-generated image, such as videos, photos, or GPS data, on a user's view of the real world.

Educational play: a term used in education and psychology to describe how children can learn to make sense of the world around them. Through play, children can develop social and cognitive skills, mature emotionally, and gain the self-confidence required to engage in new experiences and environments.

Mobile device: a portable computing device such as a smartphone or tablet computer.

Number sense: a well-organized conceptual framework of number information that enables a person to understand numbers and number relationships and to solve mathematical problems that are not bound by traditional algorithms.

Perseverance: steadfastness in doing something, despite difficulty or delay in achieving success on an activity.

Subitizing: the rapid and accurate perceptions of a small number of items. This early numeracy mathematics skill introduces basic ideas of cardinality, parts and wholes, and the beginning relationships in arithmetic.

Zone of Proximal Development (ZPD): the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers.

CHAPTER 2: REVIEW OF THE LITERATURE

Assessments at the national level have been directed towards informing educational decision making since the 1980s; with few, if any exceptions, these assessments have revealed difficulties in providing every student a pathway to high-level academic achievement in public schools across the country (Gardner, 1983; Crosswhite, Dossey, Swafford, McKnight, & Cooney, 1985; National Center for Education Statistics, 2000a, 2000b). Fast-forward 35 years and little has changed in the conversation about educational performance in the United States and our competitors around the world.

Improving the academic performance, especially by the lowest performing students in the nation, is an unresolved issue (National Association for the Education of Young Children, 2009; Obama, 2013b). Since the 2000s, the focus in the United States has targeted the early elementary population, particularly in mathematics. In 2009, the National Research Council reported a lack of quality early elementary education mathematics instruction throughout the United States (Kilpatrick, Swafford, & Findell, 2001). These mathematical deficiencies remain, along with even more concern about the frequently low mathematics performance of economically disadvantaged students (Ottmar et al., 2013), with most disparities becoming established in the earliest years of schooling and before entry into school (Anders et al., 2012). This problem is particularly detrimental for underperforming kindergarteners because research shows when this population fails in mathematics, they often continue to have difficulties in both mathematics and reading throughout their entire school career (Clements & Sarama, 2014; Duncan & Magnuson, 2011).

An essential theme raised by the National Commission on Excellence in Education (NCEE) report 30 years ago was the need to strengthen curriculum content, starting with the classroom teacher. Influenced by this recommendation, several recommendations were made. The National Council of Teachers of Mathematics ([NCTM] 1989) offered its *Curriculum and Evaluation Standards for School Mathematics*, as well as *Principles and Standards for School Mathematics* (NCTM, 2000), which promoted curriculum that placed an emphasis on conceptual understanding of mathematics, as opposed to rote practice. Classroom teachers were encouraged to move away from computational memorization and passive learning and embrace active learning with inductive and deductive reasoning of each mathematical strand, as well as authentic problem-solving opportunities for students.

A number of reviews (Bryant et al., 2008; Doabler, Fien, Nelson-Walker, & Baker, 2012; Sood & Jitendra, 2007, 2011) on curriculum have documented that many programs fail to apply these critical design elements, continuing to leave at-risk learners at higher risk for failure (Carnine, 1997). Instead, researchers have found lessons lack sufficient teacher demonstrations and opportunities for student practice through play to build mathematics proficiency (Bryant et al., 2008). M. Chen (2010) correctly asserted, “it’s not that the students are failing the curriculum; the curriculum is failing them” (p. 123).

This chapter details how implementing mathematics lessons through play and technology may enhance perseverance and mathematics instruction that benefits students, especially young and low-performing students. First, the importance of acquiring early numeracy skills of subitizing and ANS is discussed. Next, the best practices of educational play are examined by highlighting how play in mathematics, such as via board games, can engage learners, promote mathematical practices, and encourage perseverance on task. Then, a foundational understanding of the character trait of perseverance is explored. Next, models of technology-enhanced games in early elementary education are presented, along with criticism of this type of learning. Finally, the assurance is offered that the proposed change in mathematics instruction could improve students' mathematical understanding.

Early Elementary Mathematics: Number Sense

Importance of Acquiring Early Numeracy Skills

The term *number sense* refers to "a well-organized conceptual framework of number information that enables a person to understand numbers and number relationships and to solve mathematical problems that are not bound by traditional algorithms" (Bobis, 1996, p 18). The NCTM (1989) broke new ground by identifying five components that characterize number sense: meaning, relationships, magnitude, operations involving numbers, and relating numbers and quantities. These skills are considered important because they contribute to general intuitions about numbers and lay the foundation for more advanced skills. These number proficiencies also include the ability to discern number patterns, estimate quantities, count, perform simple number transformations, and to subitize small quantities (Berch, 2005).

Dehaene (2011) suggested that well before the development of formal symbols and before they enter kindergarten, children acquire pre-number experiences informally through interactions with parents and siblings. In other words, children develop some sense about numbers even before they learn to count. Students with a strong understanding of number sense develop a quantitative intuition that helps them to solve problems in a flexible manner. Later, children are able to reliably count and represent small numbers and use that knowledge to make quantity estimates (Dyson, Jordan, & Glutting, 2013).

Students with a strong understanding of number sense comprehend that numbers are representative of objects (Markovits & Sowder, 1994) and are aware that numbers can be operated on, compared, and used for communication (Kilpatrick et al., 2001; NCTM, 2000). Pre-number abilities form the basis for the development of symbolic number sense (Feigenson, Dehaene, & Spelke, 2004). A multitude of researchers have found students who have a strong understanding of number sense are also proficient in mental calculations (Sowder, 1988), magnitudes relationships (Hope & Sherrill, 1987; Trafton, 1992), computational estimation (Bobis, 1991; Case & Sowder, 1990), and recognizing part-whole relationships and place-value concepts (Fischer, 1990), as well as problem solving (Cobb et al., 1991).

In contrast to students with strong number sense, children with poor number sense often have difficulties in discriminating between quantities (Berch, 2005; Gersten & Chard, 1999), and are at risk for later failure in both mathematics and reading achievement (Clements & Sarama, 2014; Duncan & Magnuson, 2011). The work of Jordan and colleagues (Jordan, Glutting, & Ramineni, 2010; Jordan, Huttenlocher, & Levine, 1994; Jordan, Kaplan, Ramineni, & Locuniak, 2008) also implies number competencies "are highly sensitive to socioeconomic status, suggesting the importance of early input and instruction" (Jordan et al., 2010, p. 82). Students from low-income backgrounds are also likely to be less prepared than students from middle-income backgrounds in the important science, technology, engineering, and mathematics (STEM) disciplines.

Mathematics proficiency has long been seen as a gateway to highly sought-after professions in STEM (National Mathematics Advisory Panel, 2008). Many children's learning difficulties in mathematics have been explained by problems related to counting, number comparisons, and set transformations (Mazzocco & Thompson, 2005). These capabilities are all mathematical skills scaffolded from the foundational understanding of number sense.

Subitizing

An essential early number sense skill young students should master in mathematics is subitizing. The term, coined by Kaufman, Lord, Reese, and Volkmann (1949), refers to the rapid and accurate perceptions of a small number of items. According to Clements and Sarama (2009) subitizing "appears to form a foundation for all learning of numbers" (p. 50). Aside from general ideas about quantity, subitizing introduces basic ideas of cardinality, parts and wholes, and the beginning relationships in arithmetic. Sarama and Clements (2009) explained that children's ability to see small collections develops between the ages of 4 and 8 years through perceptual and conceptual subitizing. Perceptual subitizing occurs when children instantly perceive the quantity of a group of numbers without using any mathematical processes. Conceptual subitizing involves mentally decomposing a pattern, such as five dots into two and three, and mentally combining the pattern to make five again (see Figure 2 for examples).

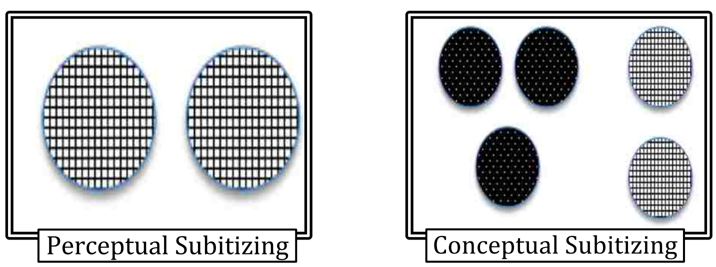


Figure 2. Examples of perceptual subitizing versus conceptual subitizing.

Processing Subitizing Quantities

There are various spatial arrangements in which a quantity can be presented: horizontal, vertical, pattern, and random (see Figure 3). As mental powers develop, usually by the age of 4, groups of four can be recognized without counting (Clements & Sarama, 2008, 2014). Although early research on subitizing found quantities higher than 4 are difficult for kindergarten-aged children to subitize, especially in random arrangements (M. C. Wang, Resnick, & Boozer, 1971;

Wolters, van Kempen, & Wijlhuizen, 1987), Clements (1999, 2014) reported the largest subitizing quantity for kindergarten-aged children to master is six. The skill of subitizing appears to be based on the ability of the mind to form stable mental images of patterns and associate them with a quantity represented by a number word. Therefore, it may be possible to recognize more than four objects if they are arranged in a familiar pattern or if practice and memorization takes place. A simple example of this phenomenon is six dots arranged in two rows of three, as on dice or playing cards. Because this image is familiar, the quantity of six can be instantly recognized when presented this way.

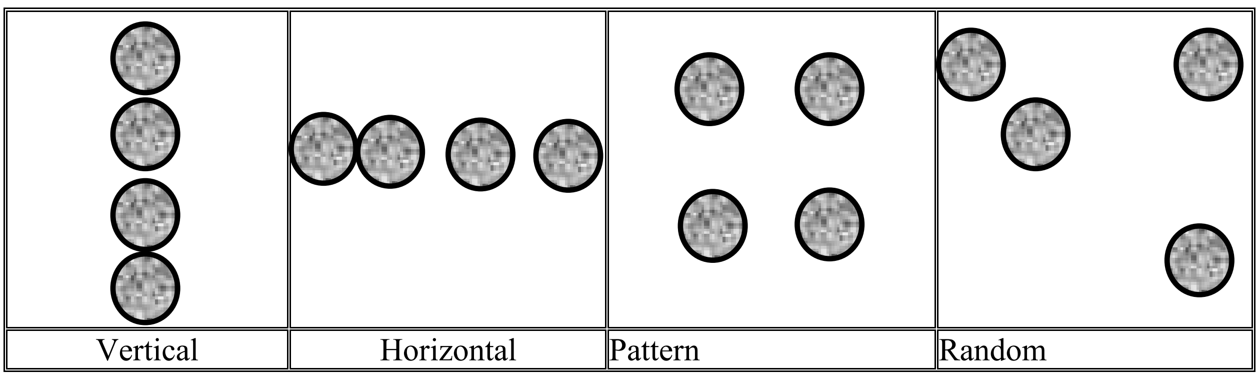


Figure 3. Subitizing spatial arrangements.

Usually, when presented with more than five objects, other mental strategies must be utilized. For example, one might see a group of six objects as two groups of three. Each group of three is instantly recognized, and then virtually unconsciously, combined to make six. In this strategy, no actual counting of objects is involved, but rather a part-part-whole relationship and rapid mental addition are used. That is, there is an understanding that a quantity, in this case 6, can be composed of smaller parts, together with the knowledge that “3 plus 3 makes 6.” This type of subitizing thinking should be nurtured because it lays the foundation for understanding operations and developing valuable mental calculation strategies. Clements and Samara’s (2009, 2014) research further suggests students should be able to subitize the quantity presented to them within 3 seconds because seeing the objects for only a few seconds challenges the mind to find strategies other than counting. When children are able to quickly subitize, they can reserve their mental energy for higher order, multistep mathematical problems.

Most children will need the concrete experience of physically manipulating groups of objects into subgroups and combining small groups to make a larger group (Back, 2014). There is multi-study evidence that tangible materials improve student attitudes towards mathematics (Sowell, 1989). For instance, Hawkins (2007) reported when students learn with concrete examples, their ability to persevere increases because the students perceived that using manipulatives was helpful when learning mathematical concepts. Shumway (2011) suggested subitizing activities are best done with tangible materials such as counters, blocks, and small toys. Playing with manipulatives is a natural partner in mathematics education because students (a) recognize that mathematical activity can be both sociable and cooperative and (b) recognize mathematical activities to be enjoyable and purposeful (Tucker, 2014). After these essential experiences, more static materials such as dot cards become useful.

Approximate Number System

The ability to accurately estimate the differences between quantities is an essential requirement for humans to perform complex calculations and numerous other mathematical skills. There is extensive evidence that many animals, ranging from monkeys to birds, bees, and even the youngest of babies have an intuitive number sense, also known as the *approximate number system* ([ANS] Dehaene, 2011; Feigenson et al., 2004; Hauser, Tsao, Garcia, & Spelke, 2003; Izard, Sann, Spelke, & Streri, 2009; Pepperberg, 2006; Sawamura, Shima, & Tanji, 2002; Xu, Spelke, & Goddard, 2005). For instance, pigeons judge relative differences in the number of items they see. Besides making relative judgments, these birds can assess absolute amounts within a small number range (Dehaene, 2011; Emmerton, 2001).

In simpler terms, ANS is a mental ability that allows individuals to detect differences in magnitude between groups without relying on language or symbols. Although ANS is an intuitive mathematical skill, it is not mistake-proof. ANS is a challenging task for young children to master. According to Van de Walle, Karp, and Bay-Williams (2012), ANS is a higher-level skill that requires students to be able to conceptualize and mentally manipulate numbers. As Jevons (1871) first showed, errors increase in direct relation to the number of items to be estimated, a property known as Weber's law (*w*). The *w* represents the ratio between the magnitudes of two stimuli. The more *w* increases, the more easily the difference between the two stimuli will be perceived (Halberda, Mazzocco, & Feigenson, 2008). Simply put, ANS has two behavioral trademarks: distance and size effects. The distance effect means it is easier to differentiate numbers that are further apart in numerical distance (3 versus 8 is easier than 3 versus 5), while the size effect means it is easier to distinguish smaller numbers compared to larger numbers at the same distance (3 versus 5 is easier than 33 versus 35).

The ability to estimate between numbers correlates strongly with mathematics achievement (Dowker, 1997; Halberda et al., 2008). This ability to hypothesize and abstractly manipulate quantities is an important skill for several reasons. First and foremost, students should be able to determine the reasonableness of their answer. Without ANS skills, students have difficulty determining if their answer is within a reasonable range. This inability to reason causes them to make computational errors. Second, students who struggle with ANS struggle to use mental math to more quickly arrive at a reasonable estimated solution for their answer (Hoffman, 2015). Even before the start of kindergarten, many opportunities exist or can be created to help children develop a foundation from which they can learn to make better estimates. As the children are learning this skill, they are also developing a better sense of numbers.

The Importance of Educational Play in Early Elementary Mathematics

As previously explained, the mathematical knowledge of young children from low-income and minority backgrounds trails behind that of peers from middle-income backgrounds even before they start school (Jordan et al., 2008). Although Reyna (1996) reported some educators use flashcards to help struggling students understand numbers and quantities, the research shows rote memorization is slow and subject to rapid forgetting, and few people are eager to do it (Boaler, 2015). These findings point to the educational importance of developing activities that improve knowledge of early numeracy skills for early elementary students. Authentic educational play is a type of activity needed to help students learn.

Educational Play

Ranging from learning how to think, remember, and solve problems, early elementary students benefit from play in a multitude of ways. Well-planned play-based programs incorporate children's interests, academic goals, and provide learning opportunities through play, which teaches children how to explore and expand on concepts. Shrier (2013) reported early elementary students who participate in play-based programs have improved academic scores and social/emotional skills, as well as an increased ability to learn abstract concepts. Play offers opportunities for the child to acquire information, which lays the foundation for additional learning.

Several educational learning theorists supported educational play. Cognitive learning theorists Piaget and Vygotsky emphasized that play is a major influence in cognitive growth because play gives children the opportunity to test their beliefs about the world. For instance, children may gain an understanding of size, shape, and texture through play (Piaget, 1952; Vygotsky, 1978). Vygotsky (1977) believes play creates the *zone of proximal development* (ZPD). The ZPD refers to the distance between the actual developmental level of a person as determined by independent problem solving and the level of potential development through problem-solving in collaboration with more capable peers.

Vygotsky wrote:

> In play a child is always above his average age, above his daily behavior; in play it is as though he were a head taller than himself ... in play it is as though the child were trying to jump above the level of his normal behavior" (Vygotsky, 1977, p. 96).

Brock, Dodds, Jarvis, and Olusoga (2013) also suggest play offers children the ability to master skills that will help them to develop self-confidence, the ability to recover quickly from setbacks, and to persevere. When teachers create play-based learning activities that scaffold play and support children's skill development can be a bridge to learning new skills.

In a longitudinal study, van Oers (2009) followed a class of 34 young children, ages 5–7, who received play-based mathematics instruction. The idea of play-based mathematics instruction was described as a creative act in which the teacher constructs novelty within mathematics instruction that involves orientation to the topic, structuring learning by offering playful opportunities that deepen and broaden their learning and provide opportunities for reflection. van Oers (2009) found that children who received this play-based instruction, with respect to their mathematical learning, measured by standardized tests of numerical achievement in young children, systematically scored above the national norm for numerical abilities for those age ranges, without having been trained on these operations in previous or specially designed lessons. It is worth noting that this study did not mention if students were above the national norm before they started the game.

Kindergarten has changed dramatically since the late 1990s: children currently spend considerable more time being taught and tested on mathematics skills than they do learning through play and exploration (Miller & Almon, 2009). Miller and Almon (2009) revealed play in all its forms is now a minor activity, if not eliminated, in many kindergarten classrooms. Most teachers in Miller and Almon's (2009) study reported they spend two to three hours each day in literacy, mathematics, and test prep, and their students have 30 minutes or less each day for play. The lack of play in education is detrimental to both academic and social development. The American Pediatric Association issued a major clinical report in 2007, concluding that

> [p]lay is essential to development. . . . Play allows children to use their creativity while developing their imagination, dexterity, and physical, cognitive, and emotional strength. Play is important to healthy brain development. . . . As they master their world, play helps children develop new competencies that lead to enhanced confidence and the resiliency they will need to face future challenges. (Ginsburg, 2007, p. 183).

Kindergarten education in Finland, for example, aims to improve children's aptitude for learning by teaching them new knowledge and skills through play. According to the principles of the national core curriculum, learning in kindergarten in Finland should be solely based on playing through exploration and concrete activities, while simultaneously intertwining creativity, knowledge, and real-life experiences when teaching (Hyvonen, 2011; National Board of Education, 2000). The power of play as the engine of learning in early elementary and as a vital force for young children's physical, social, and emotional development is worthy of being studied.

How Board Games Improve Mathematics Knowledge:

Research has suggested that when young children play early numeracy board games, their knowledge of numerical magnitudes, counting on, numeral identification, and ability to learn answers to arithmetic problems all improve (Ramani & Siegler, 2008; Siegler & Ramani, 2008, 2009, Whyte & Bull, 2008). In 2011, Ramani and Siegler reported that playing a linear number mathematics board game helped children from middle and low-income families improve their mathematical understanding. Siegler and Booth (2004) posited that the increase in young students' knowledge of early numeracy skills is explained by the games that provide visual, kinesthetic, auditory, and temporal cues to the number system. Moreover, playing board games as a small group activity is an ideal context for teachers because they can guide or direct children to meet specific educational goals by extending their learning during and after playing the game (Durden & Dangel, 2008; Wasik, 2008).

Contrary to the support for board games in school, some researchers noted that collaboration with peers while playing games can hinder learning in some circumstances (Barron, 2003; Fawcett & Garton, 2005; McCaslin & Good, 1996). Ramani, Siegler, and Hitti (2012) explained, "Some early childhood students experience difficulty with collaborative learning because they lack the interpersonal and linguistic skills needed to express themselves in ways that are informative and do not lead to conflict" (p. 662). As a second challenge, in game-playing settings for many kindergartners, winning and losing often induce extreme emotional reactions, as well as immature emotion regulation skills (Ramani, Brownell, & Campbell, 2010). Maintaining sustained attention is a third challenge; early elementary students often lose interest in games when they are not winning or when other children are taking their turns. Lastly, Rutherford (2015) reported that children often memorize answers to board games because of the repetitiveness of game play and may not retain the information over time. One purpose of this study was to identify which version of board game play decreases this type of behavioral interference.

Perseverance

Several studies conducted have examined how perseverance can be a predictor of academic growth (Duckworth & Carlson, 2013; Mischel, 2014; Shivpuri, Schmitt, Oswald, & Kim, 2006). According to Peterson and Seligman (2004), *perseverance* is defined as the "voluntary continuation of a goal-directed action in spite of obstacles, difficulties, or discouragement" (p. 229). In other words, perseverance can be thought of as a certain "stick-with-it" attitude and determination that is maintained over time, despite failure or setbacks. The U.S. Department of Education Office of Technology (Shechtman et al., 2013) found, regardless of the schools' socioeconomic status, learning environments can be designed to promote perseverance and identified several important factors of the environment that promote perseverance. First, students need opportunities to take on challenging goals that are within their ZPD. Second, students need a supportive environment to achieve the lesson objectives while developing the psychological strategies on how to persevere. Finally, students are more likely to persevere when the learning environment has a fair and respectful climate, conveys high expectations, emphasizes effort over ability, and provides necessary tangible resources.

In early elementary mathematics, teaching students how to persevere is part of the recently released Common Core State Standards Mathematics ([CCSSM] Common Core State Standards Initiative, 2010). Standard one asks students to make sense of problems and persevere in solving them. To effectively improve students' capacity for this standard, teachers must develop systematic ways of framing mathematical challenges that are clear and explicit, and then check in repeatedly with students to help them clarify their thinking and their process (Polya, 2014). The problem is teachers are looking for ways to incorporate the CCSSM perseverance standard into their lessons effectively and are struggling (Kendall, 2011). The research also suggests the best way the CCSSM standard described above can be presented to students is through playful learning opportunities. Fiore (2007) agreed, noting that when students are active participants in a play experience such as board games, they can "negotiate, solve problems, and learn perseverance" (p. 83). It is important to note that students who already have a sense on intrinsic motivation within them are more readily able to problem solve and learn how to persevere (Stewart, 2017).

Although there is limited research on perseverance involving young children (White et al., 2017), even more surprising is that there is no current research on perseverance in mathematics with early elementary students. While the current evidence is limited, several studies have examined perseverance as a driver of successful development and linked it to multiple measures of success. Duckworth and Gross (2014) deem the ability to persevere predicts academic growth. According to Duckworth and Gross (2014), longitudinal studies have confirmed that higher levels of perseverance earlier in life predict later academic achievement and attainment (Duckworth & Carlson, 2013; Mischel, 2014). Additionally, Lufi and Cohen's (1987) seminal study on perseverance and children ages 7-13 found that children who scored high on measures of perseverance were less anxious and did not blame others while trying to find solutions to difficult problems. In another study, children who were rated by parents as having higher levels of perseverance in kindergarten or first grade exhibited faster growth in reading from kindergarten through third grade, compared to children who exhibited lower levels of perseverance (Newman, Noel, Chen, & Matsopoulos, 1998).

Conversely, Willingham (2016) argued that this concept of academic growth occurring as a result of perseverance levels could be false. Willingham contended that the similarities between perseverance and conscientiousness are the same, and perhaps researchers reported gains in learning because they were working with conscientious students to begin with. In other words, some students produce good grades not because they are persevering towards a goal, but rather because they do what is expected of them. Alternatively, if they are persevering towards a goal, it may be about just one subject in which they are intrinsically motivated. A large study conducted in the United Kingdom revealed that perseverance yielded only a small improvement to standardized test scores (Rimfeld, Kovas, Dale, & Plomin, 2016), and another smaller study examining grade point average with high school academic success and perseverance also reported little improvement (Ivcevic & Brackett, 2014).

Much of the perseverance research has been based on self-reporting. An issue with self-reporting is participants may under- or over-exaggerate indicators being measured (West, 2014). To support teachers who are looking to encourage both the CCSSM standard on perseverance and provide a learning environment that supports this character trait, more information needs to be garnered from educational researchers. One way to garner this information is by conducting studies on how teachers incorporate learning opportunities based in play and if those opportunities foster perseverance.

Technology-Enhanced Games in Early Elementary Education

Children naturally explore and learn about their environments through inquiry. Technology-enhanced games offer a user-friendly vehicle for increasing the range of this inquiry. Since the early 2010s, a growing number of interactive technology games have been created for middle school and high school aged students; these games address a variety of subjects, including mathematics, science, reading, language, and social studies. However, most technology-enhanced games have yet to integrate the technology into early childhood contexts (Wang, Kinzie, McGuire, & Pan, 2010).

One of the reasons interactive technology has been well received is the impact of novelty on learning when playing with the technology. Like anything that is new or unusual, innovative technology is bound to catch a young student's eye. For example, when children's interest is peaked when playing video games, they tend to engage longer in game play than other activities (Olthouse, 2009). This occurs when students interact with technology, because the major "novelty center" of the brain, which responds to unique stimuli, links closely to areas of the brain called the hippocampus and the amygdala, both of which play large roles in learning and memory (Cooper, 2013). Although researchers are still sorting out the complexities of the effects of novelty with technology on long-term learning, studies conducted to date have revealed positive signs in academic growth (McKnight et al., 2016; Sung, Chang, & Liu, 2016).

When novelty is combined with a systematic design and technology activities are applied, the technology can foster personal qualities such as curiosity, self-reliance, and perseverance (Ritchie, 2013). Liu et al. (2011) found when students participate in digital environments, student engagement tends to increase because the technology may motivate students, which makes them more likely to persevere in difficult situations and willingly approach challenging tasks more than their less motivated peers. Marco, Cerezo, and Baldassarri (2013) stated when children use technology, they "build their mental image of the world through action and motor responses and, with physical handling, they become conscious of reality" (p. 1577). Children can benefit from the same pedagogical values as learning with materials in physical play when they learn with technologies (Price & Rogers, 2004).

Augmented Reality in the School Setting

The use of a digital environment such as AR, for example, has been found to be more powerful than customary instruction due to the features in AR. The AR technology lays computer-generated images over a user's view of the real world which has been noted to enrich the student experience, support investigative learning, and offer a new dimension to traditional methods (Kaufmann, Schmalstieg, & Wagner, 2000). Squire (2011) found students were more engaged when working with AR, due to the novelty of the technology, than when using more traditional methods. Others concurred AR makes a powerful contribution to learning and development in young children (Kerawalla, Luckin, Seljeflot, & Woolard, 2006). However, Peirce (2013) reported that despite the wealth of academic research being conducted into AR game-based learning, "only a fraction targets games for early childhood (6% of 995 papers surveyed)" (p. 4). There is even less evidence reported for early numeracy skills and AR (Sollervall, 2012).

AR technology, which involves the integration of digital information such as videos, photos, or GPS data, overlaid on items in the user's environment, has been publicized "as one of the most interesting emergent technologies for education, being a powerful and motivating tool which can involve several senses of the student by means of the proper combination of sound, sight and touch" (Cascales, Laguna, Pérez-López, Perona, & Contero, 2012, p. 104). Application of AR technology in education is just beginning to be explored, especially when using it with early elementary students (Cascales et al., 2012).

Among the first researchers to understand the potential of AR with early elementary education were Kritzenberger, Winkler, and Herczeg (2002), who developed a mixed reality platform to provide a tool for collaborative learning in physical and digital storytelling. Other studies were conducted with early elementary students' language learning, in which AR was used for improving pronunciation and memorization of the Chinese language (C.-H. Chen, Su, Lee, & Wu, 2007). Jo and Kim (2011) used AR and robots to deliver positive feedback responses to young students while they were working. Finally, others such as Kim, Song, Jung, Kwon, and Jeon (2011) used this novel technology as an interactive storyteller to enhance children's reading.

The field of mathematics has also explored using a series of AR games to help students learn mathematics. Lee and Lee (2008), for example, created an addition and subtraction AR dice game based on the book, *Ria's Math Play*, for elementary students. The two-player game required children to roll virtual dice, calculate the outcome, and move their piece on an AR-enhanced board game according to the solution. The player who arrives at the finishing point first wins the game. Because the dice game requires computation, the researchers encourage another adult or helper to play together with the children to teach the mathematical concepts. Although the concept is novel and mathematically sound, the execution with the technology missed the mark. The highly intricate game involves several cameras in specific positions and was created as a tutoring game strictly for in-home use. Lee and Lee reported parents complained about the difficulty of the game for the targeted age group because of the technology as well as poor reliability of the outcomes.

Another study conducted by Pareto (2012) involved a two-player AR board game for upper elementary students. The AR board game targets conceptual understanding in arithmetic, such as the base-10 concepts, and higher order cognitive skills, including reasoning and strategic thinking. Students were encouraged to discuss the game while trying to choose cards that would help them strategically solve mathematical problems. The game was effective in improving students' conceptual understanding in basic arithmetic, and for promoting better self-efficacy beliefs in mainstream classrooms, with the strongest effect for low-achieving students (Pareto, 2012). Unlike other AR-enhanced games in education, the game is systematically designed as an alternative for students with mathematical difficulties or intellectual disabilities, and also as a challenging and useful complement in mainstream education.

Mobile Devices in Education

Since the early 2010s, technology has become increasing common in personal and family use. According Lauricella, Wartella, and Rideout (2015), 75% of families own some type of touch screen device and 40% own a personal tablet. With approximately 65,000 education apps created specifically for Apple operating system, iPads and iPhones have endless possibilities, and there is something for every student and teacher to utilize (Mareco, n.d.). As of January 2012, approximately 1.5 million Apple iPad devices had been sold into educational institutions (Clark & Luckin, 2013).

Research suggests mobile devices in early elementary classrooms are particularly appropriate for young students' because the devices are lightweight, mobile, and are designed to be easy to use (M. Cohen, Hadley, & Frank, 2011). For example, the big touch screen, the tactile-based interface, and child-friendly operating and navigational features allow young students to interact with the digital world by simply touching or tapping the screen. Gray, Dunn, Moffett, and Mitchell (2017) reported that, contrary to initial expectations, principals and teachers claimed that the use of iPads in the classroom has enhanced children's communication skills. In many lessons, particularly those in which pupils shared iPads, there was a high level of discussion. Also, mobile devices have the potential to enhance children's numeracy skills in a more engaging and exciting way than traditional approaches because the technology complements existing teaching approaches in numeracy rather than replaces them (Chuck, 2017). Finally, digital devices have increased children's confidence because of ownership of the learning process (Gray et al., 2017). Burden, Hopkins, Martin, and Trala (2012) stated,

> Teachers felt that the use of iPads in the classroom caused them to rethink their professional role and facilitated greater collaboration between themselves and students as co-learners in partnership with each other and with students learning independently of the teacher as well as increasing peer-to-peer learning and mentoring. (p. 22)

Supporters of technology in the classroom stress the purpose of integrating technology in the classroom is not to "teach with technology," but rather to use technology to bring content to students in a more powerful, interesting, and personalized way (Rosen, 2011). Palfrey and Gasser (2008) agreed and noted, "The most important thing that schools can do is to not use technology in the curriculum more, but to use it more effectively" (p. 247). It is evident that students learn more when they are engaged and, as Rosen (2010) stated, "Technology is all about engagement" (p. 15). Supporters of mobile devices in the classroom recognize that this technology has the ability to completely differentiate and engage learning for all students, thus leading them down the path to success (Pitler, Hubbell, & Kuhn, 2012).

With regard to applying technology effectively in the classroom, Pitler et al. (2012) remarked that technology may "increases student learning, understanding and achievement but also motivates students to learn, encourages collaborative learning, and helps develop critical thinking and problem-solving skills" (p. 3). This shift in education has required educators, parents, and administrators to think differently about educational technology and the endless possibilities it offers to provide students a unique way of learning. Wood and Jocius (2014) concurred: "Like paper and pencils, technology is a tool, and it's what teachers and students do with the tool that matters" (p. 133).

To be clear, educators cannot simply give students a mobile device with an AR app and expect them to learn; there are no guarantees that the device will even be effective (Palfrey & Gasser, 2008). The integration of technology is not instantly productive or effective because of its existence in the classroom. Ritchie (2013) urged when there is a systematic design applied with AR technology, these activities can foster personal qualities such perseverance. Technology integration requires a creative and thoughtful approach to have a strong impact on student achievement. However, despite near-universal acceptance of the notion of incorporating technology in the classroom, early elementary teachers are still struggling with how to integrate mobile devices into their classrooms (Blake, Winsor, Burkett, & Allen, 2012). One key issue for the teachers has been what constitutes developmentally appropriate practices for using this technology in early elementary classrooms. Technology should be integrated into the classroom in a careful, deliberate, and personalized way to increase student achievement and accelerate learning (Northrop & Killeen, 2013). Therefore, more research is needed to support the use and learning through mobile devices in the early elementary setting.

Issues with AR and Mobile Devices in Education

Although the perception of AR is that this style of technology makes a powerful contribution to learning and development (Gee, 2007; Prensky, 2006; Shaffer, 2006), researchers of this technology were not studying AR games in early elementary settings. Vangsnes, Gram Økland, and Krumsvik (2012) reported the lack of interaction during the technology sessions with young children and their teacher meant meaningful conversations intended to foster student learning were missing.

Most of the AR systems in the reviewed studies mentioned cumbersome materials, such as specialty sensors, display projectors, batteries, and additional materials most likely not found in a typical education setting (Kim et al., 2011). Other issues ranged from tracking images in certain environments to how—if user interfaces were not designed well—these images tend to overload the user with information, and the basic step of simply getting people to use AR was more challenging than expected (van Krevelen & Poelman, 2010). Kerawalla et al. (2006) reported pedagogical issues such as the inflexibility of the content in other AR systems. For instance, the content and the teaching sequence are fixed, which means the teachers were not able to make changes to accommodate students' needs or to modify the instructional objectives for the students to accomplish them with success.

Additionally, the tasks in an AR environment may require students to apply and synthesize multiple complex skills in spatial navigation, problem solving, technology manipulation, and mathematical estimation (Dunleavy, Dede, & Mitchell, 2009). Previous research indicated one reason for students' learning challenges in AR environments lies in a lack of these essential skills (Kerawalla et al., 2006; Klopfer & Squire, 2008). Particularly for younger learners, additional scaffolding would be necessary to help students generate an appropriate plan of action, which Klopfer and Squire (2008) suggested would allow students to search for possible solutions to their problem.

Furthermore, opponents of mobile device technology, such as Palfrey and Gasser (2008) argue that the use of mobile devices with young children may be developmentally inappropriate. Burris and Wright (2001) believed there are very few instructional benefits to incorporating mobile devices into classrooms. Adversaries of this technology would prefer to have students interacting with hands-on materials, creative play, and experiments rather than using mobile devices (Chou, 2013). Some researchers believe the integration of mobile devices in school has inhibited the conversations students need to have to accelerate their learning (Armstrong & Casement, 1998; Chou, 2013; Palfrey & Gasser, 2008).

Criticism of AR and mobile devices in education coupled with a lack of research in the early elementary setting with this technology provides researchers with opportunities to potentially design AR games with mobile devices that would be more optimal. Thus, educational researchers should investigate the potential for this tool to improve student learning.

The primary researcher of the present study conducted a pilot study on the use of AR and mobile devices with prekindergarten students. The results indicated that using an AR-enhanced mathematics board game called *Creature Counting* may be a positive step toward achieving the goal of increasing children's mathematical knowledge by learning through innovative technology. The participants in the study had a foundational understanding of subitizing in all spatial arrangements for numbers 1 through 3, and a deficiency for numbers 4 through 6 in all spatial arrangements, based on the pretest results of the Preschool Numeracy Indicator (PNI). After playing with *Creature Counting*, PNI posttest results showed a positive increase with the preschool students' understanding of quantities, especially numbers 4 and 5. Qualitatively, the Early Numeracy Marking Criterion (ENMC) adapted from Jowett, Moore, and Anderson (2012) indicated *Creature Counting* had the potential to kindle perseverance, engage learners, and offered opportunities with situated learning.

Summary

Research on children's knowledge and learning of mathematics has been one of the most active topics in developmental cognitive psychology in recent years. The results have reconceptualized the nature of early mathematical knowledge, of how children acquire mathematics knowledge informally, and of how mathematics learning proceeds in school (Smith,

& Pellegrini, 2003). If schools take advantage of this opportunity, reshaping how content is delivered in ways that fully engage students in cognitively challenging tasks, the results may be students who are better prepared to succeed; all of these themes are found in educational play, mathematics, AR, and perseverance.

Play in early elementary is acknowledged to perform an important role in learning and is integral to cognitive and social development, especially with low-performing students because they may lack prior experience. As mentioned earlier, research suggests when early elementary students learn via playing with board games, their ability to persevere improves and provides opportunities for students to talk through their mathematical thinking. For the most part, though, perseverance has not been thoroughly examined, especially in the early elementary education setting.

Playful learning activities in mathematics that incorporate digital environments, such as AR with a mobile device, should be created to help students persevere with challenging tasks. If the merger of play and technology are combined with early numeracy skills such as subitizing and ANS, there is great potential for underperforming students to improve their scholastic preparedness. Therefore, purposeful activities with board games and technology is one step that can be taken towards meeting the needs of low-income students and increasing their mathematical knowledge. Educational research should begin to determine the role how perseverance plays in helping students improve their mathematical knowledge. Additionally, future research needs to make greater strides in understanding how use of novel technologies, such as AR with a mobile device, can enhance learning. By studying the effects of students' perseverance when working with an AR-enhanced board game, research results may reveal new strategies to foster students' mathematics success.

CHAPTER 3: METHODOLOGY

The purpose of this study was to evaluate whether an augmented reality (AR)-enhanced mathematics board game promoted students' subitizing and approximate number system (ANS) skills and perseverance level when compared to an identical game played without AR enhancement. Consenting students participated in one of two conditions: game play with an AR-enhanced board game (i.e., intervention group) or game play with a parallel version of the board game without the technology component (i.e., comparison group).

This study used an experimental pre-/posttest comparable condition group design. Data collected during the intervention included (a) proximal measure using a subitizing assessment via the Fastbridge Learning *earlyMath* measurement (SU-K) as a pre-/posttest; (b) a distal measure that assesses ANS aptitude via the Psychological Assessment of Numerical Ability, also known as Panamath (n.d.), as a second pre-/posttest; and (c) classroom observation protocol on perseverance (COP-P), which measures students' observed perseverance on task score during game play. Additionally, data collected during the intervention included the observation notes section of the COP-P, which were used to describe students' perseverance behaviors during game play.

Data from the instruments were collected and analyzed using 2x2 mixed repeated measures analyses of variance, analysis of variance (ANOVA), and linear regression models (Campbell & Stanley, 1963; Shadish et al., 2002). This chapter discusses the research questions and design, setting and sample, procedures for intervention and comparison groups, instrumentation, data collection, and data analyses. The chapter closes with a brief discussion of the study's limitations.

Research Questions

The study compared the effects of an AR-enhanced mathematics board game as compared to a mirrored version of the board game without the technology component on two dependent variables: number sense and perseverance levels. Researcher observed notes for students' perseverance behaviors with the task were collected and analyzed. The research questions that guided this study aimed to identify (a) if the technology version of a mathematical board game had greater gains in number sense scores, in particular subitizing and ANS over a traditional board game version, (b) if perseverance scores differ between the two board game groups, and (c) if perseverance predicts number sense scores for subitizing and ANS. The reason these questions drove this study was due to previous research in the field that promoted the effectiveness of board games (Ramani & Siegler, 2008; Siegler & Ramani, 2008, 2009, Whyte & Bull, 2008), technology (Lee & Lee, 2008; Pareto 2012), and perseverance (Duckworth & Carlson, 2013; Mischel, 2014) in an academic setting. It was important to identify how these different areas could enhance student learning when combined together.

Research Design

The study employed a pre-/posttest comparable condition group design (Campbell & Stanley, 1963). This research design was chosen because the study aimed to determine whether a program or intervention had the intended effect on participants of the study. This design allows for use of intervention and comparison groups with pre-/post assessments, which this study implemented.

Guidelines with specific criteria were identified by the researcher as to how the classrooms would be selected. Further information on how the selection of teachers and treatment groups was conducted is discussed in the following section.

Setting and Sample

The study took place in a diverse, densely populated, urban area with mostly low-income households in Pennsylvania. One public school was used in this study whose population consisted of 52.4% female students and 47.6% male students, 16.6% of whom were Black non-Hispanic, 40.2% were White non-Hispanic, 22.3% were Asian, 9.4% were Hispanic, and 11.5% were Other. Of the entire student population, 78% received subsidized lunches. The student-to-teacher ratio was 25:1 (Pennsylvania Department of Education, 2015). This school was chosen based on its diverse demographics and socioeconomic level. As stated before, students from low-resource communities often lag behind their more advanced peers in their number sense ability, thus hampering their mathematical development. Selecting a school that is similar to this demographic could offer generalizable information to other similar settings.

A purposeful convenience sample of 62 kindergarten students was obtained from the elementary school. Students who participated in the study consisted of 55% female students and 45% male students, with the mean age of students being 5.2 years old. Also, 17.7% of the sample were Black non-Hispanic, 43.5% were White non-Hispanic, 19.4% were Asian, 11.3% were Hispanic, and 8.1% were Other. Additional family demographics of the participants were not collected as part of this study.

The mandated curriculum used throughout the district is *Everyday Mathematics* (Bell, 2012), which is distributed by publisher McGraw-Hill. This program is a research-based and field-tested comprehensive Pre-K through Grade 6 mathematics program developed by the University of Chicago School Mathematics Project. The curriculum emphasizes the use of concrete, real-life examples, repeated exposures to mathematical concepts and skills, frequent practice of basic computation skills, and use of multiple methods and problem-solving strategies

(Bell, 2012). The allocated amount of time for kindergarten mathematics instruction in the school is 45 minutes per day.

Sampling Design

First, to achieve a representative sample of students, the requirements for selecting the kindergarten classrooms that were invited to participate in the study were classrooms that had (a) students at a variety of academic levels and (b) teachers who had at least two years of teaching experience. The rationale for selecting students at a variety of academic levels was chosen to ensure if one classroom had more students performing on the higher or lower end of the academic scale, the results of the study would not be influenced. Also, the criteria for teachers who had at least two years of teaching experience was selected to ensure they had more than a minimum of experience teaching and had time to get used to the school and teaching experience. After reviewing the criteria, five out of the eight teachers were selected to participate since three of the teachers did not meet the selection requirements. The five teachers provided consent to participate in the study. Using five classrooms allowed for an adequate sample size for the study. Power analysis will be discussed later in this chapter.

Informed Consent and Group Assignment

Parental/guardian informed consent forms (see Appendix A) were sent home and information describing the research project to parents was presented at Back to School Night in September. After receiving parental/guardian consent forms (see Table 1: *Parental Consent Forms*), all participants were first randomly assigned to either the intervention or comparison group based on a table of random numbers created in Random (n.d.). Then, the intervention and comparison participants were randomly assigned across classrooms via Random (n.d) into small groups of three to allow for manageable group sizes. Therefore, some groups of three had students from different classrooms within them. During game play, the three students were pulled out to play Creature Counting in the hallway. Pre-assessments on SU-K and Panamath then followed.

Table 1. *Parental Consent Forms*

Sample	Teacher A	Teacher B	Teacher C	Teacher D	Teacher E
Class total	25	22	25	25	24
Consents received	13	8	15	15	11
Treatment group	7	5	8	7	7
Comparison group	6	3	7	8	4

Instrumentation

All students took pretest measures on SU-K (see Appendix B) and Panamath (n.d.) two days before and after the experiment to measure the number sense skills. All students were also assessed via the COP-P (see Appendix C) during game play. The COP-P was administered to assess perseverance level and observed perseverance behaviors.

Subitizing-Kindergarten (SU-K)

A pre-/posttest on participants' subitizing skills was conducted via the FastBridge Learning *earlyMath* subitizing measurement, known as SU-K (Christ et al., 2015). *earlyMath* is an evidence-based assessment used for universal screening in grades Kindergarten and First and is composed of 11 subtests; the SU-K measures subitizing specifically. For the purpose of this research study, the SU-K was the only subtest implemented from *earlyMath*.

The subitizing assessment was administered in a one-on-one set-up with paper representations of dots in various vertical, horizontal, and random arrangements for numbers two through six. The entire SU-K assessment, including reading directions to students, took approximately five minutes per student to complete. The assessment portion of SU-K was completed in 2 minutes per student, and all answers were recorded on a paper version of Screen Form 1 (see Image 1).

Image 1. Example of earlyMath SU-K online data collection.

Within the assessment, each correct answer was worth 1 point, generating a range for the SU-K of 0–12. A split-halves reliability test reported by the American Institutes for Research (2013a) indicated a reliability coefficient of .87 ($N = 598$). Cronbach's alpha measures were also reported by the American Institutes for Research (2013b) to determine internal consistency reliability and yielded a score of .76 ($N = 598$). According to George and Mallery (2001), these are acceptable measures of reliability. For this study, a split halves reliability test was run on student's SU-K pretest scores comparing matched halves to determine the internal consistency reliability of the instrument. After student's answers were coded with ones or zeros, as correct or incorrect, respectively. A Spearman-Brown's reliability coefficient of .82 (N=56) was found.

Panamath

A pre-/posttest on ANS was assessed on the computer via Panamath. Halberda et al. (2008) created Panamath in 2008 to evaluate the precision of an individual's ANS by presenting subjects with differing quantities of yellow and blue circles and asking which colored group contained more of these circles. Clayton, Gilmore, and Inglis (2015) reported a test-retest reliability of $r = .29$ $p = .05$ after 321 experimental trials were given in one sitting. The trials were grouped in to two blocks. Both blocks were then repeated so that participants completed each trial twice in order to gain a measure of reliability. The order of blocks was counterbalanced so that half the participants completed a block one first, and half completed block two first. Trials within the blocks were presented in a random order.

Based on recommendations from the literature (Piantadosi, 2016), data analysis for this study focused solely on individual students' accuracy scores. The accuracy score was reported on a scale of 0–100%, which was used in this study. Participants must answer within 3 seconds. Each correct answer received 1 point, generating a possible range of 0–40. Since questions were randomly generated between pre and posttest on the Panamath assessment, a split halves reliability was not an appropriate test to use. Instead, the correlation between pre and posttest scores were run to look at the test-retest reliability. Results provided a statistically significant r =.70, p =.01.

A number of features on the application may be customized by the user, including the display time, the size and numerosity ratio of dot arrays, the number of trials or number of minutes, the colors of the dots and background, and the presence of sound and/or visual feedback following trials. For this study all of the above dimensions were chosen with the exception of sound/and or visual feedback. For instance, each trial of the task, two arrays of dots (one with blue, the other with yellow) appeared in side-by-side boxes for 1,200 milliseconds, allowing enough time for both arrays to be viewed, but not enough time for them to be counted (Halberda & Feigenson, 2008). Students in this study participated in five trials of the eight setting combinations for a total of 40 test trials, excluding one unscored practice trial. The number chosen was based on recommendations from the literature (Clayton et al., 2015; Halberda & Feigenson, 2008). The assessment took approximately five minutes to complete.

Classroom Observation Protocol on Perseverance: COP-P

COP-P is a researcher-created classroom observation protocol rubric that assesses students' perseverance on task level during each instructional session. The COP-P (see Appendix C) was developed by adapting two questions from the Scale of Determining Persistence (Lufi & Cohen, 1987) and two questions from the Overall Grit Scale ([Grit-O] Duckworth et al., 2007).

The Scale of Determining Persistence, created by Lufi and Cohen (1987), has been the instrument most heavily relied upon in the field when assessing the character trait of perseverance (McGiboney & Carter, 1993; Meier & Albrecht, 2003; Wigfield, Klauda, & Cambria, 2011). The self-reporting scale was originally created to assess the general personality trait of perseverance in children ages 7-12. The 40-dichotomous statement assessment has an internal reliability or Cronbach's alpha of 0.66 and test-retest reliability, after 6 months, of 0.77. These reliability scores are considered in the acceptable range (George & Mallery, 2001). The statements selected from The Scale of Determining Persistence that were used in the COP-P were "I do not stop my work even if it's very difficult" and "When I have difficulties doing something I prefer to get help from an adult rather than do it by myself." These items were selected because the findings from Lufi and Cohen's study demonstrate that people who persist independently in a task regardless of its difficulty were more likely to believe in their ability to direct their actions (M=25.06, SD=4.43) versus the standardization group (M=22.71, SD=4.61). Other items on their assessment were self-reflection questions based on situational examples and were not applicable for this study.

Duckworth and colleagues (2007) revised the Scale of Determining Persistence to focus on high school and college aged students who demonstrate grit. The 12-question self-reporting questionnaire called GRIT-O assesses both consistency of interest and perseverance of effort.

While the assessment is graded as a whole, the sub-categories, titled consistency of interest and perseverance of effort, are based upon the scenario in the question. Duckworth, Peterson, Matthews, & Kelly, reported a high internal consistency or Cronbach's alpha of 0.85 for the overall assessment. Consistency of interests and perseverance of effort had a Cronbach alpha of .84 and .78, respectively. Again, these scores are considered acceptable (George & Mallery, 2001). The statements selected from GRIT-O scale that were used in the COP-P were "I have difficulty maintaining my focus on projects that take more than a few months to complete" and "I am a hard worker/diligent and never give up." These items were selected because they also correlate closely to the idea that people who persist in a task regardless of its difficulty are more likely to believe in their efforts and direct their actions towards completing a goal (Schunk, 1990).

To meet the needs of the kindergarten population, the researcher adapted the questions above to create the COP-P. Due to both the self-reporting nature and discrepancies in age for the two assessments, the primary researcher worded the statements to be observational and age appropriate. For instance, the original statement from Lufi and Cohen's scale was "When I have difficulties doing something, I prefer to get help from an adult rather than do it by myself" was rephrased for the COP-P as "The student does not ask the teacher for assistance." Another example from the GRIT scale was originally worded as "I have difficulty maintaining my focus on projects that take more than a few months to complete" and was configured to the COP-P as "If student is working in a session, and it seems like the session is going to take a long time, he/she still prefers to continue working."

While each student played either one of the board game versions, the COP-P captured how the student was demonstrating the observed qualities of perseverance. The primary researcher of this study created the COP-P rubric (see image 2) with the intention of assessing students' observed qualities of perseverance. Students played one round of *Creature Counting* each day, and the student's daily perseverance score was determined. During each round of game play, the student's perseverance level was calculated as either high (3 points), medium (2 points), or low (1 points) based on the four statements mentioned above. Each statement received one to three points based on the observed behavior resulting in a range of 4–12. The perseverance scores are 4–6 points for low perseverance, 7–9 points for medium perseverance, and 10–12 points for high perseverance. These scoring categories were created by the primary researcher. At the end of the five days of treatment, an average score was calculated.

Observed Perseverance on Task	Low Perseverance 1	Medium Perseverance 2	High Perseverance 3
Student persists in what he/she is doing, despite obstacles			
The student does not ask the teacher for assistance			
Student maintains a positive attitude when working			
If student is working in a session, and it seems like it is going to take a long time, he/she still prefers to continue working			
OVERALL PERSEVERANCE ON TASK SCORE			

Image 2: Classroom Observation Protocol on Perseverance rubric

Additionally, the assessment contained a section for written comments on perseverance behaviors during game play and were taken on individual students' perseverance behaviors while playing the board game to further explain the scoring rubric.

Procedures

The following section describes procedures the primary researcher and assistants followed as well as the training they received. Also, an explanation of how *Creature Counting* was developed, how the intervention and comparison groups were conducted, and how all assessments were executed are discussed. Finally, a description of the treatment procedures are explained.

Data Collection

There were three researchers facilitating the course of the study. The first researcher, referred to as the primary researcher, was solely responsible for all rounds of game play with the comparison and intervention groups. The primary researcher was aided by two research assistants. Research Assistant 1 was responsible for administering SU-K and Panamath to the participants before and after treatment. This assistant was not involved with implementing the board game and remained blind to the condition of the students. Research Assistant 2 worked with the primary researcher during game play. This assistant was responsible for administering and scoring all COP-P data during the course of treatment with all participants, while the primary researcher implemented the board game. It is important to note that Researcher Number 2 was not blind to the conditions while scoring the COP-P. The two research assistants are graduate students at a local university. All three researchers have their kindergarten through fourth grade teaching certificate and have experience teaching early elementary students.

Researcher Training. Prior to the start of the research study, the three researchers were trained in administering SU-K, Panamath, and/or COP-P. For instance, the FastBridge software that provides the SU-K assessment delivers training modules that include information about assessments and interpretation of data using video tutorials, text, and opportunities to practice using the assessments. At the end of the training, the software produces results indicating who has passed certification. To ensure fidelity of implementation of the instrument, Research Assistant 1 completed the online training and submitted the certification of completion to be stored on file.

Additionally, prior to implementation in the intervention classroom, the primary researcher and Research Assistant 2 obtained interrater reliability on the COP-P. The primary researcher trained Research Assistant 2 by sitting with her and discussing the rubric. Then, the researcher and assistant tested the COP-P by using scorer agreement reliability methods in a separate class of kindergarten students who were not used in the study. Scorer agreement reliability refers to the consistency with which different people who score the same test agree (Boudah, 2010). Each researcher independently assessed the same five students. Afterwards, the two researchers discussed any disparities and discussed findings until 100% agreement was reached. Any revisions on the scoring guided were updated. The process was then repeated to deem the assessors as reliable with a new group of five students. It was then determined that Research Assistant 2 was prepared to administer and score the rubric during the intervention.

Designing Creature Counting

The educational objectives in early elementary are much different than other elementary aged children because they are more based on theories of play (National Research Council, 2015). The researcher drew upon this information and developed a mathematical board game called *Creature Counting*. There are two versions of the game, an AR-enhanced version and a traditional version.

Creature Counting was built with an AR system called Aurasma and was activated through mobile devices. Aurasma is an open-source web-based program and is a free iOS application. Selecting a free operating system was important because it allows all socioeconomic levels to participate with this technology. *Creature Counting* is played through a mobile device on a researcher created board game, where students use the AR technology to practice subitizing numbers 1-6 in various quantities and spatial arrangements. The primary purpose of constructing a traditional play activity with AR helps merge the benefits of AR technology and social learning as previously discussed. Additionally, the development of a fun and user-friendly AR board game was designed for teachers to use in their classrooms as a supplemental activity.

The objective of the game is to subitize the eyes of friendly creatures who are sleeping. Students must identify the quantity quickly, otherwise the creature will fall back asleep. To move throughout the board, students roll a die and were encouraged to subitize the amount of spaces they will move on the board. As they come upon a sleeping creature, students place a mobile device in front of a creature trigger image that wakes it up. The trigger image activates Aurasma and makes the missing eyes appear. The various pictorial creatures are standing on predetermined spots throughout the board.

Applying developmentally appropriate practices in *Creature Counting* were of the utmost importance. As mentioned earlier, learning experiences with young children must include interactions that support development of knowledge in an authentic and active way (Gasteiger, 2012; Papert, 1996). Therefore, one of the goals when developing the game was to include as many opportunities for students to naturally subitize numbers 1-6. Including the use of a single die, over a number spinner for instance, was chosen for this reason. Piaget (1952) posited that children acquire knowledge through physical contact, observation, and repetition of actions. The die allowed students to not only have concrete practice subitizing but also observe their peers employing this number sense skill. The repetitive actions of rolling the die and subitizing the creatures was also motivated by this idea. Additionally, as Clements and Samara's (2009, 2014) research mentioned, the ability to subitize happens rapidly. In order to have students practice identifying the subitizing quantity quickly, they must answer within a few seconds; otherwise the creature will fall back asleep. Incorporating the speed aspect in the game and the challenge of beating the creature before it wakes was intended to be a motivator for students to persevere. A list of other developmentally appropriate practices applied to *Creature Counting* can be found in Appendix D.

Intervention and Comparison Groups

Intervention group

The intervention group received the AR-enhanced version of *Creature Counting*. By placing a mobile device in front of a creature game piece, the overlay displays an aura of eyes in various subitizing spatial arrangements from numbers 1 through 6 (see Image 3). The primary researcher facilitated game play while students used a researcher-supplied iPhone to play *Creature Counting*; students played in small groups of three. The students quickly subitized the quantity presented on the creature. Game play lasted until every child was able to cross the finish line. Research Assistant 2 documented students perseverance behaviors on the COP-P during game play.

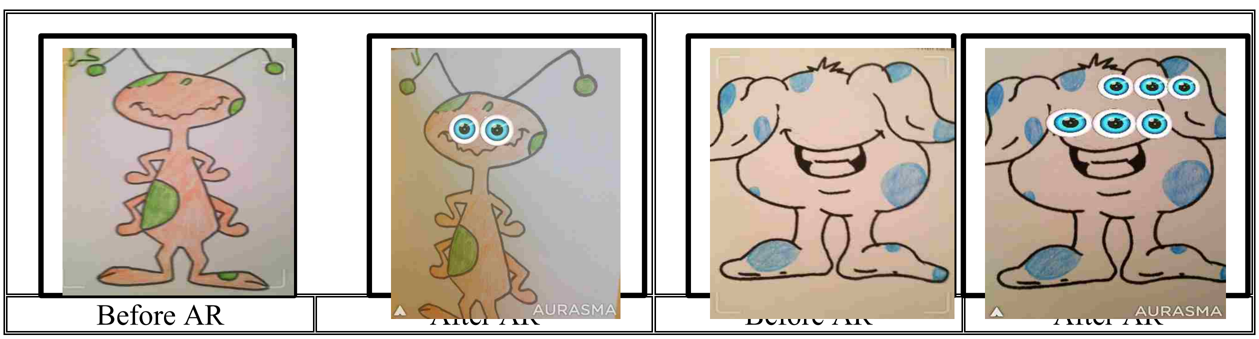


Image 3. Examples of before and after AR trigger images.

Comparison group

The comparison group consisted of students playing a technology free version of *Creature Counting*, which mirrored the AR enhanced version. The only difference between intervention and comparison groups game play involved the lack of technology; otherwise all creatures and the number of eyes on them were identical. In this version, rather than placing a mobile device in front of a freestanding creature, students selected a card that is placed face down in the middle of the board. Students had the same predetermined spot on the board for waking a creature as the technology version. The selected card showed a creature with eyes already formed in various spatial arrangements (see Image 4). The students quickly subitized the eyes presented on the card. Game play lasted until every student was able to cross the finish line. Again, the primary researcher facilitated game play while Research Assistant 2 documented perseverance behaviors on the COP-P.

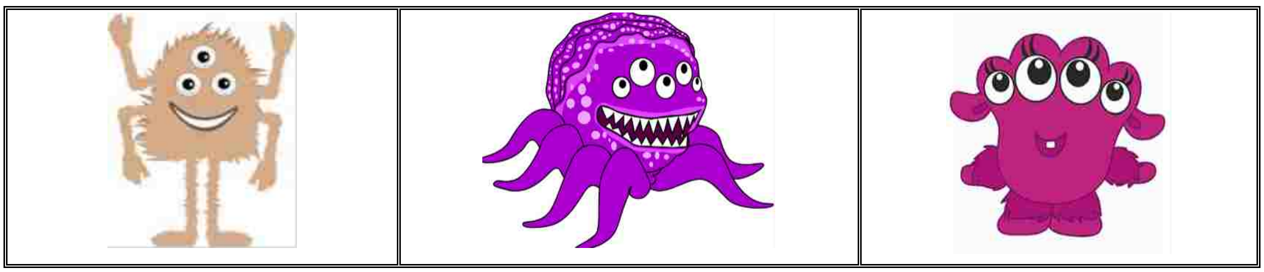


Image 4. Predetermined monster cards with various subitizing spatial arrangements.

Assessment Procedures

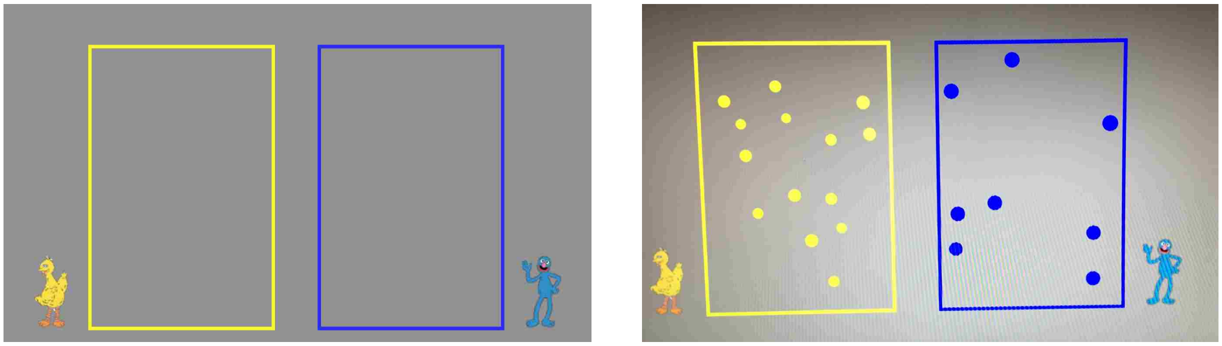
All students were assessed with the SU-K and ANS pretest. The pre-/post assessment was administered by Research Assistant 1 the two days before and after the treatment. During the five days of game play, all students were rated on the COP-P (see Appendix C) by Research Assistant 2 while the primary researcher managed game play.

SU-K

When starting the SU-K assessment, Research Assistant 1 read the prompt “We will do an activity where I will show you some dots and I want you to tell me how many dots you see. I'll do the first one. When I turn the page, without counting, I'll say how many dots I see. (flash card for 1 second). I saw four dots.” The student then had an opportunity to practice with one question. Once the practice question was over, the student moved on to the assessment, starting with Question 1 and continuing to Question 12. If the student incorrectly responded to the first three items (1, 2, and 3) during the pretest or (12, 11, and 10) during the posttest, the task was discontinued. Research Assistant 1 started the timer when the first card was flashed and stopped the timer right after the student responded to the last item. If the student paused for 3 seconds without responding to an item, Research Assistant 1 counted the entire item incorrect and continued with the next item. During administration of the posttest, the sequence of questions was reversed from 12 to 1.

Panamath

The second number sense test administered was the Panamath assessment on the computer. The assessment begins with empty yellow and blue boxes with recognizable children's television personalities (Big Bird and Grover) on either side. During the assessment, the number of yellow and blue dots was randomly displayed on the screen (see Image 5). To choose which color has the most dots, the participant selected either the *F* key for yellow or the *J* key for blue. The colored dots range from being fairly easy to distinguish the number of dots of a particular color (e.g., 20 yellow and 5 blue) to more difficult questions that display colored dot arrangement close to one another (e.g., 9 yellow and 12 blue). When students press the space bar it advances the participant to the next question. To ensure participants were focusing on the number of the dots and not using the sizes of the dots to answer, the dot sizes on each trial change with the number of dots presented. Research Assistant 1 explained to each student how to complete the assessment.



Screen image before the assessment Screen image during the assessment

Image 5. Example of before and after view of Panamath.

At the end of the 5 days of game play, Research Assistant 1 assessed all participants on the SU-K and Panamath following the same protocols used during the pretest. The order of the assessments given was counterbalanced from the pretest to account for familiarity of the assessment because the length of time between administration of the two assessments was brief.

COP-P

The COP-P was used to record students' observed perseverance behaviors while students were playing either version of the board game. These data were collected by Research Assistant 2 and remained in the assistant's possession until the end of the study. The COP-P assessment first identified if each student was demonstrating perseverance during his or her learning session based on an observation scale. Each student received a daily total score generated by adding together the observed qualities of perseverance, mentioned earlier from each of the four questions, which generated a score of 4–12. Students received the score each day over the 5 days of intervention, and after the intervention, the scores were averaged together to produce an overall perseverance on task score for the week, thereby determining whether the student had low, medium, or high levels of perseverance.

Treatment Procedures

The implementation of *Creature Counting* was conducted over nine consecutive days. A schedule of implementation is presented in Figure 4. Days 1, 2, 8, and 9 were designated for conducting SU-K and Panamath pre-/posttests, while Days 3 through 7 of implementation were selected for game play and recording observations on the COP-P.

When creating the timetable of implementation students' special periods, such as Music, PE, and lunch, had to be factored into creating the schedule. Therefore, the time of day in which each group participated, either morning or afternoon, switched each day to respect the students' learning time. Each day of game play began with participants being called into their randomly assigned group of three students and played in hallway away from their classroom. This location was chosen for two reasons: (a) there was more space for students to work as a group, and (b) this location did not allow the other students to see the alternative version they were playing when they were walking in the halls to and from special periods.

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9
a.m.	Pretest: SU-K Panamath	Pretest: SK-U Panamath	Comparison group	Intervention group	Comparison group	Intervention group	Comparison group	Posttest: Panamath SU-K	Posttest: Panamath SU-K
p.m.	Pretest: SU-K Panamath	Pretest: SU-K Panamath	Intervention group	Comparison group	Intervention group	Comparison group	Intervention group	Posttest: Panamath SU-K	Posttest: Panamath SU-K

Figure 4. Schedule of implementation.

Before the participants played either version of the game, the primary researcher demonstrated how to subitize with counter chips. For example, the primary researcher said, "I'm going to look at some circles hidden under this paper and tell how many circles there are without counting them. Watch what I do." The primary researcher then presented five counter chips on the table. "Look at this. Five circles. There are five circles. Five. Now it's your turn. When I turn over the paper, tell me how many circles there are without counting them." The primary researcher then presented students with two counter chips. Students replied in a choral response. Each day there were different subitizing quantities, all ranging from one through six, and spatial arrangements presented before game play. All examples were identical, regardless of group. The purpose of this was to model for students how to subitize and provide an example of a standard answer statement when playing.

The primary researcher then explained the directions on how to play *Creature Counting.* During game play, regardless of type of play, if students were unable to either answer the subitizing arrangement correctly or it took more than a few seconds to respond, the researcher provided a standard correction statement. For instance, the researcher would say, "Four. There are four eyes. Four," and moved on to the next player. One round of game play, which consisted of six subitizing opportunities per child, lasted until all students completed the board game. Students played once a day for approximately 15-20 minutes. See images in Image 6 for students playing *Creature Counting* with AR and Image 7 for students playing the traditional board game.

Data Analysis

Three research questions formed the basis of this study. Descriptive data were collected and analyzed to answer the following research questions: (a) do children in the intervention group make greater gains than children in the comparison group on tasks of number sense? (b) do children in the intervention group make greater gains on a measure of task perseverance than children in the comparison group? and (c) do COP-P scores predict number sense?

Data were collected using the three instruments: pre-/posttest on SU-K and Panamath, as well as the COP-P rubric used during instruction, which included a section for note taking on observed perseverance behaviors. An explanation of data analysis for each research question, which included 2x2 mixed repeated measures ANOVAs with a linear regression, follow.

Research Questions 1 and 2

Research questions 1 and 2 identified the differences in the intervention and comparison groups number sense skills and perseverance level. The 2x2 mixed repeated measures ANOVAs were selected because (a) they detect any overall differences between related means and (b) are most effective when there is a small sample size (Field, 2009). The use of a 2x2 mixed repeated measures ANOVA design also allowed for greater power, and unsystematic variance is reduced.

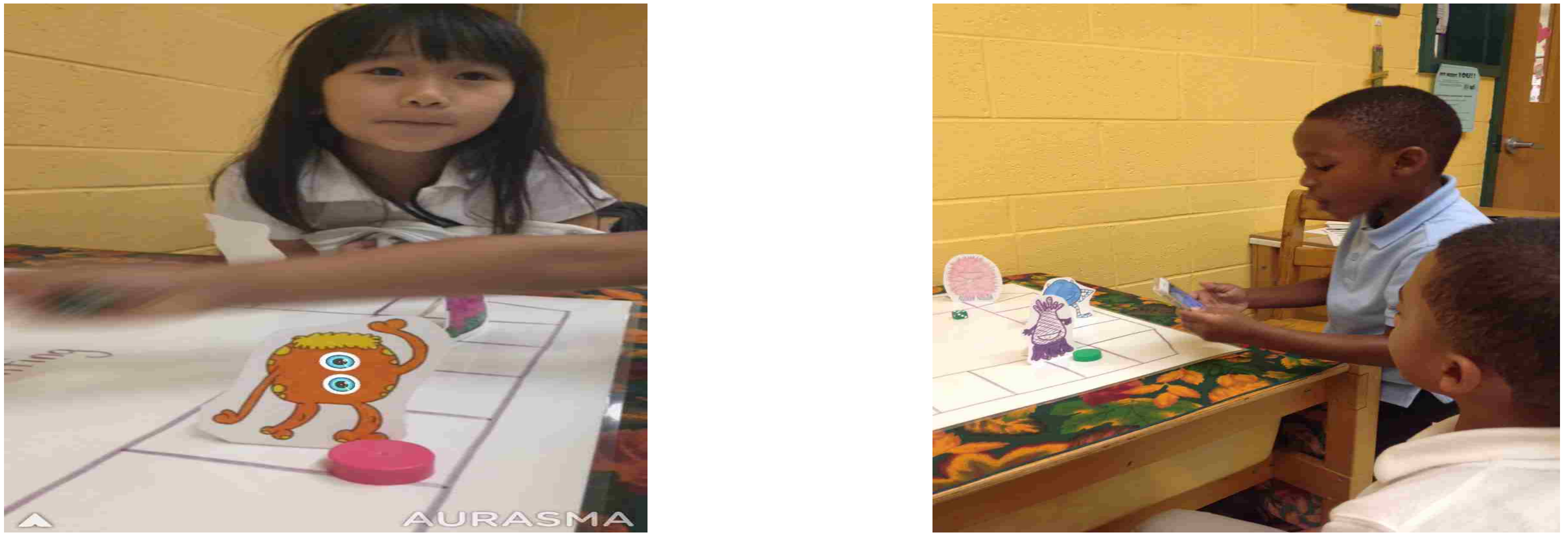


Image 6. Students playing *Creature Counting* with AR and mobile device.

Image 7. Students playing *Creature Counting* with the traditional board.

Research Assistant 1 administered the SU-K and Panamath. Each participant's analysis report was automatically generated from the respective software. For the first part of Question 1, a 2x2 mixed repeated measures ANOVA was used to determine whether an interaction occurred between groups and time and the mean differences in the SU-K scores between the groups. The variables in the test included group (represented as [comparison] and [intervention]) and time (as [preSUK] and [postSUK]. Similarly, to measure whether differences existed between intervention and comparison students' ANS scores, a 2x2 mixed repeated measures ANOVA was used. The variables again included group (represented as [comparison] and [intervention]) and time (as [preANS] and [postANS].

Additionally, students' perseverance on task level was measured and obtained using the COP-P. Research Assistant 2 administered and scored the COP-P. An analysis of variance was used to determine mean differences between the intervention and comparison students' scores on the COP-P using the variables group (e.g., where group includes [intervention] and [comparison]) and score [COP-P]. ANOVA is an appropriate test because this statistical method is used to test differences between two or more means and inferences are made about means by analyzing variance.

Research Question 3

The subsequent question, do COP-P scores predict number sense scores, was used to identify if there was a relationship between the observed perseverance levels and students' posttest SU-K and Panamath scores. The main purpose of using a simple linear regression was to describe the relationship from one variable to another. The criterion variable was number sense scores and the predictor variable was perseverance level for each of the two linear regression tests. In this study, one regression was used to identify the relationship between students' subitizing score and their observed perseverance level, as well as another test to determine whether a relationship exists between students' ANS scores and their observed perseverance scores. The other key component of linear regression is that this model also predicts values of one variable from values of another; this measure was important for the study because it helped find the direction of the relationship between variables.

The COP-P also allowed for data collection on how the student demonstrated perseverance through the note taking section. This section was intended for the researcher to document perseverance behaviors through both verbal and non-verbal responses. The anecdotal notes section was reviewed for salient themes. Although the analysis of the themes naturally transpired from the notes taken, there were themes from the perseverance literature that were anticipated to appear. For instance, students who demonstrated perseverance were more likely to display a certain stick with-it attitude. This attitude of determination may be maintained over time, despite being unable to answer questions correctly or face other setbacks (Peterson & Seligman, 2004). Additionally, students with perseverance tend to independently attempt to solve problems, rather than rely on others to assist them (Bass & Ball, 2015). These anecdotal themes were used to support the findings from SU-K, Panamath, and COP-P.

Power Analysis

Power analysis was conducted on the more robust tests - 2x2 mixed repeated measures ANOVA and linear regressions - to determine which test required a larger sample size. A medium effect size ($f = 0.25$) was selected based on the literature from Ramani & Siegler (2008) when using a RM-ANOVA to study board games as an intervention. An alpha level of .05 and power of .80 (Field, 2009) were used. Based on these specifications, a sample size of 34 students per group was needed for the 2x2 mixed repeated measures ANOVA for a total of 68 students.

Results from the power analysis for the linear regression model using a medium effect size (*f* = 0.15), an alpha level of .05, and power of .80 determined a necessary total sample size of 43 (Cohen, 1992; Field, 2009). Sixty-two students returned consent forms to participate in the study. While the number of participants in the study is less than the required amount, the test may be slightly underpowered.

CHAPTER 4: RESULTS

Overview

The nature of this study was to (a) determine whether differences exist in students' number sense outcome scores based upon the type of game play they received and (b) find whether variances occur in students' ability to persevere based upon the type of play instruction they received. Because improving instruction in early elementary mathematics is a pressing matter in the field of education, this learning activity can provide materials designed and tested to integrate into classrooms with the goal of increasing components of early number sense.

The study included 62 students of which 56 students were consistently present, completed all paired pre-/posttests, played all 5 days of game play, and were included in the final data analysis; of the six excluded students, four students were removed due to not participating in all five days of game play and two were removed due to ceiling out on the SU-K pretest. Three of the four students removed were in the comparison group and the fourth was in the intervention group. One student from each condition group ceilinged out on the SU-K pretest. This chapter explains the analyzed results from each of the three research questions. To determine whether learning gains occurred in the intervention group following the treatment compared to students in the comparison group, repeated measures-ANOVAs were used to analyze the early numeracy skills of subitizing with data from the SU-K assessment and the Panamath to measure Approximates Number System. Overall differences in pretest and posttest scores on the SU-K and Panamath instruments between the intervention and comparison groups are discussed. A one-way ANOVA was used to analyze the perseverance scores between the intervention and comparison group. Last, scores from the intervention group members' two posttest instruments and the COP-P were analyzed using linear regression to determine if students' perseverance predicted students' abilities to subitize and improve number sense based on the type of game they played. All statistical tests were conducted using IBM Statistical Package for the Social Sciences (SPSS) Statistics, Version 21.0.

Findings from the Analyses

Descriptive statistics for each of the instruments used in the study are provided in Table 2. Effect sizes for each of the pre-/posttest comparisons are also reported in the table and are discussed in the sections describing those assessments. Statistical analyses examined the research questions to determine intervention and comparison group differences following the implementation of game play with each group. Pretests for SU-K and Panamath were administered two days before the first day of classroom instruction and posttests were given following the final two days of the study. The results for each research question follow.

Table 2. *Descriptive Statistics for Outcome Variables*

	Intervention group (*n* = 30)		Comparison group (*n* = 26)		Total sample (*n* = 56)	
	M	*SD*	*M*	*SD*	*M*	*SD*
SU-K						
SU-K pretest	7.40	2.87	8.65	2.28	7.98	2.67
SU-K posttest	10.27	1.84	9.42	2.12	9.88	2.00
ANS						
ANS pretest	79.92	16.30	78.17	13.26	79.11	14.86
ANS posttest	86.00	12.42	84.90	10.71	85.49	11.56
COP-P						
Rubic score	7.27	1.55	5.50	1.75	6.45	1.86

Note. The SU-K instrument range was 0–12 with Spearman-Brown's reliability coefficient of .823 (N = 56). The ANS instrument range was 0–100 with split halves reliability of $r = .703$, $p = .05$, and the COP-P rubric range was 4–12 with coders reaching 100% consensus.

Type of Game Play and Number Sense: SU-K

To test whether the students' number sense skill of subitizing increased based on type of game play, RM-ANOVA was conducted to determine whether the scores of the intervention and comparison groups differed between the SU-K pre-/posttests and specifically how those groups differed. An independent samples t-test was also run to determine the differences between how the comparison and intervention groups scored on the SU-K pretests. Results indicated that the pretest scores of the groups were not statistically significantly different (p =.08). Before running the RM-ANOVA, several assumptions were tested and met. Because the scores from both the pre-/posttest approximated normal distributions and their skewness and kurtosis values were within Lomax's (2001) acceptable ranges for normality (between -2 and +2), the assumption of normality was met. The homogeneity of variance assumption was also met for both the pre-/posttests based on Levene's test of equality of error variances, $p > .05$. Box's M value was used to determine that the assumption of equal variance and covariance matrices was also met, p = .411.

The results from the RM-ANOVA demonstrated that there was a significant interaction effect between time and condition, $F(1, 54) = 9.71$, $p = .003$, partial $\eta^2 = .15$, where the impact of group differences was dependent on the times of the tests—whether pre- or posttest (see Table 3). Since the interaction effect was significant, the significant main effect of time, $F(1, 54) = 29.33$, $p < .001$, partial $\eta^2 = .35$, may be misleading because the effect of condition on the outcome varies with the time of the tests and it is unclear which of those variables is impacting the scores more. No significant main effect was found for condition, $F(1,54) = 0.15$, $p = .70$, however. Because of the presence of a disordinal interaction between the groups and times of the tests, it is difficult to determine whether the intervention was, in fact, effective. Thus, it is necessary to examine the simple effect analysis of mean differences on each level of time and condition (Field, 2009). The means and interaction plot (see Figure 5) showed that while comparison participants had higher scores on the SU-K pretest ($M = 8.65$, $SD = 2.28$) compared to intervention participants ($M = 7.40$, $SD = 2.87$), the intervention participants scores were higher on the posttest (*M* = 10.27, *SD* = 1.84) following the treatment than the comparison participants (*M* = 9.42, *SD* = 2.12).

To address this interaction effect and determine which variables were significant, Stevens (1999) recommended a one-way ANOVA should be performed after recoding the variables to include the interaction between groups and times of tests. The interaction variables were recoded into four new categories of the variable [interaction] where time and condition were represented as interactions. For instance, intervention+pretest was coded as 1, intervention+posttest was coded as 2, condition+pretest was coded as 3, and condition+posttest was coded as 4. Results from the one-way ANOVA of the new four-category interaction variable were found to be significant, $F(3, 108) = 8.23$, $p < .001$, partial $\eta^2 = .19$. Post hoc comparisons using the Tukey HSD test confirmed that the scores of the intervention group between the pre-/posttest were significantly different ($p < .001$), while the comparison participants' scores following the intervention were not significantly different ($p = .63$). These results indicate that the AR intervention had an effect on the SU-K test scores of the intervention group.

Additionally, another one-way ANOVA was run using SU-K gain scores to corroborate whether there was a difference between the groups. Gain scores were calculated by subtracting SU-K pretest scores from SU-K posttest scores. Assumptions were tested and met, and the one-way ANOVA demonstrated that a statistically significant difference existed between $F(1,54) = 29.33$, $p < .001$, partial $\eta^2 = .35$. The intervention participants had better gains (*M* = 2.87, *SD* = 2.76) following the intervention than the comparison participants (*M* = 0.77, *SD* = 2.18). These results further support the findings that the AR intervention had an effect on the SU-K test scores of the intervention group.

Table 3. *Mixed Repeated Measures Analysis of Variance for SU-K Pre- and Posttests by Condition*

Source	*SS*	*df*	*MS*	*F*	*p*	η²
Between subjects						
Condition	1.17	1	1.17	.154	.697	.003
Error	409.35	54	7.58			
Repeated measures						
Time	92.43	1	92.43	29.33	.000	.352
Time x condition	30.60	1	30.60	9.71	.003	.153
Error	170.16	54	3.15			

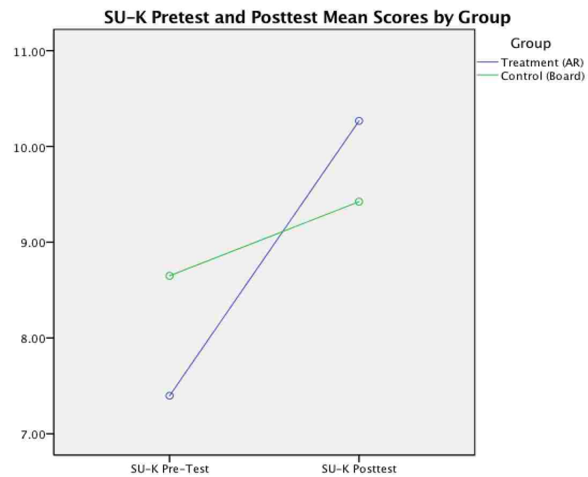


Figure 5. Means and interaction plot.

Type of Game Play and Number Sense: Panamath

To further determine whether the AR game increased students' number sense skill of ANS, a RM-ANOVA was conducted to investigate whether the scores earned by the intervention and comparison groups differed between the Panamath pre-/posttest and precisely how those groups differed. An independent samples *t* test was performed to determine the differences between how the comparison and intervention groups scored on the Panamath pretests. Results indicated that the pretest scores of the groups were not statistically significantly different (p = .67). Prior to running the 2x2 mixed repeated measures ANOVA, several assumptions were tested and met. The assumption of normality was met because the scores from both the pre-/posttest approximated normal distributions and their skewness and kurtosis values were within

Lomax's (2001) acceptable ranges for normality (between -2 and +2). Based on Levene's test of equality of error variances, the homogeneity of variance assumption was also met for both the pre-/posttests, $p > .05$. The Box's *M* value indicated that the assumption of equal variance and covariance matrices was also met, $p = .737$.

The results of the ANOVA indicated there was no significant main effect by condition, $F(1, 54) = 0.19$, $p = .67$, partial $\eta^2 = .003$, meaning that regardless of the treatment the students received, the scores of both groups increased over time (see Table 4). There was a significant main effect of time, $F(1, 54) = 19.90$, $p < .001$, partial $\eta^2 = .27$, meaning that there was a difference in pre-/posttest scores over time. However, there was no significant interaction effect between the tests and the groups, $F(1, 54) = 0.05$, $p = .823$, partial $\eta^2 = .001$, where the scores of the groups varied in much the same ways, regardless of the treatment provided. While students ANS abilities increased between pre and posttests, it is uncertain whether game play, time, or another confounding variable were the reason for the changes.

Table 4. *Mixed Repeated Measures Analysis of variance for Panamath Pre- and Posttests by Group*

Source	*SS*	*df*	*MS*	*F*	*p*	η^2
Between subjects						
Group	56.16	1	56.16	.186	.668	.003
Error	16336.19	54	302.52			
Repeated measures						
Times	1143.54	1	1143.54	19.90	.000	.269
Times x groups	2.92	1	2.92	.05	.823	.001
Error	3102.83	54	57.46			

Type of Game Play and Perseverance

Research Question 2 sought to identify in which conditions (AR versus traditional board game) the potential changes in perseverance occurred. The use of the COP-P score were used to determine these outcomes.

In the intervention group, 0% scored in the high perseverance range (n=0), while 70% demonstrated medium perseverance (n=21), and 30% scored in the low perseverance range (n=9) (see Table 6 for distribution of student COP-P scores). In the condition group, 0% scored in the high perseverance range (n=0), while 23% demonstrated medium perseverance (n=6), and 77% scored in the low perseverance range (n=20).

Additionally, a one-way ANOVA was conducted to examine the differences between the intervention and condition groups on the COP-P scores. The data were evaluated with regard to meeting the statistical assumptions of the procedure prior to conducting the one-way ANOVA analysis. Observations were independent; there were no significant outliers; and the dependent variable was normally distributed for each group. To test for the homogeneity of variance, Levene's test was also met for the groups, $p > .05$.

Results from the one-way ANOVA indicated there was a statistically significant difference between groups on the COP-P scores, $F(1, 54) = 16.04$, $p < .001$, partial $\eta^2 = .23$ (see Table 5). Mean scores from the perseverance test were higher for the intervention group (M = 7.27, SD = 1.55) than for the condition group (M = 5.50, *s.e.* = 1.75). Students who participated in the AR intervention scored higher on the COP-P than students who played the board game alone. Students baseline scores in perseverance were unknown.

Table 5. *One-Way Analysis of Variance for COP-P by Group*

Source	*SS*	*df*	*MS*	*F*	*p*	η^2
Between subjects	43.47	1	43.47	16.04	.000	.229
Within subjects	146.37	54	2.71			
Total	2517.00	56				

Table 6. *Distribution of Student COP-P Scores*

	Intervention group (n = 30)			Comparison group (n = 26)		
COP-P	Range of	Students		Range of	Students	
perseverance	scores	n	%	scores	n	%
High	10–12	0	0	10–12	0	0
Medium	7–9	21	70	7–9	6	23
Low	4–6	9	30	4–6	20	77
Total	4–12	30	100	4–6	26	100

Note. The COP-P rubric range was 4–12.

Qualitative Findings on the COP-P

The themes that emerged from the anecdotal notes on the COP-P revealed several themes to support the results. First, 70% of students in the intervention group tended to demonstrate medium levels of perseverance, whereas 23% of the comparison group demonstrated some levels of perseverance. A perseverance attitude is one that shows determination is maintained over time despite being unable to answer questions correctly or face other setbacks. For example, Student Intervention 05 consistently got the answer incorrect when she played. However, the observation notes revealed this student more often displayed a stick-with-it attitude throughout the entire course of the study. She made statements such as, “That’s okay. I get to play again and maybe get the girl monster,” or, “I’ll try again. At least I did my best.” When Student Intervention 05 successfully subitized a quantity after several failed attempts, she gleamed, “I knew I could do it!” Additionally, Student Intervention Student 29 made declarations over the course of the study such as, “I don’t think I know the answer, but I’ll still try.”

Another demonstration of perseverance emerged when students independently attempted to solve problems, rather than rely on others to assist them. Twenty-four students in the intervention group and 11 students in the comparison group demonstrated this level of perseverance. Students in the intervention group made statements such as, “Wait, I didn’t want you to tell me. I knew this one was 5.” After Student Intervention Student 09 realized a standard response answer would be given if he answered incorrectly or timed out, he said, “Can you wait to give me the answer until I’m ready? I just like this monster. I know I can figure this out.” Student Intervention Student 09 consistently provided an answer even when he knew it was incorrect. Students in the comparison group, such as Student 15, made statements such as, “I am going to try my best all by myself this time, okay? I think I can do it.” In contrast, six students in the intervention group and 15 students in the comparison group more often paused and waited for the response to be given, asked the primary researcher for the answer, or skipped the question entirely rather than attempt an answer. For example, students Intervention Student 01, Intervention Student 28, Comparison Student 02, Comparison Student 14, Comparison Student 26, and Comparison Student 33 immediately looked at the primary researcher and waited for the standard response answer during every turn. Student Comparison Student 05, for example, found the higher the numbers (e.g., 4–6) were difficult and exaggerated his frustration during every session.

Lastly, 18 students in the intervention group demonstrated more excitement toward their version of *Creature Counting* than the comparison group’s version, which included seven students. In regard to the comparison group, Comparison Student 5 laid down his head on the table or gave up and refused to keep trying early on in gameplay during days 3 through 5 of treatment. Even though other students in the comparison group showed signs of happiness (e.g., smiling) or did not give up quickly during game play, they were not as excited as the intervention group. Many times, when members of the intervention groups were called to meet, they rushed to the door, asked who could hold the iPhone first, or asked the Primary Researcher when they would be called to the hall, anxious for their opportunity to play. There were consistent “ohh’s” and "ahh's" when the AR technology revealed the creature's eyes, even if they saw the creature from the previous days round of game play.

One case from the intervention group that stands out the most is when the teacher for Student Intervention Student 08 pulled aside the primary researcher at the end of the study and told her this student had been identified with a learning disability and often would not participate in any class discussions. When academic work was assigned, he characteristically put his head on his desk or was disruptive in class. His teacher commented on Intervention Student 08's behavior as follows:

> [He was practically] bouncing out of his seat the entire time he was waiting to be called into the hallway to play. His behavior has been transformative this week and has been so amazing to watch. Providing him with an alternative way of learning seemed to increase his confidence. He went from never participating in math class to being one of the first to join in learning. (Intervention Student 08's teacher)

A supplementary finding from the notes that is that students in the comparison group often reported memorizing the creature's quantities. For example, three individual students in different comparison groups stated they remembered the number of eyeballs based on the characteristics of the creature before even looking at the full body. Student Comparison Student 13 said, "Oh, I remember this one. I had the red one yesterday. It's 3." Student Comparison Student 21 quickly answered, "6," without revealing the entire card. The other student in the group asked how she knew it was 6, and Student Comparison Student 21 responded, "It was the furry guy. He's always 6." Even though the intervention group had the equivalent creature, several intervention group students made statements that suggested they were waiting to identify the quantity rather than remember the number of eyeballs. Student Intervention Student 04 said, "I hope I get to the green one. I really wanted him yesterday. I wonder what number he will be?" Student Intervention Student 17 on Day 4 of treatment said, "Do you think the baby monster has one or two [eyes]? He has a little body, so he can't have too many of them. I've always wanted this one."

Perseverance and Number Sense

It was important to analyze whether perseverance predicted stronger number sense skills. To analyze whether COP-P scores predicted subitizing scores, a regression analysis was conducted to examine the relationship between the COP-P scores and subitizing SU-K posttest scores. Assumptions of linearity, no significant outliers, independence of observations, homoscedasticity, and normality of residuals were checked and met. Results from the regression suggested that COP-P predictors explained only about 3% of variation in the model and the COP-P did not significantly contribute to the outcome scores on the subitizing posttest, $F(1, 54) = 1.37$, $p = .247$.

To ensure that SU-K pretest scores were not impacting the outcomes of perseverance on number sense, a hierarchical linear regression model was run controlling for pretest scores. Again, assumptions of linearity, no significant outliers, independence of observations, homoscedasticity, and normality of residuals were tested and met. Pretest alone accounted for 13% of variation in subitizing posttest scores, $F(1, 54) = 7.91$, $p = .007$. After adding the COP-P predictor, 16% of variation in the outcome scores was then explained by pretest and COP-P, and after controlling for pretest, COP-P did not significantly contribute to the outcome scores on the subitizing posttest, $F(1, 53) = 1.70$, $p = .20$, $\Delta R^2 = .03$.

Also, when examining whether COP-P scores predicted ANS scores, another simple linear regression was run to establish whether perseverance could predict ANS posttests. Again, assumptions of linearity, no significant outliers, independence of observations, homoscedasticity, and normality of residuals were checked and met. It was determined that COP-P scores statistically significantly predicted students' accuracy on the Panamath assessment, $F(1, 54) = 5.79$, $p = .020$ and students' perseverance accounted for 10% of the explained variability in accuracy scores. For each point students increased on the COP-P, students' scores on the Panamath test increased by 1.94 percentage points.

However, to ensure that ANS pretest scores were not impacting the outcomes of perseverance on number sense, a hierarchical linear regression model was run controlling for those pretest scores prior to testing for the impact of COP-P on ANS posttest scores. Similarly, assumptions of linearity, no significant outliers, independence of observations, homoscedasticity, and normality of residuals were tested and met. In this case, pretest alone accounted for 50% of variation in ANS posttest scores, $F(1, 54) = 52.75$, $p < .001$. After adding the COP-P predictor, only an additional 3% of variation was then explained by COP-P, for a total model variance of 53%. When controlling for pretest, COP-P no longer significantly contributed to the outcome scores on the ANS posttest, $F(1, 53) = 3.45$, $p = .07$, $\Delta R^2 = .031$.

CHAPTER 5: DISCUSSION

The current attention on improving early elementary mathematics instruction, especially for struggling students in low-income areas, has affected elementary schools across the United States. This spotlight has prompted modifications to mathematics programs to equip students with a stronger mathematics foundation, particularly with number sense skills. Educators are still struggling with how to incorporate lessons that challenge, motivate, and create a solid foundation in mathematics. The primary focus of this study was to offer suggestions on how educators can support young learners in mathematics by supplementing number sense activities through play and technology. A secondary goal of this study was to identify how the interventions may have played a part in improving students' perseverance and if having the ability to persevere made a difference in students' number sense gains.

In this chapter, connections between the findings from the data and those reported in the literature are explained. An explanation of the relationship between early numeracy skills, playing with board games, technology, and perseverance is offered. The chapter concludes with a discussion of recommendations for how educational board games with technology, plus fostering students' ability to persevere, should be incorporated into early elementary mathematics instruction.

Research Question One: Do children in the intervention group make greater gains than children in the comparison group on tasks of number sense?

This study tested whether students' number sense skills of subitizing and ANS increased based on an AR-enhanced version of a number sense board game or the traditional version of the board game they played. The results of this study correspond with previous findings of board games and AR. The data revealed that regardless of the treatment the students received, the number sense scores of children in both groups increased over time. In other words, the intervention of playing with any version of a mathematics board game may improve students' subitizing and ANS ability. Researchers have endorsed the use of board games in elementary mathematics for quite some time and have reported mathematical growth after using board games as an intervention (Whyte & Bull, 2008). Mathematical learning occurs because board games give students additional opportunities to deepen their mathematical understanding and reasoning (Ramani & Siegler, 2008; Siegler & Ramani, 2008, 2009).

A theme that emerged from the analysis was a difference between the pre-/posttest subitizing scores of the two groups. The intervention participants had statistically significant gains compared to the comparison group on the SU-K posttest following the intervention. In other words, the outcome indicated the students participating with the AR version of *Creature Counting* scored higher on the SU-K posttest than those playing with the traditional board game version. It is important to note that even though these results indicate that the AR intervention had an effect on SU-K test scores of the intervention group, the interpretation of the interaction effect from this test is limiting: the effects of time and condition may depend on one another in relation to subitizing scores (Field, 2009; Stevens, 2009).

Additionally, subitizing is a skill that requires repetition rather than being directly taught (Clements & Sarama, 2014). Students may have improved their subitizing scores due to the number of opportunities they had to practice in both versions of *Creature Counting*. However, the use of visual imaging in AR may have helped the students understand the concept more than the comparison group, who were more likely to memorize the subitizing quantity.

In regard to ANS outcome, the results of the study indicated that regardless of the treatment the students received, the ANS scores of both groups increased over time. Although the scores of both groups increased, the scores varied in the same way regardless of the treatment provided. These results could also feasibly be explained due to the fact the ANS assessment was used as a distal measure.

The results of this study further support the limited research available on incorporating mobile devices and AR into early elementary lessons. The integration of this technology could offer educators opportunities that allow students to make connections and see a purpose to solving problems—a vital component in mathematics. Using AR enhanced board games showed students that mathematical activities can be purposeful. In regard to helping educators implement technology that could help number sense skills, using an AR-enhanced board game could be a supplemental activity they can begin investigating in their classroom because it may improve students' subitizing skills.

While there are many benefits to also implementing traditional board games, it is important to note some students in the comparison group were quick to memorize the quantities when playing with the traditional version of *Creature Counting*. Rutherford (2015) and Mather and Jaffe (2002) also claimed that children often memorize answers to board games due to the repetitiveness of game play and may not retain the information over time. Mather and Jaffe (2002) explained the downside for memorizing is that concepts are not fully understood and, later, frustration may develop if the unlearned concepts are not developed. This shortcoming may lead to a lack of confidence and effect self-esteem as a result of not understanding more complex mathematical concepts. The demise of self-confidence will, in turn, also hinder students' ability to persevere. Memorizing was not an issue with the AR group because the use of visual imaging in AR helped students better understand things they have learned. Di Serio, et al (2013), concurs that when students use AR to learn they achieve high levels of concentration while performing a task which may aid in retention.

Research Question Two: Do perseverance scores differ between children in the intervention group and children in the comparison group?

The combination of play and mathematics encourages students' curiosity, which drives them to attain their goals regardless of difficulty (Tickell, 2014). Early researchers in perseverance claimed that students with higher levels of this character trait have the potential to perform better academically. The findings from the current study indicated that students who participated in the AR intervention scored higher on the COP-P than students who played the board game alone. While we do not know students baseline perseverance levels and whether it was the technology, the board game, or both improved those scores, students' perseverance may be impacted by the use of games and in early elementary mathematics and students' perseverance. Specifically, AR-enhanced games like *Creature Counting* may even be more motivating than the traditional game versions.

The analysis of the data indicated more students who played the AR-enhanced version of *Creature Counting* demonstrated better levels of perseverance than the comparison group. One of the themes throughout this study was connecting students who had high levels of perseverance to academic growth, but the ages of the participants in this study must be taken into account. The typical 5-year-old has difficulty retaining lengthy and high levels of concentration, and even the student with the strongest observational notes about perseverance can have an "off" day. Additionally, the challenge of the game never changed throughout the week, so students' perseverance scores began to dip as the week went on due to the lack of incentive for the students to "stick with it." A similar finding was also reported by Zagal, Rick, & Hsi (2006).

They found the repetitive nature of board games with predictable end results caused students to become distracted the more they played the game.

Even though zero students scored in the high perseverance range for either group, there was a significant difference between the ranges in the intervention and comparison groups. Also, the results of the one-way ANOVA suggest that the intervention showed differences on perseverance scores; students who participated in the AR intervention scored higher on the COP-P than students who played only the board game. Several factors contributed to these scores. First, the novelty effect of using this technology may have affected students' perseverance. Studies have shown that innovative AR-based activities are especially useful in increasing perseverance because they encourage students to engage in their learning processes and stir their natural curiosity (Marco et al., 2013).

Second, as mentioned previously, when novelty is combined with a systematic design in technological activities, the technology can foster personal qualities such as curiosity, self-reliance, and perseverance (Ritchie, 2013). The findings of a relationship between AR board games and perseverance are in line with researchers such as Di Serio et al. (2013), who endorses the use of AR technology to promote students' ability to persevere when problem solving. While Di Serio et al.'s study focused on middle school students, the pattern holds true with younger students as well. Liu et al. (2011) found when students use AR, student engagement tends to increase because the AR activity motivates them, which makes them more likely to persevere in difficult situations and willingly approach challenging tasks more than their less motivated peers. Third, when children perceived learning using mobile devices as play, they were more highly motivated, enthused, and engaged with the tasks presented (Gray et al., 2017).

Technology may make a positive impact on the way in which students learn and gather information. Observation notes on the COP-P indicated students who used the AR-enhanced version of *Creature Counting* demonstrated a more relaxed mood than the comparison group when answering the query. More students in the comparison group often looked to the primary researcher for signs of the correct answer. The ability to feel at ease appears to have allowed the intervention group students to develop their abilities, build self-confidence, and foster their perseverance. The observation notes on the COP-P also showed students in the intervention group were more willing to attempt answers and not give up because they each wanted to have their chance to operate the mobile device and identify the auras that appeared on the monsters.

Research Question Three: Do perseverance scores predict number sense scores?

The USDOE-OT (Shechtman et al., 2013) suggested that, to understand the connection between perseverance and learning, researchers must develop empirically based models that will lead the exploration on how to develop perseverance over time within disciplinary contexts such as mathematics. The USDOE-OT also endorsed the use of new and emerging advances in technology to develop innovative methods that could reach a wide range of students. The most motivated and successful students are ones who believe in their own skills and talents and embrace perseverance through learning (Dweck, (2007). Duckworth and Eskreis-Winkler (2013) and Duckworth et al. (2007) also remarked that students who are able to persevere are better equipped to overcome challenging tasks and, therefore, improve learning.

The idea that academic growth occurs due to perseverance levels has been argued (Willingham, 2016). Several studies reported that perseverance only contributed to a very small improvement in standardized test scores (Ivcevic & Brackett, 2014; Rimfeld et al., 2016). A lack of sufficient research in this field to make the case that perseverance is a predictor of academic success underscored the importance of conducting this study to examine the topic in more depth.

The results of this study found perseverance does not predict subitizing scores (via SU-K) or ANS scores (via Panamath). These findings further support previous research that shows simply because one is able to persevere it does not necessarily mean they will perform better academically (Ivcevic & Brackett, 2014; Rimfeld et al., 2016; Willingham, 2016). This is important to identify because some schools across the country are trying to apply a concept that still has not been proved to effectively work in an academic setting. Some school districts, for example in the San Francisco area, began testing students on perseverance; other schools have instituted things like Perseverance Week, in which students set goals for their scores on upcoming standardized tests (Zernike, 2016). This idea that if students just dig deeper when facing a difficult problem can make them stronger in school may have lasting psychological effects. Some students can begin to see themselves as failures because their best wasn't good enough (Denby, 2016; Silver & Stafford, 2017). When in fact, students need to be taught how to persevere (Tough, 2013; Slade & Hoerr, 2014). Further research is essential on how to properly implement this character trait in classrooms as well as effective ways to teach students how to persevere.

Implications of the Findings

This study found suggestive evidence to support recent calls for curriculum improvements for early elementary mathematics, especially in the area of number sense. The study appears to support the argument for a change in how number sense interventions can be delivered. By incorporating more authentic, play-based learning opportunities and the use of educational technology in classroom, the potential for mathematical growth is promising. For instance, incorporating AR and mobile devices with a board game seemed to improve students' number sense scores. Plus, a greater number of students persevered when using this technology than when playing the board game. Granted, although novelty may have played a part in the outcomes of this study due to the use of innovative technology, it is important to not overlook this finding. Novelty has the possibility to motivate struggling learners to continue to try. Also, when students used these technologies, student engagement increased because the technology may motivate students, which make them more likely to persevere, and approach challenging tasks more than their less motivated peers.

Educators should not feel discouraged if their school district is unable to offer financial support to provide the technology. The results also showed the use of a traditional board game brought improvements to students' number sense. The use of a traditional board game still offered play-based learning opportunities for children to build their numeracy skills. Students' knowledge of early numeracy skills increased even without the technology-based game because board games provide visual, kinesthetic, auditory, and temporal cues to the number system.

Teaching students how to persevere is part of the CCSSM. To successfully increase students' ability in this standard, teachers must develop systematic ways of framing mathematical challenges that are clear and explicit. The results of this study indicate that the students who persevered felt excited about engaging in and successfully completing the activity because they were involved and motivated to learn. By providing opportunities for students to persevere through playing board games, they began to identify effort in mathematics as worthwhile and perceived themselves as capable of and successful at learning and doing mathematics.

Perseverance has the potential to help students succeed in various ways, but further research is needed. Educators are still looking for ways to incorporate the CCSSM perseverance standard into their lessons effectively; they need more guidance. Additionally, students need to be taught how to preserve when faced with a difficult situation. Also, stronger perseverance assessments must be created that are geared toward young students. This gap in the knowledge base and literature must be addressed. The themes that emerged from this study are all part of the ongoing discussions about curricular change, perseverance, and early elementary mathematics education. Successful implementation of board games, specifically those enhanced with AR, and perseverance can lend support to those discussions.

Significance of Study

There is evidence showing mathematics programs that incorporate meaningful play activities such as board games may promote a myriad of positive attributes, including long-term academic achievements, increased inventiveness, and perseverance (Bodrova, 2001; Elofsson, Gustafson, Samuelsson, & Träff, 2016; Fisher, Hirsh-Pasek, Newcombe, & Golinkoff, 2013; Leong, 1996; Leong & Bodrova, 2007). Previous research findings on AR indicate promise in formal educational settings (Dunleavy & Dede, 2014), but few researchers have empirically studied AR in the formal learning environment of young children (Peirce, 2013). To address this gap in the literature, a goal of this study was to research the effects of using AR in kindergarten classrooms and identify if this learning tool could help students improve their number sense skills. The results of the study demonstrated that using this technology with a younger population has the potential to improve student learning.

A secondary focus of this research study was to empirically test whether students who exhibit the characteristics of perseverance experienced greater learning gains in subitizing and

ANS. Based on the results of this study, there is evidence that using board games in mathematics may help students understand mathematical concepts such as subitizing and ANS. To further improve learning in students, especially the under motivated or low-preforming student, implementing a meaningful AR-enhanced board game may motivate students to persevere more and improve learning.

Limitations of the Study

Although there were many successes throughout this study, there were also some limitations. First, the sample of students was small and chosen from a single urban elementary school. As such, the sample does not allow for the generalization of findings to all early-elementary students. Students' ability and knowledge levels may not be representative of other demographically similar students. Also, the implementation of the game in 5 out of 9 days might not ultimately impact long-term numeracy skills. Instead, additional research that includes multiple locations across a longer time span is recommended to identify a stronger correlation between the groups and intervention.

Second, the lack of a third control group who did not participate in either treatment was a limitation. The absence of this third group may have resulted in a weaker comparison between the two groups. Students who received only regular classroom instruction from the *Everyday Math* curriculum may have demonstrated little to no gains compared to students who participated in board or AR games.

Third, extraneous variables related to teachers' experience, instructional knowledge, and classroom efficacy might have influenced the findings in this study. The types of instructional strategies implemented in each classroom varies from each room and may have had an impact on student performance.

Fourth, Research Assistant 2 was not blind to the treatment groups when collecting data on the COP-P. While the research assistant was trained on the COP-P to ensure interrater reliability, because she was cognizant of treatment groups this may have caused unintentional bias when documenting the results.

Finally, while the iPad- and AR-enhanced nature of the board was enthusiastically appreciated and grabbed students' attention, its newness was at times a bit distracting. Students were excited to have the iPhone as part of their learning, however conversations about apps and other games used on their parent's phone or iPads needed to be tempered before rounds of game play the first few sessions. Also, some students needed encouragement to pass the iPhone on quickly rather than hold it for personal enjoyment. Another important idea to note about novelty is if the technology is used too often, students' interest may dwindle, which in turn could affect perseverance abilities.

Recommendations for Future Research and Practical Applications

To offer a solution to the challenge of creating innovative ways to improve early numeracy skills in young students, the first step was to merge the instructional ideas researchers have suggested to work in mathematics, play, technology, and perseverance. The next step was to synthesize these concepts and apply them in a way that can educate young students in mathematics, which is what this study aimed to achieve when creating and implementing multiple versions of *Creature Counting*. Based on the results of this study, the following recommendations are offered:

Incorporate Board Games Judiciously

A major finding of this study revealed that regardless of the kind of game play in which students participated, their number sense ability in subitizing and ANS improved. In simpler terms, board games appear to be effective. Students tend to be less self-conscious about failing or making mistakes during a game because they can explore math in formats with which they are familiar and that they enjoy. Likewise, students have opportunities to discover real-life ways to apply math skills.

Students who participated with the AR-enhanced board game tended to score better in both areas of number sense. The AR version of *Creature Counting* motivated the learners, which led them to persevere during difficult subitizing configurations. This form of intervention should be use sporadically during the school year, so the appeal of the technology game is not diminished. Traditional board games should also be used intermittently to keep students engaged and motivated.

Furthermore, an analysis on the game design of Creature Counting is needed. Due to the repetitive nature of the game, perseverance may have been affected by the design of the game. For example, in the study regardless of the students position on the board, everyone crosses the finish line. This means for some students it did not matter if the same student always comes in first, because everyone is a winner. This may have impacted students' perseverance scores because they may not have seen a need to work harder and pass students in the lead. In a new design of the game more traditional board game characteristics, such as loose a turn, move ahead/back a space, may impact students' perseverance scores because it gives them opportunities to preserve and overcome a challenging opponent.

Study Perseverance

Perseverance has a special place in the classroom. It has the potential to transform student learning. There has been limited research conducted in early academics that focuses on the initial development of perseverance, including the psychological processes that facilitate it. The paucity of research is concerning. First, research studies are needed to examine students' perseverance ability with more challenging tasks for young students. Developing the ability to persevere with challenging mathematics requires opportunities to struggle with puzzling problems in which the solutions are not always obvious. Simply getting stuck in math class does not lead to useful perseverance opportunities. Researchers and educators must evaluate what the nature of the mathematical task is that can engage students in a productive struggle, rather than a frustrating trap. To appropriately measure this level of perseverance, more effective perseverance assessments must be developed and examined with early elementary students.

Seek Professional Development Sessions

In regard to applying the findings of this study into current classrooms, Chuck (2017) noted that principals and teachers agree that digital devices have the potential to complement all areas of the curriculum and that schools have not yet realized the full potential of these devices. More professional development sessions on the use of AR with mobile devices are needed. Educators need to collaborate on how to create and successfully implement innovative mathematics activities using AR and mobile devices in the classroom. A recommended starting point to on how to use this technology is to incorporate it with board games. Incorporating opportunities for students to practice applying perseverance traits may be achieved with board games. Additional research, particularly with early elementary grade levels, is needed.

Summary

Studying the effects of students' perseverance when working with an AR-enhanced board game yielded results that suggest this new strategy fosters young students' number sense skills. Early elementary students' mathematics ability has been an active topic in developmental cognitive psychology research in recent years. The research suggests theory of play in early elementary education serves an important role in learning, reasoning, and socioemotional development. Perseverance has not been thoroughly examined, especially in the early elementary setting, to determine how this character trait effects students' ability to achieve in school. The outcomes of previous research suggest there is a need for a major reconceptualization of the type of early mathematical knowledge students acquire, how children develop mathematics knowledge informally, and how mathematics instruction proceeds in school. This study aimed to address these issues. As mentioned earlier, the results suggest there is, in fact, a correlation between early elementary students' ability to succeed in number sense skills and their ability to persevere when they learn by playing board games, in particular when they play board games that use AR and mobile devices.

The integration of play and technology with early numeracy skills such as subitizing and ANS has potential for students to improve. Therefore, conducting focused activities designed with play and technology is a worthwhile step toward addressing the mathematical ability of students in their early years, which could establish a stronger foundation for future academic success. Future research must make a more focused effort to understand how the use of novel technologies such as AR with a mobile device can enhance learning. Additionally, the effects of students' perseverance in younger populations and the correlation between perseverance and academic growth needs to be examined in much greater detail.

If schools take advantage of the opportunity to remodel content that fully engages students to persevere in cognitively challenging tasks, the results of the effort may lead to students who are better prepared to succeed in mathematics. Educational research must dive deeper into examining the role of how character traits helps students improve in mathematics.

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APPENDIX A: PARENTAL CONSENT FORM

LEHIGH UNIVERSITY

Dear Parents or Guardians,

My name is Megan Stotz and I am a fourth-year doctoral student in Teaching Learning Sciences Technology at Lehigh University. I am working under the guidance of Dr. Lynn Columba, professor of teacher education, on my qualifying research project.

I will be conducting a research study at your child's school to investigate student's number sense while playing with an augmented reality math game. Students will play in small groups. I will provide the iPad during each session.

This form is to request your permission to examine and analyze your child's responses to assessments prior to and after playing the game. Some photographs may be taken for documentation purposes and for use in peer-reviewed research articles. If you would like your child to participate in the study, but would not like your child's photo taken, please indicate this on the bottom of the page.

By granting me permission to examine your child's responses to pre and post assessments, in addition to mathematical behaviors, your child will be helping me to understand whether we can raise the level of understanding in mathematics through augmented reality games.

Any responses to assessments and other activities will remain confidential with regard to your child's identity. Your decision about your child's participation in this study is voluntary.

If you have any questions about this study, you may call me at 813-300-0955 or email me at med710@lehigh.edu

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), you are encouraged to contact Naomi Coll at (610) 758-2985 (email: nac314@lehigh.edu) of Lehigh University's Office of Research and Sponsored Programs. All reports or correspondence will be kept confidential.

To confirm your consent of your child's participation in this study, please sign below, and return by **Friday, September 16th**. Thank you.

****

Student name: ____________________________________

Please check:

*I **do agree** to have my child participate in the study and have my child be photographed for use in peer-reviewed journals. _____________

* I **do agree** to have my child participate in the study but **do NOT agree** to have my child be photographed for use in peer-reviewed journals. _____________

*I **do NOT agree** to have my child participate in this study. __________

_______________ ____

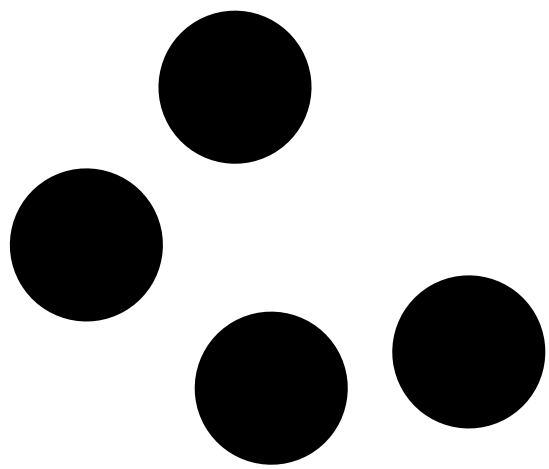
Date Signature of minor participant's parent or guardian

_______________ ____

Date Investigator's Signature

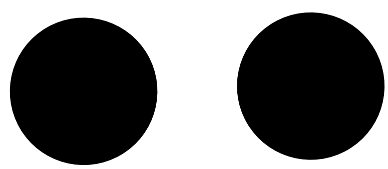
APPENDIX B: SUBITIZING ASSESSMENT MATERIALS

Example Item



Subitizing & Array Identification

Practice Item



Subitizing & Array Identification

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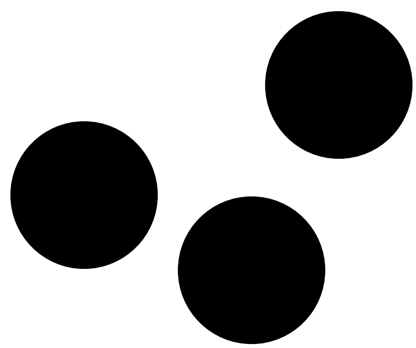

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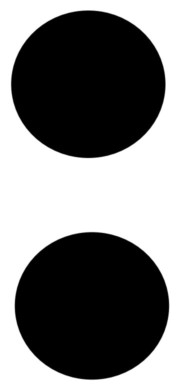

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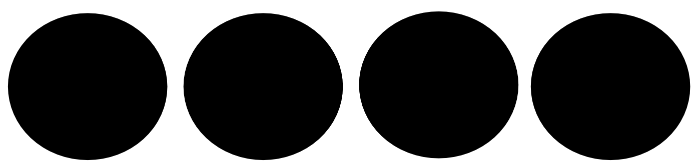
Subitizing & Array Identification

Item 3



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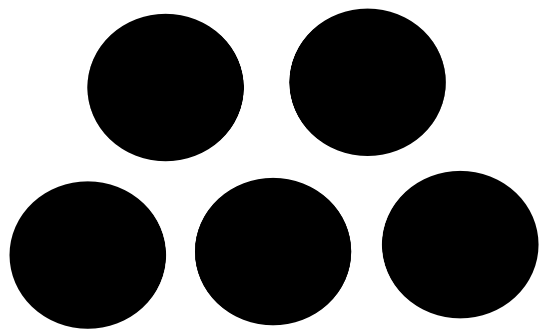

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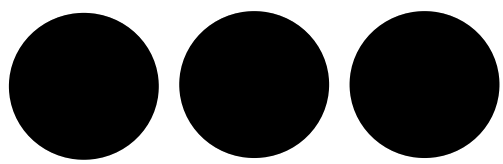

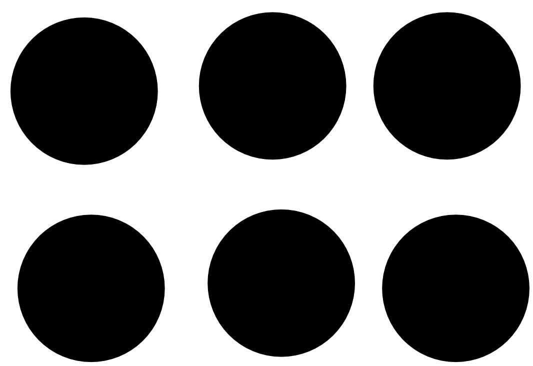

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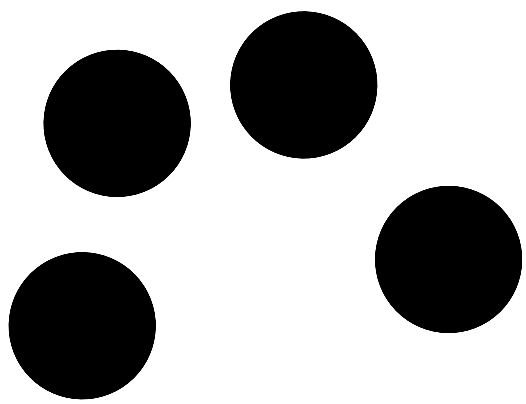

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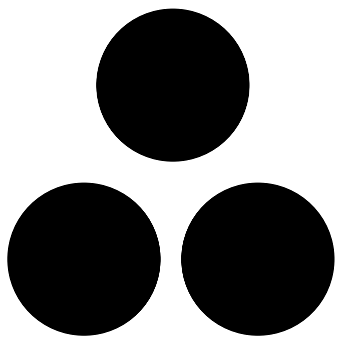

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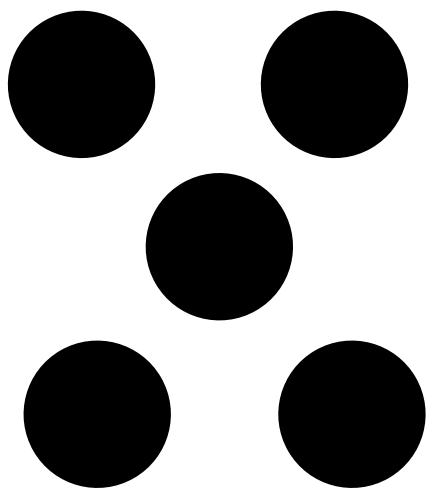

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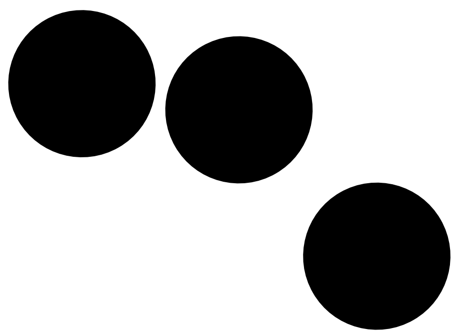

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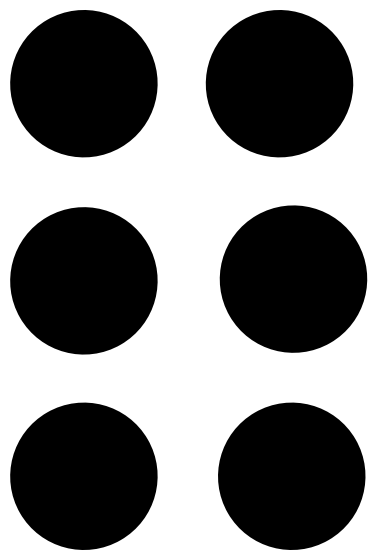
Item 11



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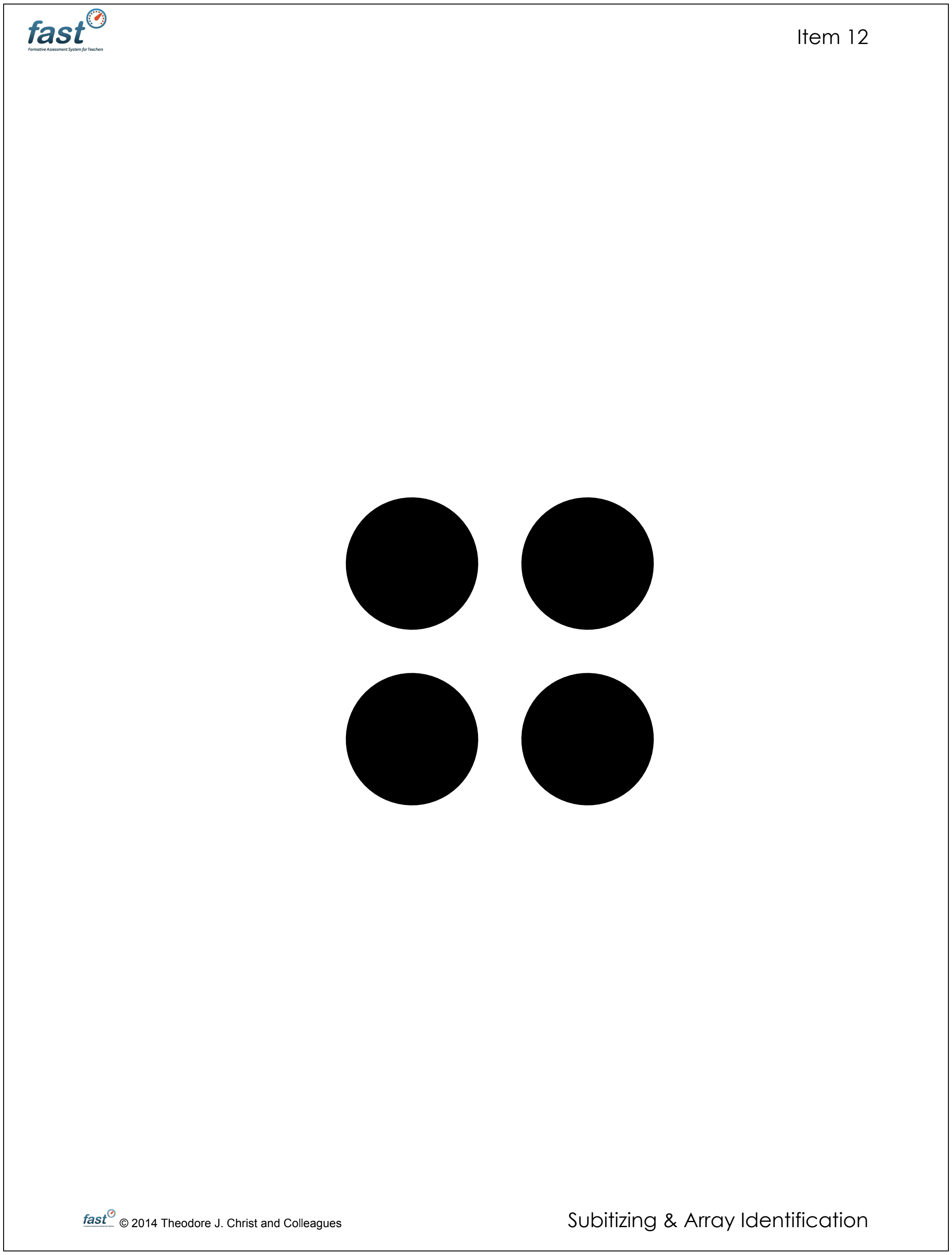

Note. Adapted from *Formative Assessment System for Teachers Technical Manual: EarlyReading, CBMReading, aReading, aMath, and EarlyMath,* by T. J. Christ, Y. A. Arañas, J. M. Kember, A. J. Kiss, A. McCarthy-Trentman, B. D. Monaghen, . . . M. J. White, 2014. Copyright 2018 by Formative Assessment System for Teachers.

APPENDIX C: COP-P

Classroom Observation Protocol – Perseverance on Task level

COP-P

DATE(S): ______________ **INSTRUCTIONAL SEQUENCE DAY:** ___________ **Group #:** __________ **Student #** ____________

Observed Perseverance on Task	Low Perseverance 1	Medium Perseverance 2	High Perseverance 3
Student persists in what he/she is doing, despite obstacles			
The student does not ask the teacher for assistance			
Student maintains a positive attitude when working			
If student is working in a session, and it seems like it is going to take a long time, he/she still prefers to continue working			
OVERALL PERSEVERANCE ON TASK SCORE			

Researcher Notes:

APPENDIX D: DEVELOPMENTALLY APPROPRIATE PRACTICES IN *CREATURE COUNTING*

Subitizing	Supports children's development of knowledge and skill in mathematics in an authentic way
Augmented Reality	Provides visual in an innovative way Supports curiosity Active participation Guided discovery Situated learning Problem solving Engagement Social Learning
Board Game	Supports play Opportunities to improve self-regulation Supports children's development of knowledge and skill in an authentic way Active participation Situated learning Problem solving Repetition of actions Engagement
Dice	Repetition of actions Reinforces spatial arrangements Observation of others subitizing
iPad	Engagement

VITA

MEGAN D. STOTZ

109 RESEARCH DR. BETHLEHEM PA 18015
MED710@LEHIGH.EDU

PROFILE

Knowledgeable teaching professional with over 15 years of experience in elementary education and pedagogical expertise in the area of language arts, mathematics, special education, and technology integration. Respected, influential leader with open, collaborative style.

EDUCATION

DOCTOR OF PHILOSOPHY · TEACHING LEARNING TECHNOLOGY *· Current GPA of 4.0*

Fall 2010-May 2018 | Lehigh University | Bethlehem, PA

MASTERS OF EDUCATION *· READING K-12 · Graduated Magna Cum Laude with a GPA of 3.8*

Fall 2005-Spring 2008 | University of South Florida | Tampa, FL

ENGLISH FOR SPEAKERS OF OTHER LANGUAGES (ESOL) CERTIFIED · K-12

Fall 2002-Spring 2004 | School District of Hillsborough County | Tampa, FL

BACHELOR OF ARTS *· ELEMENTARY EDUCATION K-6 · Graduated Cum Laude with a GPA of 3.5*

Fall 1997-Spring 2001 | University of Tampa | Tampa, FL

PROFESSIONAL EXPERIENCE

Teaching Expertise

SUPERVISOR OF FIELD INSTRUCTION AT PENN STATE ABINGTON — *FALL 2013-PRESENT*

- Coordinate the process for student teaching and practicum application and field placement, developing and maintaining relationships with local schools throughout Montgomery, Bucks, and Philadelphia counties.
- Plan and execute a series of weekly student teaching seminars, conducting formal written student evaluations, maintaining data, managing student electronic portfolios, assigning and supervising additional part-time student teacher supervisors.
- Incorporate technologies such as VoiceThreads, Adobe Connect, Canvas, and Prezi into course instruction, in order to include all students, stimulate learning, and organize material

PRE-SERVICE EDUCATION AT LEHIGH UNIVERSITY — *2012-2013*

- Co-taught TLT 428 Math and Numeracy Prek-4 with Dr. Lynn Columba, main responsibilities entailed content development for technology integration in the Prek-4 math classroom, course site moderator, weekly communication with students.
- Developed weekly tutoring sessions for University enrolled ELL students.
- Initiated and designed SMARTboard training for the pre-service educators to support their future roles in the field.

KINDERGARTEN, FIRST, AND SECOND GRADE TEACHER — *2001-2010*

- Fostered a stimulating learning environment integrating cooperative learning, role-playing, music, art, and critical thinking skills to establish relationships between course material and students' life experiences.
- Assessed students via anecdotal records, portfolios, student teacher conference, checklists, and peer evaluation.
- Integrated technology through all subject areas in order to engage, motivate, and meet the needs of all learners in the classroom.

Coaching/Mentoring

READING COACH K-3 *2004-2008*

- Increased cognitive coaching cycles and communication of instructional decisions with teachers to ensure timely implementation of new and effective research based educational strategies.
- Performed as a model classroom for language arts, mathematics, and technology integration for educators within my school, county, and state in both Florida and Tennessee.
- Voted Teacher of the Year 2008-2009 by my fellow educators while a Reading Coach.

PROFESSIONAL PRESENTATIONS

- 2004-2008 District trainer for School District of Hillsborough County, Tampa FL.
  -Developmental Reading Assessment
  -Fluency First
  -Creating Strategic Readers
  -Writing Toolbox
  -Children's Literature in the Content Area
  -DIBLES Assessment
  -Readers Notebook
  -Power of Retelling Book Talk
  -Voracious Vocabulary
  -Reading with Meaning Book Talk
  -Mosaic of Thought Book Talk
  -Readers and Writers Workshop
  -Literacy Centers for K-3 classrooms
- 2007 Just Read Florida Conference -Using Assessment to Drive Instruction (Orlando, FL)
- 2008 Just Read Florida Conference -Matching Curriculum and Standards (Orlando, FL)
- 2008 Tennessee ESL State Conference- Language and Literacy (Nashville, TN)
- 2011 Research Council of Mathematics Learning (RCML)– Teachers Perceptions of Children's' Literature in Math (Charlotte, NC)
- 2012 National Council of Teachers of Mathematics (NCTM) - ABC's and 123's: Using Children's' Literature in Mathematics (Hartford, CT)
- 2012 National Council of Teachers of Mathematics (NCTM) –ABC's and 123's: Using

Children's' Literature in Mathematics (Chicago, IL)
- 2012 School Science and Mathematics Association (SSMA) -Inquiry Illustrated: Using Children's Literature to Teach Science (Birmingham, AL)
- 2012 Pennsylvania Council of Teachers of Mathematics (PCTM) - Children's' Literature and Augmented Reality in Mathematics (Hersey, PA)
- 2013 Pennsylvania Educational Technology Expo & Conference (PETE&C) -Augmented Reality in Education (Hersey, PA)
- 2013 Research Council of Mathematics Learning (RCML) - Pre-service Elementary Teachers Perceptions of the CCSSM and their Beliefs on Teaching Mathematics (Tulsa, OK)

COMMITTEES

- School District of Hillsborough County Textbook Adoption Committee
- Reading First Assessment Coordinator
- Professional Learning Committee for Lanier Elementary
- United States Department of Education Research Panel
- Williamson County Schools Reading Curriculum Committee
- Williamson County Schools Mathematics Curriculum Committee
- Character Education Curriculum Committee
- National Council Teachers of Mathematics Journal Reviewer
- Lehigh University Assistant for Middle States Association of College and Schools: Five Year Review
- Lehigh University College of Education Open House
- Lehigh University College of Education Representative at the 2013 Pennsylvania Educational Technology Expo & Conference (PETE&C)
- Penn State University Education Club
- Kappa Delta Pi

PUBLICATIONS

- Columba, L., & Stotz, M. (2016/17). Shifting preservice teacher beliefs: The power of the Common Core State Standards in Mathematics. *Mathematics Teaching- Research Journal Online. 8*(3-4), 6-28
- Stotz, M. D., & Columba, L. (In review). Using augmented reality to teach subitizing with preschool students. *Journal of Interactive Learning Research.*

AWARDS

- Teacher of the Year Nominee for Hillsborough County Schools 2008-2009
- Lehigh University: Dr. Sasso Presentation Travel Award 2010-2011
- Lehigh University: Dr. Sasso Presentation Travel Award 2011-2012