IMPROVING FOUNDATIONAL MATH SKILLS IN STUDENTS WITH AUTISM USING VIRTUAL INSTRUCTION

by
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Abstract

The purpose of this study was to directly measure whether implementing virtual or didactic instruction was more effective with high school students that had higher functioning autism (hfa) in learning about partitioning rectangles and applying partitioning skills to irregular shapes. The study aimed to compare the effectiveness of the i-Ready™ program to didactic instruction. Although some students with hfa have shown that as a group, their academic performance is consistent with the national average, Individualized Educational Programs (IEPs) in math calculation and problem solving indicate that students are actually performing at a much lower level and require additional foundational skills to improve their chances of graduating. The i-Ready™ math component is a virtual, online program that provides individualized, progressive instruction and was used as the intervention to improve the foundational math skills of students with autism spectrum disorder. A concurrent, multiple baseline design was used to evaluate the implementation of the i-Ready™ program, when compared to didactic instruction. Five participants completed the study where they were instructed and quizzed on how well they were able to partition geometric shapes during the baseline, didactic instruction, i-Ready™ instruction and generalization phases. Data showed that the i-Ready™ program successfully improved the foundational math skills of participants, as well as their motivation and focus, however, the didactic instruction was also successful for some students who did not need additional measures to remain focused or motivated to learn. The research suggests that for optimal results, teachers should use a blended approach to instruction, where both virtual and didactic instruction are utilized.

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Dedication

This dissertation is dedicated to my family. To my parents, Selena and Ellsworth Langhorne, you taught me that no matter how difficult and challenging the struggle may be, keep moving forward and never give up on your dreams. You have been there with me from day one and I appreciate all of the sacrifices you both made for me. I want you to know that you enabled me to get this far in my education and I am forever grateful to you for providing me with the necessary time I needed for the many years of late nights and long hours of research and writing. You supported me throughout this journey with your endless love and encouragement and I hope I have made you proud. To my daughter, Inaya Jones, who showed unwavering patience and stayed right by my side while I spent hours writing and studying, know that this was all for you. Words cannot express how much I love you all.
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Executive Summary

Students with autism spectrum disorder (ASD) are capable of obtaining the same academic achievement as their peers, however, their learning disabilities in mathematics impacts their standardized tests scores required for graduation. Many students with ASD are having difficulty meeting these high mathematic expectations because they lack the foundational math skills necessary to pass the standardized tests and required math courses.

In order to improve their mathematic abilities, accommodations, best practices and instructional techniques must be provided to address the specific needs of students. Initial findings during the needs assessment indicated that students with ASD had difficulty applying their math skills to real world examples and problems that were not exactly like the example shown during instruction.

As technology evolves within the classroom, instructional methods are moving more toward virtual education. Studies have shown that individualized instruction, engaging lesson plans and motivational techniques are all components that are critical to the mathematic success of a student with ASD. In order to improve the students’ foundational math skills, i-Ready™, a virtual program, was implemented as an intervention to address students’ math deficiencies while providing real world application of the math content.

The purpose of this study was to determine whether implementing the i-Ready™ program or using didactic instruction improved students’ skills in partitioning rectangles with unit squares and if these skills could be generalized to measure the area of irregular shapes.
A concurrent, multiple baseline design was used to evaluate the effectiveness of didactic instruction and instruction using the i-Ready™ program. The five participants in the study had the opportunity to completed four phases: a baseline phase, a didactic intervention phase, an i-Ready™ intervention phase and generalization phase.

The data analysis indicated that the i-Ready™ program improved some of the participants’ ability to partition rectangles, while didactic instruction improved the partitioning skills in others who did not need additional measures to remain focused or motivation to learn. Neither intervention was able to improve the participants’ ability to apply partitioning skills to measure the area of irregular shapes.

Based on the study, teachers can use the current research design the identify which instructional method would be appropriate for each learner to use in the classroom so that the class can be separated into instructional didactic and virtual stations. Future research should be conducted using a more diverse study group that includes a true sample of the school’s population. Since the study was limited to analyzing only one standard, partitioning shapes using unit squares, it is recommended that future research be conducted across other math strands to determine if the instructional method remains effective for the participant. It is also recommended that future research be conducted on the effectiveness of using a train sufficient exemplars approach to generalization improves the scores generalization skills on partitioning irregular shapes.
Chapter 1

Introduction of the Problem of Practice

Low scores on the Maryland math standardized test, known as the Algebra High School Assessment (HSA), indicate that students are having difficulty in Algebra I, which could potentially influence their success rate in higher level math courses or hinder their ability to graduate high school due to the lack of acquired math credits. Studies on students who are considered to have higher functioning autism (HFA) have shown that as a group, the overall academic performance of these students is consistent with the national average (Wei, Christiano, Yu, Wagner, & Spiker, 2014). However, when viewing the grade level abilities on Individualized Educational Programs (IEP) in math calculation and problem solving, there are indications that students are actually performing at a much lower level and require additional foundational skills to adequately perform well in their current math classes. This denotes that there is a growing need for providing an alternate method for learning math to students who struggle with foundational skills.

Students with autism spectrum disorder (ASD), who are working toward obtaining a high school diploma, are left with very few options for obtaining assistance to acquire basic math skills, which can later influence the number of math credits they earn, as well as their ability to pass the Algebra HSA. In Maryland, all students are required to obtain three math credits, Algebra I, Geometry and another math, in addition to passing the Algebra HSA in order to obtain their high school diploma (Jacobs et al., 2010). This may prove to be a difficult task for students with ASD who are below level math students or lacking foundational math skills.
As the demand for alternative educational methods grows, virtual programs are now being developed to meet the rising needs of students who continue to struggle with math in traditional institutions (Vilardi & Rice, 2014). The implementation of a virtual mathematics program, which individualizes instruction, would provide an alternate educational system for students with ASD that strengthens core skills and serves as a supplement to traditional high school math classes, so that students have the opportunity to improve their comprehension of math content as well as their chances of graduating.

Even though a virtual math course would provide students with the opportunity to “fill in” the gaps where necessary, additional measures must be taken to ensure that students comprehend and apply the content. Since math is an abstract subject, many students with ASD find that the content may be too difficult to relate to, which makes comprehension a challenge (Lochmiller, Higgins, & Acker-Hocevar, 2012). Strategies must also be devised to provide students with an environment that offers engaging instruction, while simultaneously assisting students in retaining information and remaining motivated.

**Review of Literature**

In order to understand why students with ASD receive low scores in mathematics on standardized tests, it is necessary to analyze why students in this population struggle with comprehending math concepts and how teachers are addressing the issue through instruction. This literature review discusses the mathematic expectations of students with ASD to gain some perspective on why emphasis needs to be placed on improving the mathematical achievement in this content area. In order to provide some insight on potential improvements for low achievement and poor academic performance in math, a
critical analysis of learning environment components and instructional strategies that students with ASD frequently encounter in class are reviewed.

**Students with ASD**

ASD is a developmental disability that previously encompassed multiple diagnosis, such as autism, Asperger’s Syndrome, childhood disintegrative disorder and pervasive development disorder (Center for Disease Control and Prevention, 2016, p.1). It is now, however, considered as a single diagnosis of autism spectrum disorder and currently affects one in every sixty-eight 8 year olds (Center for Disease Control and Prevention, 2016). The number of children diagnosed with ASD has been steadily increasing and data now shows that there has been a 289.5% increase in diagnosed children since 2008 (Christensen et al., 2016).

ASD is typically diagnosed within the first three years of life when abnormalities in social skills, speech, and restricted behavior and play become apparent (Mahmood, Saleemi, Riaz, Hassan, & Khan, 2015). Some diagnosed children meet developmental milestones, however, they begin to show signs of regression in communication, speech, and social skills between the ages of 1 and 3 (Mahmood, et al., 2015). Although this disability can affect children of any race or ethnicity, data collected by the Center for Disease Control’s Autism and Developmental Disabilities Monitoring (ADDM) Network shows boys are 4.5 times more likely to be born with the disability than girls.

Individuals that have ASD not only exhibit difficulties with communication, they also struggle with social interactions, and repetitive behavior. The severity of these symptoms determines an individual’s placement on the autism spectrum, which can range from very low functioning individuals who are non-verbal with severe behavior issues, to
students with HFA that have mild disabilities and can be instructed within a general educational setting (Mahmood et al., 2015). According to research conducted by Bertrand, Mars, Boyle, and Bove (2001), approximately 48% of the ASD population have IQs that are below 70, while the remaining 52% of the population are considered to be high functioning (Whitby & Mancil, 2009).

Students with HFA are capable of meeting the same academic goals as their peers, including graduating high school and college and obtaining meaningful employment. However, specific interventions and accommodations must be in place to ensure their success, especially in critical content areas like math (Whitby & Mancil, 2009). Interventions and accommodations specific to their needs are required for students with HFA to academically compete with their peers (Whitby & Mancil, 2009). Without these academic supports, students with HFA risk losing their opportunity for success to poor academic performance while in school (Whitby & Mancil, 2009).

Although individuals with ASD can be clinically diagnosed as having HFA, the participating school classified students that were placed on the diploma track with nonclinical higher functioning autism (hfa). The classification of nonclinical hfa was determined during the extended school year (ESY) review meeting, held by the IEP team, at the end of the 8th grade school year. During this ESY review, the IEP team decided if the student was capable of passing the state mandated high school assessments based on their previous standardized test scores, classroom based assessments and teacher observations. Once the IEP team decided that a student was capable of passing the state mandated tests, the student was placed on the diploma track once they entered high
school, as opposed to the certificate of completion track, and considered to be a student with nonclinical hfa.

**Math Expectations in Students with ASD**

Mathematics has become one of the most critical areas of instruction for all students, not just those with ASD, and is frequently measured using high stakes, standardized testing, which is also a graduation requirement (Hord & Bouck, 2012). New mathematics Common Core State Standards (CCSS), which have been implemented in 43 states, determine what every student should know in both primary and secondary school regardless of disability. The math CCSS require students to process a complete understanding of foundational mathematic concepts and acquire the ability to apply concepts to solve real world problems (Bae, Chiang, & Hickson, 2015). The acquisition of these skills is now assessed using the standardized Partnership for Assessment of Readiness for College and Careers (PARCC) test (Bae, Chiang, & Hickson, 2015). Federal legislation changed standardized testing requirements by aligning them with No Child Left Behind Act (NCLB), which requires states to use standardized testing to measure student achievement and accountability, with the Individuals with Disability Education Act (IDEA) in 2004 (Hord & Bouck, 2012). This new legislation requires students that are intellectually disabled to participate in federally mandated, standardized testing, which emphasizes problem solving and content application (Hord & Bouck, 2012; Barnett & Cleary, 2015). Low scores on these tests can result in students graduating with a certificate, also known as an “alternative diploma” instead of a high school diploma (Hord & Bouck, 2012).
Alternative diplomas, also known as certificates of completion, are given to students who are unable to meet the course requirements for graduation set by the state or who cannot participate in the required standardized testing set forth by the state (Rubin, 2015). Students entering the work force after leaving high school with these types of diplomas have limited options, since many employers prefer to hire students with high school diplomas, rather than those who have only received alternative diplomas or certificates of completion (Rubin, 2015). Students who intend to attend a postsecondary institution to obtain a two or four year degree will need either a high school diploma or General Education Development (GED) to enroll (Rubin, 2015) making it impossible for a student with an alternative diploma or certificate of completion to ever attend college.

The Maryland State Department of Education (MSDE) graduation requirements state that all students must pass a high school standardized assessment in Algebra, in addition to acquiring three math credits. Students with ASD may have difficulty meeting these expectations with a deficit in math skills (2014 Maryland Report Card, 2014). Although the current High School Assessment (HSA) exams are now being phased out, standardized testing within Maryland will be converted over to the PARCC exam, which will assess the new CCSS in Maryland.

These high expectations that students are required to achieve in order to graduate seem like lofty endeavors for a student with ASD. One reason that many students have difficulty meeting these expectations is because they lack the foundational math skills to be successful in meeting the requirements for a standard diploma (Hua, Morgan, Kaldenberg, & Goo, 2012).
Math Skills Deficits

Mathematic abilities are often affected by the symptoms of ASD. Research indicates that students with ASD often have difficulty developing problem solving and critical thinking skills required for math (Hua et al., 2012) and that 25% of students with ASD have a learning disability in mathematics as well (Mayes & Calhoun, 2003). Although many students with ASD have adequate computational skills, their problem solving and critical thinking skills are affected by their lack of executive functioning abilities and weak central coherence, thus making higher level comprehension and real world application of math concepts difficult (Whitby, Travers, & Harnik, 2009).

Students with ASD typically have little difficulty in elementary school, where the focus in math is on memorizing facts and procedures. However, the success in math diminishes when the students face middle school math, which requires higher level thinking and comprehension of abstract concepts that involve problem solving (Mayes & Calhoun, 2003), as math classes move away from fact memorization and algorithms to mathematical reasoning (Barnett & Cleary, 2015). Working memory, organization, attention and self-monitoring also impact mathematic development (Barnett & Cleary, 2015).

Studies have indicated that one of the main areas of concern for students with ASD is numerical operations, which focuses on problem solving and computation (Griswold, Barnhill, Myles, Hagiwara, & Simpson, 2002; Chiang & Lin, 2007). A literature review conducted by Whitby and Mancil (2009) evaluated six research studies between 1998 and 2004 that focused on the academic achievement profiles of students with HFA. Participants in the studies ranged between the ages of 3 to 17 and had IQs
greater than or equal to 80. The literature review suggested that in the math content area, there were no deficits in computational skills, however, problem solving and applied math skills were impaired (Whitby & Mancil, 2009). This was largely due to the deficits in attention and organizational skill sets (Whitby & Mancil, 2009).

Whitby, Travers, and Harnik (2009) conducted a study on Solve It!, a math program developed for HFA students. Middle school students with HFA were taught a problem solving algorithm that included seven cognitive strategies and three metacognitive strategies that led the user through steps from reading the problem to computing the answer (Whitby et al., 2009). Over a four-week period, the students in the study mastered the problem solving algorithm within five training sessions and increased completion of correct problems from 20% to 100% (Whitby et al., 2009). Students with ASD need to be taught how to learn and utilize external supports that are available since, “Cognitive and metacognitive strategy instruction for children with HFA/ASD must be tailored to meet the unique cognitive profile for [these] children …” (Whitby et al., 2009, p. 9). This study suggests that an algorithm, which explains each step in detail, should be used when instructing students with HFA/ASD in order to improve their math comprehension.

Griswold et al., (2002) conducted a study where 21 students with ASD completed the Wechsler Individual Achievement Test (WIAT) and the Test of Problem Solving (TOPS). These standardized tests were created to measure academic strengths of the students in reading, mathematics, language, and writing, as well as their problem solving and critical thinking skills. The independent variables for this study were the age and race of the participants, while the dependent variable was the test scores. The study revealed
that numerical operations, which measure a student’s ability to answer and solve mathematical problems, received the lowest scores when data from TOPS and WIAT test results were compared (Griswold et al., 2002). Further investigation of existing data indicated that the low test scores were common among students with ASD due to the math skill deficits in the population (Griswold et al., 2002).

Similar findings were observed when Chiang and Lin (2007) conducted a meta-analysis on the mathematic abilities of students with ASD. The meta-analysis included 18 articles, all published between 1986 and 2002, as well as a combined population of the 837 individuals with ASD, ages 3 to 51, who were studied in the articles. Chiang and Lin (2007) found that when comparing the standardized testing results from individuals with ASD to scores from the rest of the population, the scores in math were significantly lower.

Research from both Griswold et al. (2002) and Chiang and Lin (2007) show that students with ASD exhibit a deficit in math skills leading to an adverse impact on their high standardized test scores. Since standardized testing relies heavily on problem solving skills and the application of math content, it is necessary to bolster students’ abilities in these areas using the best practices and effective instructional techniques for teaching mathematics to students with ASD.

Organization and attention deficits in students with ASD can impair problem solving skills, however, a systematic approach to thinking would help students develop a plan to begin a math problem and identify the next steps required to solve it (Whitby et al., 2009). Students with ASD should be taught cognitive strategies to help them not only develop procedures to apply math concepts to problems that deviate from the examples,
but also solve problems involving real world applications (Whitby et al., 2009). With these strategies, students can learn how to use a process to solve a problem while simultaneously self-monitoring to know when and where the strategy should be applied (Whitby et al., 2009).

**Instructional Techniques**

**Traditional Instructional Techniques**

Students with ASD have traditionally been taught mathematics using the state’s general education curriculum, however, there has recently been a transition in the curriculum from focusing on basic skills to focusing on math application and problem solving (Hord & Bouck, 2012). In order for students with ASD to develop math application and problem solving skills, they need to first develop their foundational math skills so that they can understand mathematical concepts (Hord & Bouck, 2012).

Hua et al. (2012) found that the best way to develop foundational math skills in students with ASD is to use a step by step, explicit instructional approach, where students first review the prerequisite skills then the teacher models the information and finally students are led through guided and independent practices. The teacher chunks the information so that each step required for solving the problem is clearly identified and uses examples to solicit student responses and provide them with the immediate feedback they need to understand the content (Hua et al., 2012).

This step by step instructional method has been very successful in teaching lower level math content and problems that can be learned through rote instruction to students within the ASD population (Hua et al., 2012). Step by step instructional method, however, does not enable students to develop the strategic math skills necessary for
solving real world problems (Hua et al., 2012). Students with ASD have difficulty determining which strategy to use for a given problem because they are not aware of how to apply the usefulness of the strategy to other problems beyond the example (Hua et al., 2012). Exposing students to methods of using their problem solving strategies outside of its normal context and teaching them how to manipulate strategies based on the task would be the most effective method of teaching cognitive strategies to students with ASD (Hua et al., 2012).

Additional issues that reside with traditional face to face instruction are the potential lack of immediate feedback from the instructor and confidence required to ask for help. Although small group instruction is possible, teachers are most likely to be unable to address every comment or issue that every student has every day, so the expectation of immediate feedback is not always achieved. Students may also feel uncomfortable within their learning environment when they have to frequently ask for help, thus limiting their questions and potential for comprehension (de Oliveira Malaquias, Lamounier, & Cardoso, 2013).

**Virtual Approaches to Teaching Mathematics to Students with ASD**

The introduction of educational technologies has brought about a shift in instructional practices. Face to face teaching, once the most commonly used method of instruction, has now given way to new methods of instruction using technology. Studies have consistently shown that technology has been successfully used to teach students with ASD for more than 35 years with the use of assistive technology (Moore & Calvert, 2000). Moore and Calvert (2000) found that there was a preference for computer-based learning, also known as virtual instruction, over face to face instruction when a
comparison study was conducted with students with ASD. The study on vocabulary acquisition was conducted with 14 elementary school aged students with ASD to see if there was a preference for either the drill and reward method used by the teacher, where rewards were either auditory or physical rewards, or a computer program, which mimicked the teachers drill and reward method, but with sensory reinforcement used as the reward instead (Moore & Calvert, 2000). A pretest and posttest research design was used as the learning measure. While patterns identified from the responses on the pretest and posttest measured students’ attention and engagement, motivation was determined by students’ verbal response to a survey that questioned their preferred intervention method (Moore & Calvert, 2000). The study revealed that although the instructional methods were similar, students indicated computerized instruction was preferred to the face to face instruction. Engagement was measured by how long a student remained focused on the task during instruction throughout the study. While the teacher offered verbal praise for correct answers, the computer program offered an 8 second sensory reinforcement that included lights, music and animation (Moore & Calvert, 2000). The results of the study indicated that the computer program kept students attentive and focused during instruction 97% of the time, whereas the teacher only held their attention 62% of the time (Moore & Calvert, 2000). This indicates that the use of computerized instruction can improve a student’s focus on a task and motivation due to the unique sensory reinforcement techniques used by the computer program, which are very effective with students who have ASD (Moore & Calvert, 2000).

Although the use of this type of technology with students who have ASD is not a new concept, few studies have been conducted on the use of a virtual instructional
program to teach mathematic skills specifically to students with ASD (Moore & Calvert, 2000). Ortega-Tudela and Gomez-Aria (2006) conducted a study that is considered one of the few virtual mathematic studies that included 18 students with intellectual disabilities to determine if counting skills could be improved through virtual instruction. The study results revealed that the ten students who were selected to learn counting through the use of the virtual software, outperformed the eight students who learned with a traditional worksheet approach within 15 sessions of instruction (Ortega-Tudela & Gomez-Ariza, 2006).

Research performed by de Oliveira Malaquias et. al (2013) used virtual instruction to measure the ability of 15 students with intellectual disabilities, to classify and sequence, as well as improve memory and concentration with a program called VirtualMat. VirtualMat is considered a serious game since it provides the opportunity for students to work at their own pace and repetitively complete interactive activities that challenge students through a gradual increase in difficulty, while maintaining student engagement throughout the duration of the game (de Oliveira Malaquias et al., 2013). VirtualMat integrates math content and real world situations into its virtual programming to help students improve critical thinking skills (de Oliveira Malaquias et al., 2013). Researchers were also able to observe interactions between the student and computer that would not have occurred in a traditional classroom setting. Students that normally presented limited participation during class with their teachers became fully engaged participants with the VirtualMat program and improved their time on task as they completed their virtual assignments (de Oliveira Malaquias et al., 2013). In addition, all students who participated in the study experienced an increase in their mean scores.
demonstrating that VirtualMat not only motivated students, but became an efficient source of instruction as well (de Oliveira Malaquias et al., 2013).

The results from these studies indicate that there is a preference for virtual instruction over face to face instruction in students with ASD. Virtual instruction provides a safe environment for students to explore their comprehension of the mathematic content without ridicule, while providing them with the opportunity to test their newly acquired skills (de Oliveira Malaquias et al., 2013). In addition, students that participated in virtual instruction consistently outperformed those that did not, indicating that the virtual programs were reliable sources of instruction for students with ASD (de Oliveira Malaquias et al., 2013).

Regardless of what instructional strategy meets the needs of the ASD population a sound theoretical framework is necessary to guide the teaching and learning. In the next section, the theoretical and conceptual framework will be reviewed, including an emphasis on learning environment, motivation and student focus.

**Theoretical and Conceptual Framework**

Executive functioning (EF) and central coherence (CC) are two cognitive theories that have been used to explain the deficits in ASD as they relate to math (de Vries, Prins, Schmand, & Geurts, 2015). EF skills are necessary for an individual to manage behavior and resources in order to understand and complete a task (Semrud-Clikeman, Fine, & Bledsoe, 2014). When these skills are not present, planning, organizing and cognitive flexibility are unattainable (Semrud-Clikeman, Fine, & Bledsoe, 2014; Wiley & Jarosz, 2012). Students with ASD have deficits in EF making it difficult for them to mentally develop an “action plan” to solve a problem by organizing thoughts
and steps required for problem solving or determining the correct equations and formulas necessary for the problem solving process. This is primarily due to an impaired working memory, a main component of EF that temporarily stores information within the brain so that it can either be manipulated or used at a later time (Wiley & Jarosz, 2012). In math, the working memory is a critical component during the problem solving process and is used to maintain partial results of problems while additional information is gathered, monitor the solution to partial results, organize steps to solutions when multiple steps are required, and retrieve math facts necessary for the partial or complete solutions to a problem (Wiley & Jarosz, 2012).

Central coherence enables most individuals to maintain both an overall perspective of a problem while mentally managing the details. Students with ASD, however, have weak central coherence (WCC) and are unable to focus on the global perspective. Instead, students with ASD focus their attention solely on the details of the problem, unable to make the connection with the overall goal (Barnett & Cleary, 2015; Harnois, 2016). Weak CC also limits students’ ability to apply concepts to problems that vary from the examples. This is primarily due to students inability to identify connections between problems similar in nature but different in content. Although in mathematical problem solving, attention to detail is critical, it is also necessary to understand the role that the significant details play in determining the solution. This includes eliminating details that are not necessary and identifying the details that may be needed at a later point in the solution.

Bae, Chiang, and Hickson (2015) conducted a study that compared the word problem solving abilities of students with ASD to their peers. Forty students, ages 10 and
11, participated in the study and half of the students were diagnosed with ASD. Students were given multiple standardized tests to evaluate their abilities in computation, word decoding, math vocabulary, math knowledge and attitude toward math. The study suggested that with appropriate instruction, students with ASD were able to function at the same level of academic achievement as their peers (Bae, Chiang, & Hickson, 2015). Appropriate instruction for the students should include accommodations that not only teach students the basic math knowledge that is needed to have a solid understanding of foundational math skills, but to also incorporate life experiences in the problem so that students can understand what the problem is asking (Bae, Chiang, & Hickson (2015). Bae, Chiang, and Hickson (2015) stated that, “The ultimate goal of mathematics instruction is for students to learn essential skills to solve their real-life problems. If mathematics instruction can be connected to real-life experiences, the problem solving ability of children with ASD in real-life situations may potentially grow” (p. 2207).

Improving the cognitive abilities of students with ASD requires both teaching and learning that is grounded in well-developed learning environments that are centered around student motivation, focus, and individualized instruction.

**Learning Environment**

Lochmiller et al., (2012) found that a common problem with students’ learning environment was due to teachers’ inability to incorporate real world application into the content, which indicates that students receive a narrow view of how to use the content. When students have nothing to compare or relate the content to, it becomes more difficult for them to remember, since a link between content and the real world has not been formed. Although challenging, the implementation of a program that would be conducive
to real world applications would allow the student to see the benefits and applications of math from a different viewpoint and ways it could be utilized by different disciplines.

Over the years, as technology developed and media evolved, the field of instructional design (ID) has been directed away from a behaviorist viewpoint and became influenced by more modern learning theories, such as constructivism, where virtual pedagogy could be considered as a method of constructing a personalized learning environment (Richey, Klein, & Tracey, 2011). The National Council of Teachers of Mathematics (NCTM), an organization committed to improving the access to quality math instruction throughout the United States, indicated that “Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances student learning” (National Council of Teachers of Mathematics, n.d.). This has also influenced the shift in the focus from instructional media to the ID process, where it is currently considered both a field of study, as well as a process. Reiser and Dempsey (2011), defined the field of ID as an area of study that is founded on research and theory and incorporates systematic processes as one of its six integral components of its knowledge base. However, the process itself focuses on the design and development of instructional materials and resources from the principles of learning (Reiser & Dempsey, 2011).

Learning environments should not only incorporate technology and virtual pedagogy, they should also be designed so that students have access to the accommodations, instructional materials and resources that they need in order to construct their own understanding of the content. Constructivism views learning as an understanding, which is generated from one’s own environment (Harlow, Cummings, &
Aberasturi, 2006). Jean Piaget (1975) introduced the theory of cognitive development, which viewed knowledge as a unique, self-developed understanding of the world that stemmed from the analysis of previous experiences and observations (Harlow, Cummings, & Aberasturi, 2006). Comprehension of the material is developed from the learner observing and interpreting new information, which is compiled from participating in new experiences, then comparing it to background knowledge in order to develop an understanding of the content (Ertmer & Newby, 1993). This form of assimilation and accommodation enables the learner to construct new schemas through experiences and real world activities (Piaget, 1975). Bransford, Brown, and Cocking (2000) believed that, “Teachers who use a learner-centered approach recognize the importance of building on the conceptual and cultural knowledge that students bring with them to the classroom” (p. 134). This enables learning to be focused on individual students and personalizes information for better retention.

Due to the heterogeneous nature of autism, it is prudent for students with ASD to individualize their instruction and construct their own understanding of the content (Bae, Chiang, & Hickson, 2015). With the use of real world activities, which relate the content to concepts and practices that students already are familiar with, students with ASD are able not only to retain the content, but they are able to develop their own understanding of how it relates and can be applied to the world they are already familiar with (Bae, Chiang, & Hickson, 2015). These real world scenarios can be recreated as activities in a virtual learning environment (VLE) and reviewed by students with ASD in order for students to construct a complete understanding of the content.
Motivation

Student motivation has been viewed as a key component to sustaining a student’s drive for academic success, however, in a typical classroom, students with ASD often exhibit poor behavior, from mild to severe when confronted with an academic task that they do not want to complete, in an effort to avoid the challenge of the task (Koegel, Singh, & Koegel, 2010). This lack of motivation leads to disruptive behavior within the classroom and hinders the opportunities for academic achievement (Koegel et al., 2010).

In their research, Koegel et al. (2010) studied four young students with ASD, who were between the ages of 4 and 7. They aimed to determine if motivational variables had any effect on academic performance. All four students, who were identified with high functioning ASD, were presented with both math and writing assignments (Koegel et al., 2010). Initially, the students were asked to complete the assignments without any motivational factors in order to develop a baseline for their behaviors. All students displayed varying levels of latency, a behavioral form of avoidance, and increasingly displayed disruptive behavior (Koegel et al., 2010). However, when presented with a natural reinforcer in conjunction with the intervention, such as allowing students to make decisions on the materials they used and the items available for use in their study environment, the latency and disruptive behavior immediately decreased, and in some cases was eliminated (Koegel et al., 2010).

Hinton and Kern (1999) found similar results in a study that they conducted with 5th grade students, who ranged in age from 10 to 12. As part of the study, these students were given math homework assignments to complete three times per week. Each homework assignment covered content appropriate word problems for 5th grade students.
The homework was considered complete if it was turned in within 24 hours and 75% of the problems were done. Initially, only 59% of the students completed the homework within the given timeframe. In order to motivate the students to complete their homework, an incentive was added where any participants who completed their homework the previous night had their names and the names of family members included as characters in the word problems that they were given the following day for homework. After implementing the intervention, homework completion increased to 96% indicating that students enjoyed seeing their names as part of the word problems and became motivated by the intervention to complete the homework. Once the intervention was withdrawn, the percent of completed homework assignments declined once again demonstrating that the implementation of a reward motivates students and improves academic achievement (Hinton & Kern, 1999). Although the removal of the reward does not necessarily mean that learning has not occurred, it does indicate that students are less likely to feel driven to complete their assignments if some form of a reward is not present for motivation.

This indicates that when students with ASD are confronted with tasks that they either find challenging or want to avoid, the presentation of a reward, in the form of an interest, aids in maintaining student engagement and improving forms of disruptive behavior. This motivational strategy would prove to be useful when introducing unfamiliar concepts or topics that might be difficult to initially comprehend. By having a reward system embedded within the instruction, students will be more engaged in the activity, thus improving performance (Koegel, et al., 2010).
Student Focus

Learning games have often been seen as an instructional motivator that can improve student engagement by increasing students’ focus and time on task due to their ability to represent the content in a format that students can easily understand. Learning games also create an environment that allows the students to feel in control of their own instruction and progress (Carroll, 1989). Vogel, Greenwood-Ericksen, Cannon-Bowers, and Bowers, (2006) also viewed learning games as method of engaging the student and stated, “When people play, they allow for more efficient learning and cognitive intake that they would in a more traditional setting” (p.106). Since learning games require a higher level of interaction from the learner, student engagement is increased as well as the motivation to overcome the challenges provided by the game (Vogel et al., 2006). Using learning games for math instruction provides students with ASD the same opportunity to improve their time on task through virtual learning while enhancing their motivation and successfully increasing their foundational math skills.

Individualized Instruction

ASD is a heterogeneous disability where symptoms and their level of severity vary from student to student (Mahmood et al., 2015). Due to the heterogeneous nature of ASD, it is imperative that instructors are familiar with each student’s academic profile to help determine which strategies best fit the student’s unique instructional needs (Whitby et al., 2009). This requires individualized instructional methods that are tailored to each student’s abilities, however, teachers often try to develop academic plans that utilize a single intervention that is generalized for the entire class (Whitby et al., 2009). When this
occurs, the single intervention may not address all of the academic needs of all students (Whitby et al., 2009), potentially leaving gaps in students’ comprehension of the content.

This issue of generalization within the classroom has been exacerbated since academic achievement studies rarely compare students with ASD to one another since the ASD symptoms can vary (Jones et al., 2009). Instead, students with ASD are either compared to students with other types of disabilities or categorized with the general population of students with disabilities in academic studies (Wei et al., 2014). This form of generalization is often reflected in the classroom where the academic deficits of the class as a whole are used to drive instruction, instead of individualized instructional methods, leaving students’ individual strengths and weaknesses overlooked and not addressed. This becomes apparent in the math class when teachers instruct the class as a whole, yet seldom identify the specific, basic skills that students are missing, and rarely individualize instruction to address the issue (Wei et al., 2014). Although the Individual Educational Plans (IEPs) of students with ASD mandate individualized instruction, due to the varying student abilities, it can be difficult for a teacher to accurately address the individual weaknesses of a class of students with ASD (Whitby et al., 2009).

Mayes and Calhoun (2003) were correct when they noted that an intervention that works for the entire class might not work for specific students. Students with ASD have very unique methods of comprehending information, so instruction must be individualized and developed from the students’ academic profile in order to meet their specific instructional needs. In order to meet the needs of these students, teachers can use students’ academic profiles to develop individualized instructional interventions (Whitby et al., 2009).
In a face to face learning environment, teachers typically develop an academic profile, which identifies the strengths and weaknesses of the entire class, and then use it to establish an initial point of instruction. Since standardized test scores only provide a snapshot of a student’s capabilities, teacher observation of a student’s academic achievements during class provides a more precise indicator of an individual’s strengths and weaknesses (Whitby et al., 2009). Teachers use collected data to develop individualized interventions to instruction and improve students’ academic achievement in the class (Whitby et al., 2009). Although this method of determining individualized instruction is a viable technique for addressing individual student needs, it can be laborious, time consuming, and require multiple interventions to successfully reach each student in class. This may be one of the main reasons why current instructional techniques are not improving the ASD students’ math skills.

In order to simplify the process of individualized instruction, teachers develop their interventions based on the average intellectual ability of the class, since academic achievement in math typically corresponds to general intellectual functioning. This generalization of instruction frequently masks the abilities and deficiencies that may not be consistent with the class’s intellectual ability.

In a study by Jones et al. (2009), the researchers observed that when the placement of 100 teens with ASD in academic areas based on the students’ full scale IQ, was evaluated, 72.7% of students with ASD were incorrectly placed in one of the academic areas; reading, spelling, reading comprehension, arithmetic, and broad math skills, due to unknown academic strengths, weaknesses, and learning disabilities that were not recognized based on their general intellectual functioning. Communication
difficulties, repetitive behaviors, and poor social skills are prevalent among students with ASD, Jones et al. (2009) expresses the importance of identifying the true academic capabilities of students with ASD by stating, “It suggests the need for vigilance for individuals whose islets of ability or difficulty may mask their true intellectual level (leading to over- or under expectation) or remain undiscovered” (p. 727). Identifying individual weaknesses and strengths helps to identify the specific needs that are required for academic achievement to occur during instruction for students with ASD.

**Conclusion**

Due to their symptoms, students with ASD often have learning disabilities in mathematics, which adversely impacts their standardized tests scores required for graduation. Although these students are capable of the same academic achievement as their peers, accommodations coupled with best practices and instructional techniques that address the specific needs of students with ASD are necessary to bolster their mathematic abilities. In order to determine the most effective approach to improving their academic achievement, an analysis of instructional techniques and learning environments must be performed.
Chapter 2

Needs Assessment

The low math scores received from students with ASD on standardized tests can be attributed to the deficit in their math skills, which stems from inadequate learning environments and ineffective instruction. Although traditional instructional methods have been successful in the past, they do not equip students with the necessary skills needed to fully comprehend the content or teach students how to determine which mathematic strategies are needed for problem solving and content application. Individualized instruction helps students develop their own understanding of math content, thus personalizing the instruction for better retention. Identifying the best practices and instructional methods necessary for individualized instruction will help develop a better understanding of how to improve math performance in students with ASD.

Well designed learning environments are also critical for the mathematical success of students with ASD. Creating learning environments that not only keep the student engaged, but also allow for the exploration of practical uses for the content, stimulates students’ ability to link content knowledge with real world applications.

The literature review outlines the components necessary for the academic achievement of students with ASD in mathematics. Studies in the literature review indicate that a learning environment, which addresses the math needs of each student by providing individualized instruction that is both engaging and motivational, has a positive impact on academic success. In order to provide a well designed learning environment, the current instructional methods, best practices, and learning environments need to be
analyzed to determine the most effective methods for improving the mathematical performance of high school students with ASD.

**Research Questions**

In order to evaluate learning environments and best practices, the needs assessment was guided by the following research questions:

Research Question 1: What components of a mathematics environment are critical to a student’s, who has ASD, success in math?

Research Question 2: Which best practices and instructional methods in math are required for the individualized instruction of a student with ASD in order to produce successful results in math performance?

The needs assessment determined the most efficient methods of instructing each student and identified any factors that may have inhibited learning. It was also used to determine the most effective components necessary for developing a learning environment that individualizes instruction and facilitates learning for students with ASD. Finally, instructional methods that encourage focus, comprehension, and retention were identified.

**Description of Content**

Two variables, success rate and student focus, have been identified for data collection based on the results of the studies highlighted in the literature review, therefore for this study the following variables will be used: i) the success rate of a student with ASD and ii) the impact of focusing on a task. Identifying both variables would be beneficial in determining the program components that support an effective learning environment and increase mathematical achievement.
Although success in mathematics can be dependent upon individual perspectives, if comprehension is attained using certain instructional methods or practices, one can say that the student is successful in comprehending the content. The studies in the literature review suggested that two of the most influential factors that can improve the success rate of a student are remaining engaged by improving time on task, as well as remaining motivated (Carroll, 1989). Even though some form of assessment is necessary to invoke students’ with ASD critical thinking and problem solving skills, other facets of content comprehension should be available to students to define their success and not solely be indicative of a standardized test score (Hardiman, 2012).

For the purpose of this study, success will be measured as an improvement in foundational math skills indicated by formal assessments. Student engagement has also been identified as an essential component for learning, therefore various learning environments will be analyzed to determine what aspects of instruction improve student engagement.

**Method**

Qualitative data is typically used when the collection of personal data is required for a study (Soriano, 2013). In this needs assessment, participants were interviewed to collect personal data on how they felt about their comprehension and feelings towards their current math class. Open coding was then used to analyze the qualitative data collected from the interview completed for the needs assessment study (Vaughn & Turner, 2016). A predetermined theme structure, developed from the questions used during the interview, was initially used to identify the major theme categories (Vaughn & Turner, 2016).
Environmental and instructional aspects were analyzed to determine: i) what aspects of instruction lead to students’ ability to comprehend math content, ii) what components are required to construct a successful learning environment and iii) which best practices have been applied in math for educating students who have difficulty comprehending mathematical concepts or suffer from math anxiety.

Purposeful sampling was used to select the ten participants with ASD, 6 - 11th graders, ages 16 through 18, and four - 10th graders, ages 15 -16, since students who were either currently taking or had previously taken Algebra I were necessary for the needs assessment. Qualitative data was collected from the participants who participated in the interview regarding their perspective on the difficulty of the current class content, their best modes of instruction, and the ideal learning environment. There was a 100% response rate from participants participated in the interview.

Participants were interviewed using the survey questions in Appendix A regarding their comprehension and overall feelings toward their ability to complete work in their current math course. The questions were specifically developed to be as simple as possible for easy comprehension.

Once the interviews were complete and data was collected, data was then analyzed and categorized using coding. Open coding was used to develop five major themes from the data: example usage, instructional grouping, hands on learning, and competition.
**Data Collection and Analysis**

Responses to the surveys questions were collected from all 10 participants and were coded using a predetermined theme structure as indicated above. Data coding and analysis yielded the following themes:

The first theme, *example usage*, identified whether or not the teacher frequently utilized examples as models for the class. Coding was used to identify whether the classwork required students to follow similar steps as the model or apply their knowledge and challenge their comprehension by applying the concepts to other problems that vary from the example. All participants indicated that examples were frequently provided in class and many assignments resembled the examples. Participants also indicated that they did not like any problems to vary from the examples since new problems made them confused and made them frustrated because they no longer knew what to do once the problems were different. This indicates that participants are capable of learning material that is frequently modeled in the exact same format, however, when participants need to apply their newly acquired math techniques, which usually requires them to rely on the use of their foundational math skills, they begin to struggle.

The theme for *instructional grouping* described students’ preference for working together in small group or individually. All of the selected participants indicated that they preferred to complete work independently, unless they needed help and only then would they actively collaborate with other classmates without being prompted to do so in order to determine the answer. This is consistent with the preference for lack of social interaction among students with ASD (Barnett & Cleary, 2015). Collaboration with other students in class is difficult for students with ASD because social activities must be
taught as a skill and are not innate to students (Barnett & Cleary, 2015). The participants also indicated that the method of instruction that they preferred was group instruction, where the teacher modeled the steps to solving problems with several different methods.

The theme for **hands on learning** was used to describe whether students preferred math related activities. Coding was used to determine whether or not students enjoyed using manipulatives to complete math problems and reasons why. All of the participants stated that they learned best when they had the opportunity to use manipulatives to solve the problems themselves. Participants stated that they preferred using projects because the “hands on” approach that they were using with the project based learning assignments in class made it more engaging and easy to understand and remember the concepts.

**Competition** was the final theme, which indicated participants’ desire to compete against other classmates. This coding category identified the reward system and reasons that drove the competitiveness among peers. Participants stated that although prizes were enjoyed, the thrill of winning was stimulating enough even if there was no reward. When placed in a competitive environment, the participants not only wanted a prize, they also wanted to win. This competitive nature could be harnessed within the classroom and utilized as a factor to motivate students to want to learn even when a physical “prize” is not available.

According to the National Autism Center (2009), students with ASD comprehend the material after frequent modeling is introduced first. Many tasks must be taught using a step-by-step approach repeatedly; so behavioral and cognitive approaches to instruction define the algorithm that the student follows in order to obtain the answer (National Autism Center, 2009). Behavioral modeling is the preferred therapeutic approach to
teaching students with ASD new behaviors (Dionne & Martini, 2011). In addition, they must also be taught how to relate the content to real world applications and then have the processes modeled for them before they are able to do it themselves, which may require frequent repetition and a strong foundation in mathematics before students are capable of accomplishing the task on their own (Lochmiller, et al., 2012). The treatment process usually combines a step-by-step approach to instruction with positive reinforcement, where the student follows the modeled algorithm in order to obtain the desired behavior or response (Dionne & Martini, 2011).

**Conclusion**

The needs assessment indicated that the participants had difficulty applying their math skills to real world examples and problems that were not exactly like the example shown during instruction. Although participants enjoyed their math classes and were engaged when manipulatives, math projects, and activities were introduced, they frequently required step-by-step approaches in order to solve problems and often became frustrated with the content when they did not know how to approach or complete a new problem that required the use of their foundational math skills.

In order to improve the students foundational math skills, a virtual program will be implemented as an intervention to address students’ math deficiencies while providing real world application of the math content.
Chapter 3

Intervention Literature Review

Current instructional practices are leaving students with ASD without the skills necessary for math application or the capability to solve real world problems. Alternate methods of instruction, such as virtual learning, must be investigated to provide students with a learning environment that offers engaging and individualized instruction, motivation and the foundational math skills they are missing. Both the research from the literature review and empirical evidence from the needs assessment in Chapter 2 indicate that effective virtual learning should be explored. The goal of this chapter is to explore research that supports the use of virtual learning environments (VLEs), as they relate to math instruction, and instructional techniques that are used within them.

Effective Components of VLE designs

The foundation of a successful virtual program is the design of its VLE components. In a program where content is provided using a gaming platform, it is essential that the design components of the game are entertaining and resemble a game and not a math problem. This method of stealth learning is one effective component of a VLE’s design that maintains student engagement with the content (Downey, 2011).

Although a theory-based, universal design approach to virtual instruction would simplify designing effective VLEs, one has not yet been developed. One study conducted by Mueller and Strohmeir (2011) tried to research the characteristics of an effective VLE and found 25 relevant studies within the last 20 years. The studies identified over 30 different VLE design characteristics, indicating the lack of a universal design approach. Since very little research has been completed on the universal design of learning
environments for virtual platforms, instructional designers are left ill equipped for designing effective learning games (Downey, 2011). Research has shown that, “For the most part, instructional designers know little about game development and video game developers may know little about training, education and instructional design” (Hirumi, Appelman, Rieber, & Van Eck, 2010, p. 27). Though a universal design approach to VLEs has not been identified, some studies, however, have shown instructional frameworks that have been successful in their application.

A study presented by Downey (2011) addressed the need for a framework that clearly identified the components of a successful and effective VLE. In the study, Downey (2011) noted that the design of effective VLEs would require a combination of instructional theories and techniques, in addition to visual stimuli and fun activities for the user. Using these concepts as a design guide, the Instruction for Massively Multiplayer Online Learning Environment (I-MMOLE) was developed. I-MMOLE is a VLE framework that was used to develop virtual lessons for multiple age groups and disciplines. Downey (2011) found the success of the I-MMOLE framework was attributed to its components, which were based on prominent instructional techniques within the virtual platform. Problem-based learning and experiential learning, which focused on real world application, along with gaming components were the basis of many of the I-MMOLE lessons (Downey, 2011).

Providing instructional content in a virtual environment should not be the sole focus of the design of VLEs. The presentation of the content within the design framework should also be considered in order to determine how student engagement and motivation will be maintained throughout the lesson. Five phases are used in I-MMOLE to create
engaging lessons that enable learners to select a learning quest that has been developed from various instructional materials, real world simulations, multiple assessments, and expansion activities. The phases that comprised the framework for I-MMOLE were: establishing context, investigating underlying concepts, providing experiences, assessing knowledge, and expansion activities (Downey, 2011).

In the I-MMOLE framework, the contextual phase is considered critical to game play, since the manner in which problems are presented to the learners determines their level of engagement and can influence their interest in achieving the desired learning goals (Downey, 2011). By presenting problems in a fun and creative manner that is meaningful to the learner, students, including those with ASD, maintain a level of engagement by increasing their time on task, which is one of the reasons why real world problems motivate student learning.

In the design of effective VLE components for students with ASD, it is also imperative to understand how virtual instructional techniques are used in the presentation of the content, so that users remain engaged and motivated throughout the learning process.

**Virtual Instructional Techniques**

In a study conducted by DiPietro, Ferdig, Black, and Presto (2010), it was evident that establishing virtual instructional techniques within a virtual program is essential because they support the motivation and engagement of students while they interact with the content. The study focused on key instructional techniques within a VLE. The researchers observed 16 teachers from the Michigan Virtual School who were interviewed twice a day on their instructional practices. Researchers analyzed data on
their instructional techniques that was both observed, as well as collected, during the interview process. From data collected, three pedagogical strategies were identified as most essential for the academic success of students and could be adapted to all instruction within a VLE. First, multiple modes of assessment and unique methods of recognizing a student’s comprehension of the material were determined to be crucial in a virtual setting (DiPietro et al., 2010). Finding various methods of assessing students allowed for creative approaches to problem solving to be explored (DiPietro et al., 2010). Utilizing this pedagogical strategy in a VLE would allow students with ASD the opportunity to express their understanding of the content in other forms other than formal assessments.

Secondly, maintaining student engagement with the content, in addition to finding ways to make the course meaningful for students, are additional strategies identified for student success (DiPietro et al., 2010). By providing opportunities for students with ASD to relate to the course, positive relationships between the student and the content can be established (DiPietro et al., 2010).

Finally, by providing support and maintaining forms of student-instructor communication, which would include feedback as well as student-student interaction via discussion boards, students feel a sense of community through the VLE (DiPietro et al., 2010). This communication minimizes the feeling of isolation from the class while progressing through the program. Most students are used to receiving feedback from teachers immediately in a face to face environment (DiPietro et al., 2010). This technique needs to be emulated within the program, in order to avoid a disconnect in engagement which may lead to students losing the motivation to continue (DiPietro et al., 2010).
A virtual instructional technique that is gaining popularity in educational establishments is gaming. Gaming provides a virtual platform where play is combined with instruction to motivate the user and maintain focus on an instructional task during learning.

**Game-Based Learning**

Students with ASD need a system of support to improve the typical lack of motivation that is exhibited when confronted with tasks that they are unwilling to complete or have difficulty completing (Koegel et al., 2010).

The inclusion of game based learning in a VLE has been established and is considered a common method for both promoting engaged learning (Ke, 2008) and improving motivation. Different from gaming, which focuses solely on entertainment, game-based learning uses games, principles of game design or gamification, and game dynamics as the primary source of instruction for the user (Blotcher, 2015). Gagné, Wager, Golas, and Keller (2004) identified nine events of instruction that are necessary for the instructional effectiveness of the game; obtaining attention, informing the objective, presenting instruction, providing guidance, recalling prior knowledge, practice and feedback, assessing performance, and enhancing retention and transfer. Many of the events required for the development of an instructionally effective game also cater to the cognitive deficits in students with ASD (Grynszpan, Weiss, Perez-Diaz, & Gal, 2014).

Game-based learning frameworks and a blended gaming approach, which combine games and learning activities, are used to engage and motivate students with ASD within a VLE. Although these students have difficulty with EF skills such as working memory, attention, reasoning and generalization, game-based learning has been
able to motivate them and keep them engaged so that they are learning successfully (de et al., 2013) by utilizing the motivation factors such as learning during play to influence instruction (Vogel et al., 2006).

Motivation within game-based learning can be attributed to the self-determination theory (SDT) (Denzine & Brown, 2015). The SDT states that students are driven and motivated based on the need for competence, autonomy, and relatedness. Students select experiences to fulfill the need to be successful within their academic environment and rely on themselves, as an autonomous learner, to make decisions relevant to their academic success (Denzine & Brown, 2015). In game-based learning, this motivation can be seen when students select and try to successfully complete particular quests and tasks within a game to either obtain a reward or the self satisfaction in knowing that they were able to complete their task.

Games not only use motivation to drive the student, they also use pictorial graphics, audio and text to clearly define the user’s objective and provide instructional tasks during the use of the game. Instructions are easily identified and constantly provided throughout the game (Grynszpan, Weiss, Perez-Diaz, & Gal, 2014) making it easy for students with ASD to comprehend and follow.

During play, the control of learning and feedback are both user-centered, since the amount of learning and feedback a user receives is dependent on the amount of time the user plays the game. This immediate feedback is critical to the success of students with ASD, since corrective measures can be immediately accessed to allow users to know exactly where they made an error. In learning games, play is also used as a design tool for engagement, where the interaction between the learner and the game, combined with the
challenge of the task is scaffolded to individualize the instruction so that the engagement level is maintained throughout the game (Vogel et al., 2006).

Fifteen students with intellectual disabilities, ages 13 to 22, were selected to participate in a study to determine if a learning game, VirtualMat, improved logical mathematical concepts (de et al., 2013). The program used real world activities to emulate family life experiences such as going grocery shopping (de Oliveira Malaquias et al., 2013). The required interaction and exploration within the VLE kept students engaged in their activities. Games motivated the player to continue playing regardless of circumstances. Retention of the content was assessed and reinforced through the use of points, badges, ranks, and levels that require players to remain engaged in the task at hand and retain the content in order to obtain their “rewards” which are visual representations of their achievement (Tu, Sujo-Montes, & Yen, 2014). The VirtualMat study data showed that there was a significant increase in students’ mathematical confidence and achievement when users correctly answered questions and obtained rewards for the successful completion of their problems. Students were immediately provided with feedback and were able to see the results of their efforts, thus bolstering their self-esteem in mathematics (de Oliveira Malaquias et al., 2013).

Chen (2014) found that an ID framework based on a blended instructional design approach provided both a meaningful and efficient learning when incorporating a constructivist and objectivists design method. The key to this framework is not only the design of a problem-based assignment, but also a real world task that is used as a capstone assessment instead of distinct quests (Chen, 2014). The use of real world tasks
would help students with ASD construct their own understanding of the content by conceptualizing the problem and linking it to real world concepts.

Game-based learning frameworks must sustain both engagement and motivation throughout the game. This requires a delicate balance between play and instruction to be maintained during the game’s use. In a study conducted by Ke (2008), gaming components that did not take into consideration the balance between instruction and entertainment were used in math games for a summer camp. Ke (2008) investigated the use of gaming by studying 4th and 5th grade students who participated in a gaming summer math camp where the games used basic graphics that required the answers to math problems in order to play the game. During the camp, students’ attitudes toward math games were assessed using a modified “Attitudes Towards Math Inventory (ATMI)” (Ke, 2008). Students quickly expressed their dissatisfaction toward the games through the ATMI to indicate that too many calculations were required, which replaced the fun of playing the game. It was evident that once students realized that math calculations were required for the game, they became frustrated or bored and were no longer motivated to complete the game.

In contrast, the Zhi-Hong, Liao, Cheng, Yeh, and Tak-Wai (2011) investigation produced more positive results when the researchers studied the effects of an integrative approach to gaming between learning activities and the gaming world. This three-tiered approach created a multiple level world where students could learn the content through various activities in the learning tier (top tier), allow for guidance through the VLE to keep students on task in the coupling level (middle tier), and be engaged with playing the game in the gaming tier while being motivated to continue the quest. In the same study,
the authors studied the influence of The My-Pet-My-Quest, a game developed utilizing the three-tiered approach, on elementary students to determine the influence of the game on student learning (Zhi-Hong et al., 2011). Two versions of the game were implemented, one with and one without quest, a designated task that related the game to the math skill (Zhi-Hong et al., 2011). Results of the study indicated that although students were learning the same content, they were more willing to complete the tasks when they were presented in the form of a quest instead of a math problem (Zhi-Hong et al., 2011). Students were more willing to complete the tasks when embedded in the game, showing that gaming could increase participation and sustain engagement if students are guided to learn through embedded tasks within the gaming system itself. The embedded use of tasks within the game provided “stealth” learning opportunities that allowed both the play and learn balance, as well as users’ engagement, to be supported throughout the duration of the game, which supports the SDT in game based learning.

Since students with ASD require a learning environment that provides individualized instruction while maintaining motivation and student engagement, a virtual program that has been design using a game based learning framework will be used as an intervention for this study.

**The Intervention Program**

i-Ready™ was selected as the intervention program because it provides a VLE that utilizes an ID framework where multiple modes of interactive instruction can be accessed and gaming is seamlessly combined with learning for a game based learning approach to instruction. The ID approach incorporates both student-instructor
communication and an embedded reward system to foster communication during use and promote positive feedback with opportunities to motivate and engage the user.

**i-Ready™ Virtual Program**

i-Ready™ is a virtual, online program that provides individualized, progressive instruction to students who have mathematical abilities that range from kindergarten to 12th grade (Curriculum Associates, 2014). The program has been designed to improve the math skills of students to meet the new Common Core State Standards (CCCS) through virtual instruction (Curriculum Associates, 2014). The i-Ready™ VLE is comprised of four key components: individualized lesson development, assessments, progress monitoring, and the token based reward system. The i-Ready™ program will be used as the intervention in this study to help improve foundational math skills in students with ASD.

The proposed i-Ready™ intervention for the study incorporates assessment flexibility; time on task monitors and immediate feedback for both the student and the teacher. The i-Ready™ program allows student assessment through the use of standard diagnostic exams, but also assess students’ knowledge using quizzes at the end of each lesson. The internal time on task tracker, tracks the student engagement with the program during lessons and diagnostic testing and notifies the instructor if a student seems to be randomly selecting answers. The i-Ready™ program also notifies the student of any errors in calculation and provides an explanation as to how the correct answer was determined. This immediate feedback is necessary for the student’s successful continuation through the content (DiPietro et al., 2010).
The i-Ready™ program also uses game based learning as the mode of instruction, which provides games that incorporate individualized lesson plans and personalized instruction and feedback in order to teach foundation math skills. Each instructional component consists of real world activities within interactive games, which motivate and engage students as their confidence in mathematics develops.

The program provides the user with structured, interactive lessons, which are comprised of instruction, modeling and assessment modules that combine learning with real world settings. Users partake in tasks that apply the mathematical concept to real world applications where both verbal and pictorial explanations of content are used to increase the effectiveness of the program (Mayer & Sims, 1994). Lessons give students the opportunity to learn concepts virtually from a real world perspective as mathematical tasks are established for the student to complete. Tasks are explained by modeling the concept using real world applications and virtual manipulatives. Students must then complete the tasks independently for credit.

After students have completed the initial diagnostic, their results are analyzed and any weaknesses in skill sets are identified and categorized according to each specific domain and assigned to the grade level where the skill sets are learned. Students’ competency in the domains; numbers and operations, algebra and algebraic thinking, measurement and data, and geometry, is determined and used to create individualized, interactive lessons that progressively become more challenging until the student is either on or surpasses level grade materials.

Instruction within the i-Ready™ program is interactive with animated, teen avatars, which replace teachers and act as agents throughout the virtual lessons.
Multimedia is used throughout the program, along with the avatars, to not only provide a student friendly approach to the lessons, but to also promote content interaction through the use of computer enhanced audio and visuals (Clark & Feldon, 2005). Wang and Shen (2012) stated, “Verbal and nonverbal cues have a profound impact on memory, recall and cognition and together can have an addictive effect on learning (p. 562). The animated avatars in the i-Ready™ program use audio led activities involving virtual manipulatives to interact with the user by guiding them through the lesson to create an interactive learning environment within the program.

The i-Ready™ has a reward system embedded in its programming, which allows students to accumulate tokens as they successfully complete lessons. Students who achieve a score of 70% or higher on their lessons “task” assessment receive 50 coins toward their video games, which they can use at their leisure after they have acquired the 150 coins to play a single game. This reward system ensures that students continue to strive for academic achievement within the program, while providing them with a mental break.

**i-Ready™ Research**

A validity study on the i-Ready™ program has been conducted on schools in New York, along with case studies in Ohio, California, and Virginia. In New York, the Education Research Institute of America was contracted by Curriculum Associates to perform the study on students from 22 elementary and middle schools in five districts in New York. Since the New York State English Language Arts (NYS ELA) and Mathematics Tests (NYS Math) are standardized test used for the PARCC exam, the objective of this study was to determine if the i-Ready™ diagnostic was a good indicator
of future PARCC exam scores. Students from each school took the diagnostic exams for both reading and mathematics. Once complete, scale scores were used in data analysis to determine the correlation between the diagnostic results to the standardized New York State English Language Arts (NYS ELA) and Mathematics Tests (NYS Math). In the analysis for both the reading and math, a strong positive correlation was identified, ranging from .79 to .85 and .72 to .84 respectively. These results revealed that the i-Ready™ diagnostic was a strong indicator of prospective PARCC scores so that administration and teachers can easily predict future scores and determine areas in which students need additional assistance in by using i-Ready™ diagnostic results.

The current i-Ready™ research has been conducted in schools that have special education programs, but has not been conducted specifically for the ASD population to determine the program’s impact on the mathematical achievement and foundational skill development of students with ASD.

**Synthesized Research**

Since mathematics is one of the most critical areas measured by using high stakes, standardized testing, it has also become a hindrance for graduation for students within the ASD population. Many students with ASD are having difficulty meeting these expectations because they lack the foundational math skills necessary to pass the standardized tests and required math courses.

A critical analysis of the documented research has shown that even though motivation and individual instruction are necessary components in teaching students with ASD, the face to face instructional method, currently used in most schools, is less effective and least selected when a virtual instruction option is offered. Students prefer
using a computer program, in lieu of instruction from a teacher, because the former provides a reward system.

This does not mean that all virtual programs are equal. In order to maintain student engagement and increase time on task, math instruction and problems should be presented in a fun and creative manner that is meaningful to the learner. This can be achieved through gaming and stealth learning, as long as the design components of the game are entertaining and resemble a game and not a math problem. Currently, many math programs are taught using gamification measures. The interaction of the learner with the game combined with a challenge of the task must be scaffolded to individualize the instruction and maintain student engagement. Research shows that gamification keeps students engaged in the content and improves their time on task. Positive reinforcement and responses from both virtual sources, such as badges and level enhancements, and nonverbal sources such virtual instructor communication form the programs have been used to improve student motivation in addition to achievement.

The i-Ready™ virtual program supports these design aspects in addition to providing individualized lessons for each student. Although current i-Ready™ research indicates that the diagnostic results can be used as strong indicator of prospective PARCC scores, a study of the virtual program has not been conducted on special education students with ASD to evaluate foundational math skill development. It is proposed that the i-Ready™ virtual program be used to evaluate and improve the foundational math skills of students with ASD.
Conclusion

Instructional methods are moving toward virtual education, where participants with ASD can learn math content independent from the traditional classroom experience, in a VLE. Several research studies have indicated that participant achievement in math is directly related to the effectiveness of the virtual program in participants who have ASD. The i-Ready™ program shows promise in improving the foundational math skills of participants due to its unique design, which individualizes instruction, provides a motivating reward system embedded in the program, and allows participants the opportunity to learn at their own pace in privacy.

Individualized instruction, engaging lesson plans, and motivational techniques are all items that should be provided in the instruction for every participant. As more teachers begin to attend the professional development provided by the i-Ready™ staff, they too will learn the full capabilities of the virtual math program that caters to the individual learning styles of participants with ASD.
Chapter 4

Intervention Design Methods and Procedures

The goal of this chapter is to describe how the i-Ready™ intervention was implemented using a concurrent, multiple baseline design. As discussed in Chapter 3, the i-Ready™ program provides an opportunity for students to learn independently from a traditional classroom with the use of virtual instruction. This chapter outlines the process used to implement the i-Ready™ program and the evaluation methodology.

Intervention

In this study, a concurrent, multiple baseline design was used to evaluate the effectiveness of didactic instruction and virtual instruction using the i-Ready™ program. Participants in the study completed a baseline phase, intervention phase and generalization phase to determine the effectiveness of the i-Ready™ program. Each session occurred during the participants’ regular 50 minute math class. Sessions during both the baseline and generalization phase were comprised of a five-problem quiz taken within 30 minutes and no instruction, while each session during the intervention phase included a 30 minute instructional lesson followed by a five-problem quiz taken within 20 minutes. Although a 30 minute quiz was given during the generalization and baseline phases, regular class time constraints permitted only 20 minutes, instead of 30 minutes, to complete the quiz during the didactic and i-Ready™ phases due to the allotted 30 minutes of instruction.

During the baseline phase, participants were given a five-problem assessment to determine their prior knowledge on partitioning shapes, as well as develop an individual baseline. Participants who scored 80% or higher on the baseline quiz did not participate
in the study, since their scores indicated that they understood the content prior to the implementation of the intervention.

Students who scored below 80% correct, with a consistent and stable baseline of at least three data points, were selected to participate in the intervention phase, which consisted of didactic and i-Ready™ instruction. During the 30 minute didactic instruction sessions, the teacher used an “I do, we do, you do” lesson structure in a small group setting of three students or less to teach the participants how to partition shapes. The teacher provided verbal praise for student who were successful in obtaining the correct answers during the “we do” and “you do” segments of the lesson. This was equivalent to the virtual rewards the participants received from the i-Ready™ program. Participants took a five-problem quiz after each didactic instruction session. After three stable scores were acquired, participants continued to the i-Ready™ phase of the study if they scored 60% or lower. If a participant scored three consecutive scores of 80% or better, they remained in the didactic phase until the end of the study, then continued to Phase 4, the generalization phase. Three scores were used to indicate stability because consistency could be easily observed over a period of time.

During the i-Ready™ phase, participants completed the virtual i-Ready™ lessons on partitioning shapes. As participants completed the lessons within the program with a score of 80% or more, they were able to accumulate coins that they could use for video games imbedded within the i-Ready™ program for breaks. After participants completed the lesson they took a five-problem quiz on partitioning. After three stable scores of 80% or more have been reached, the participant then moved to the final phase of the study, the generalization phase.
During the generalization phase, participants took a series of five-problem quizzes to see if they can apply the knowledge they have gained to more difficult shapes and tasks. The quizzes in the final phase required participants to partition irregular shapes using unit square tiles and determine the area based on the number of squares.

The logic model (see Figure 1) describes the interaction between the input activities, interventions and outcomes. The input activities include the administration’s ability to continue to provide financial support of the study through the purchase of i-Ready™ materials and technology needed to support the program. Teacher training is paramount in order to implement the program effectively, and to allow participants the opportunity to access the individualized virtual lessons developed to improve their foundational math skills, as shown in the intervention activities of the Logic Model.

Frequent use of the program should lead to several short-term and long-term outcomes for participants. The intended short-term outcomes are the ability of participants to maintain engagement in learning their lessons and improving their time on task. Participant’s engagement should lead to improved foundational math skills, which may lead to the long-term outcomes of pursuing higher level math courses and obtaining the credits needed to graduate high school.
Figure 1

Logic Model

**Input/Activities**

**Teachers**
- 1-day training to become familiar with the program features and components and method of implementation
- Students take 45 minutes training to become familiar with program features and use of the components and method of implementation
- Teachers provide 10th-11th grade study participants with the 30 minutes training during class to complete the study for 3 times per week for 1-month.
- Baseline Phase - administer a 5-problem quiz on partitioning rectangles after each lesson.
- Didactic Phase - provide small group instruction on partitioning rectangles.
- i-Ready Phase - use i-Ready data from the quizzes to identify participants’ math deficiencies and ability levels in partitioning rectangles and polygons.
- 10th-11th Grade Students with ASD
  - Baseline Phase - take a 5-problem quiz on partitioning rectangles.
  - Didactic Phase - participate in small group instruction with the teacher on partitioning rectangles. Take quiz.
  - i-Ready Phase - complete virtual lessons and lessons quiz.
- Administration provides necessary resources to purchase i-Ready materials and technical support options.

**Intervention Activities**

Teachers will select which 10th-11th grade students with ASD will complete the study.
- Teachers will administer lesson quizzes after each session and determine the correct number of answers. Teachers will conduct didactic lessons on partitioning rectangles and provide success to the i-Ready program. Teachers will administer end-of-study survey.
- 10th-11th Grade Students with ASD will participate in all phases of the study and complete a lesson quiz at the end of each session. Students will complete a survey at the end of the study on their participation in the i-Ready program.

**Assumptions**
- Students selected for the study are familiar with using the computer for educational purposes.
- Students are fluent in using the computer with little assistance.
- Students will want to do their best to succeed in order to improve their math skills.

**External Factors**
- Students may go into stress and refuse to complete the lessons.
- Students may be absent from school during implementation for illness or inclement weather.

**Goal Statement**

The purpose of this study was to directly measure the effectiveness of implementing the i-Ready™ program, when compared to traditional didactic instruction. Current deficiencies were identified in the participants’ foundational mathematic ability to partition shapes, which hindered them from fully understanding and comprehending subsequent math concepts such as fractions, surface area, volume and composite shape development.
Common Core State Standards (CCSS) in mathematics are the standards that students are required to learn and demonstrate in school to prepare them for life after graduation (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). The CCSS regarding the partitioning of shapes impacts math standards that span over multiple grade levels. The CCSS on partitioning are initially introduced in the first grade where students are taught how to verbally describe the fractional representation of a shape that has been partitioned into equal areas. This skill is then built upon during the second grade where students are required to partition rectangles using unit squares of equal size. In the third grade, students learn how to use partitioning skills and unit squares to determine the unit fraction of a shape and express the fractional area numerically (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). According to CCSS (2010), by sixth grade students are using the knowledge of partitioned shapes and unit squares to calculate the surface area and volume of shape and applying the skills to solve real world area and problems in seventh grade. Without the understanding of partitioning shapes, students would be unable to master concepts taught from first to seventh grade.

By determining the most effective instructional techniques for each student; an individualized learning plan was implemented that met the personal mathematical needs of each student in order to improve his or her core math skills in partitioning shapes.

**Description of Participants**

The study took place at a specialized high school for students who have been diagnosed with ASD, located on the outskirts of a large metropolitan city within the Northeastern hemisphere of the United States. The participants selected for the study
were students from grades 10 through 12 and performing significantly below grade level in math.

Prior to recruitment, all study procedures, activities, permission forms, assessments and questionnaires were submitted to the Johns Hopkins Homewood Institutional Review Board (HIRB). The HIRB reviewed and approved the research conducted in this study and the design, methodology, and procedures were followed exactly as indicated in the HIRB submission to ensure ethical practices were followed.

During the recruitment period, parents received a full explanation of the experimental procedures prior to giving their written consent. The parents were told that their child’s participation in this study would be entirely voluntary and that they could stop participation at any time, without any penalty. Students were recruited by first introducing them to the study by reading the recruitment script to all the 10th, 11th, and 12th graders in the presence of the grade level social worker. Students interested in participating signed a student assent form and took a parental permission form and recruitment letter home. Potential participants had one week to return the completed parental permission form in order to participate in the study.

From a pool of 15 potential participants, four African American and one Latino, male, high school students from grades 10, 11, and 12 were selected as participants in the study. The participants selected were different than those students selected to participate in the needs assessment, since some of the needs assessment participants no longer attended the school. Each of the participants selected had the following demographic descriptions: no previous history of severe behavioral issues; family with socioeconomic backgrounds that ranged from low to middle class; IEPs, which provided detail on their
individualized educational plan indicating performance significantly below grade level in math; and math skills that ranged from a 2nd grade to a 5th grade according to scores on standardized tests given in both middle school and high school, as well as classroom assessment given by the teacher. Table 1 summarizes the participant’s nationality, current grade level and the mathematic grade level assessed by standardized tests and in class assessments, according to their IEP.

Table 1

Description of Participant

<table>
<thead>
<tr>
<th>Participant</th>
<th>Current Grade</th>
<th>Tested Math Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>11th</td>
<td>5th grade</td>
</tr>
<tr>
<td>Student 2</td>
<td>10th</td>
<td>3rd grade</td>
</tr>
<tr>
<td>Student 3</td>
<td>12th</td>
<td>3rd grade</td>
</tr>
<tr>
<td>Student 4</td>
<td>12th</td>
<td>2nd grade</td>
</tr>
<tr>
<td>Student 5</td>
<td>12th</td>
<td>2nd grade</td>
</tr>
</tbody>
</table>

All participants were previously diagnosed with ASD and also were considered to have higher functioning autism (hfa) based upon the school’s classification and placement on the diploma track, however, this classification was not meant to be a clinical diagnosis.

Even though all participants had previously tested significantly below 10th grade in mathematics on standardized tests, most of the participants had been able to learn the concepts that they were taught previously in class. However, one of the issues in class became the retention rate of the material and generalization, the ability to apply concepts
outside of the demonstrated models. Since the participants were lacking foundational math skills necessary to fully understand the content, they were only able to complete the steps taught to them with the model and had difficulty with problem-solving skills when they were asked to recall a concept or apply it in a different area than they were previously exposed to with the modeling, indicating a deficiency in generalization skills.

The IEPs of all five participants indicated that they used some form of assistive aids such as calculators, graphic organizers, notes, textbook, tables, manipulatives, and charts to complete their problems and worked toward waning teacher cues for assistance, which included auditory, visual, and direct and indirect verbal cues.

**Context for Instruction**

Technology has been successfully used to teach students with ASD for more than 35 years and studies have consistently shown the positive impact that assistive technology has on improving the linguistics and behavior issues in students with autism. Moore and Calvert (2000) found that there was a preference for computer-based learning over face to face instruction in a study they performed on a class of 14 students with ASD. This study compared a preference for either the drill and reward method used by the teacher, where rewards were auditory or textile, or a computer program, which mimicked the teachers drill and reward method, but with sensory reinforcement used as the reward instead when teaching vocabulary (Moore & Calvert, 2000). The study revealed that although the instructional methods were virtually similar, students preferred the computerized instruction to the face to face instruction. Student attention in this study was measured by the amount of time a student was recorded looking at either the teacher or computer. The attention getting features of the program, which used color, animation
and sound in conjunction with immediate reinforcement, kept students attentive during instruction 97% of the time, whereas the teacher, who used verbal praise or allowed time for student play with a toy, only held their attention 62% of the time (Moore & Calvert, 2000). Motivation was measured by the number of students who preferred to continue working on their drill, as opposed to the number of students who would rather play. None of the students in the face to face instruction wanted to continue working on their drill, however, significantly more students wanted to continue their drills on the computer instead of playing (Moore & Calvert, 2000). The results of the Moore and Calvert (2000) study indicate that the use of computerized instruction can improve both the attention and motivation due to the unique sensory reinforcement techniques utilized by the computer program, which are very effective with students who have ASD. Although the use of this type of technology with students who have ASD is not a new concept, few studies have been conducted on the use of a virtual instructional program to teach mathematic skills.

As stated in the literature review, individualized instruction is essential to ASD student success, to that end, the i-Ready™ program provides individualized instruction based on the results of assessments. After students completed the initial assessment, their results were analyzed and any weaknesses in skill sets were identified and categorized according to each specific domain and assigned to the grade level that the skill sets are learned. Students’ competency in the domains; numbers and operations, algebra and algebraic thinking, measurement and data, and geometry, was determined and used to create individualized, interactive lessons that progressively became more challenging until the student was either on or surpassed level grade material. In addition, the program provided students with interactive lessons, comprised of instruction, modeling and
assessment modules that combine learning with real world settings, teachers were represented by characters or avatars. The student was required to partake in tasks that apply the mathematical concept to real world applications through modeling. In order for students to complete the lessons, they must model the technique on their own as an assessment of their knowledge.

It is possible for students with ASD to exhibit some form of math anxiety, or the fear of anything associated with math interactions. Math anxiety can manifest as tension, apprehension, and fear when faced with a mathematical situation (Park, Ramirez, & Beilock, 2014). This form of math anxiety can prevent students from taking higher level math courses, deter them from pursuing careers that involve any sort of calculations, and even impair long term financial planning, so it is imperative that students learn how to manage their anxiety. When a person suffers from math anxiety, it forces the working memory to entertain toxic thoughts of mathematical inability, instead of numerical manipulation and mathematical processing, making difficult to focus on the solution to a complex problem (Schunk, 2008).

In students with ASD, feelings of anxiety can also be amplified and manifest as behavior problems (Lang, Regester, Lauderdale, Ashbaugh, & Haring, 2010), however, positive behavioral support (PBS), such as rewards, have been shown to sufficiently reduce anxiety in this population (Neufeld, Law, & Lucyshyn, 2014).

Neufeld et al. (2014) performed a clinical case study on the effects of PBS by studying a five-year-old boy with ASD who had behavior issues that stemmed from extreme anxiety over riding escalators. Several steps were taken to relieve his anxiety, including a rewards system that allowed him to visit any store in the mall whenever he
rode the escalator in order to gradually eliminate the anxiety around riding escalators (Neufeld et al., 2014). Over a 4.5-month period the young boy mastered each step in the anxiety hierarchy and was capable of eliminating his anxiety toward escalators (Neufeld et al., 2014). Although the boy exhibited anxiety over riding escalators instead of completing math problems, similar steps can be taken to construct an environment for students to help relieve them of their math anxiety. This could be accomplished by implementing a reward system as a PBS so that students with ASD are able to minimize or eliminate their anxiety toward math.

The i-Ready™ program gives students the opportunity to learn skills that challenge them in a private setting while providing the opportunity for PBS in the form of a reward for correct answers (Curriculum Associates, 2014), which may alleviate some of the stressors that trigger math anxiety. The i-Ready™ program provides multiple opportunities for success with an embedded self check system that allows the student to periodically check their comprehension of the content throughout the lesson (Curriculum Associates, 2014), which may also enable students with ASD to learn in a safe environment without being embarrassed in front of peers for selecting the wrong answer multiple times. The program also utilizes a token system as a reward for correctly answering practice quiz problems. Tokens can be collected and used toward playing the video games embedded in the i-Ready™ Program (Curriculum Associates, 2014).

The i-Ready™ program provides individualized instruction based on the results of the diagnostic exams. After a student has completed the initial diagnostic, their results are analyzed and any weaknesses in skill sets are identified and categorized according to each specific domain and assigned to the grade level that the skill sets are learned.
Students’ competency in the domains; numbers and operations, algebra and algebraic thinking, measurement and data, and geometry, is determined and used to create individualized, interactive lessons that progressively become more challenging until the student is either on or surpasses level grade material.

Learning Objectives

The publishers of the program designed i-Ready™ to be implemented by first training both the students and instructors on the function and capabilities of the program; then giving students an assessment that identifies their deficiencies; having students complete individualized lessons that improve their deficiencies; and taking an assessment to measure the improvement. By implementing the i-Ready™ program as the publisher’s designed and by following the program provided individualized learning plan, students will be able to remain engaged with the materials while improving their foundation math scores.

Learning Objective: Improving Foundational Math Skills

The learning objective focuses on the participants’ improving their foundational math skills during their participation in the program and relates directly to the problem of practice since it identifies whether or not participants have made any improvement in their foundational math skills. This objective states that given the virtual i-Ready™ assessments, prescribed lesson plans, and the use of assistive aids indicated in their IEPs, participants in the study will demonstrate that they have improved their ability to partition rectangles with unit square tiles and measure the area of irregular shapes with unit square tiles.
**Strategies**

The following strategies were employed to achieve this objective:

1. Real world application was incorporated into the i-Ready™ lessons.
2. Lessons were task oriented, requiring the student to complete some sort of assignment to complete the level.
3. Student friendly vocabulary and animated scenarios were used for instruction.
4. Virtual manipulatives for problem solving were used.
5. All instructional and testing accommodations were provided as stated in the student’s IEP.

**Instructional Activities**

Before participants began the i-Ready™ study, they were introduced to the program’s features. The participants needed to understand how to select and customize their avatar, check their progress, view their grades, and select a gaming break. Participants also had to familiarize themselves with how to use the mouse to select answers, create tables and graphs, and move virtual manipulatives.

Study participants completed all components of the virtual i-Ready™ lessons, including the virtual instructional tutorial, practice opportunities, and program generated practice assessment, within each 30 minute session. Lesson quizzes were administered at the end of each lesson to measure the student’s foundational math achievement in partitioning shapes. During the generalization phase, quizzes were given to determine if participants were able to apply the concepts they learned on more complex shapes.
Learner Participation

Prior to starting the i-Ready™ study, participants had the opportunity to practice using the software during training. Since the i-Ready™ program incorporates all of the strategies listed for the objective, students practiced using the i-Ready™ program in order to become acclimated to the program’s components and features.

Instructional Media

i-Ready™ is a virtual instructional program that requires the use of a computer with a mouse for manipulation and headphones for verbal instructions, in addition to an Internet connection. No additional media was required since the program is all-inclusive.

Assessment

This objective was measured by comparing the scores of the lesson quizzes from each phase of the study. Following the intentions of the i-Ready™ designers, participants’ improvement on partitioning shapes were indicated as an increase in percentage points on the lesson quizzes as participants advanced through the phases.

Implementation Plan

The publishers of the program designed i-Ready™ to be implemented using four key components, which consist of: training instructors on the function and capabilities of the program; utilizing assessments to identify and monitor progress in deficient areas within each math domain; provide individualized instruction based on assessment results to improve the deficiencies; and report instructional recommendations for students who require additional support outside of the virtual instruction (Curriculum Associates, 2014). Although these components comprise the i-Ready™ implementation process,
students were evaluated for improvement on their foundational skills using summative assessments.

Teachers who completed the one-day i-Ready™ professional development training, provided by certified i-Ready™ trainers, implemented the i-Ready™ program as designed by its publishers for 2 months during the school year. The study participants received a 30 minute window during class to complete their assigned work for the study. Students first took the baseline quizzes to determine the areas or strength and weakness. Participants were then introduced to the i-Ready™ program, where they completed the individualized lessons in their principle area of math instruction, based on their scores from the initial diagnostic exam, for three 30 minute sessions per week. Each individualized lesson plan was comprised of three segments, an instructional tutorial, an opportunity to practice, and a practice quiz (Curriculum Associates, 2014). The practice quizzes were given within the virtual program and served as the summative assessment, so that the participants could see their mastery of the lesson topics (Curriculum Associates, 2014). Participants completed i-Ready™ lessons during the second half of the intervention phase of the study. A paper based, five-problem quiz was given by the instructor after the completion of each i-Ready™ session to measure participants’ improvement in their partitioning skills.

In addition, as participants proceeded through their lessons, they had the opportunity to collect tokens that they could have used toward playing games in the gaming component of the program as a method of maintaining engagement (Curriculum Associates, 2014). The teacher controlled the gaming component of the program, however, for this study all participants had access to the games. When the gaming
component is on, participants had the opportunity to automatically collect 20 tokens if they passed the lesson quiz, which had a default setting of 70% or more, or no tokens if they do not pass (Curriculum Associates, 2014). Once participants accumulated 50 or more tokens, they had the option of using their tokens to play a game, which costs 50 tokens to play and lasts at most 4 minutes (Curriculum Associates, 2014). Participants could continue to play games as long as they had enough tokens for the game. If the gaming component is off, participant would only be able to complete lessons, without access to the tokens or gaming module.

**Summative Assessments**

Participants were required to complete quizzes after each session within all phases of the intervention. The baseline phase quizzes were used to identify the participants’ mathematical areas of strength and weakness on partitioning. The results of the exams were utilized by the i-Ready™ program to develop individualized lesson plans that addressed the deficiencies in partitioning shapes (Curriculum Associates, 2014). Subsequent quizzes were given following the completion of each 30 minute session during the intervention phases of the study. Quizzes given during the baseline and intervention phases of the study required students to partition rectangles given their lengths. The quizzes given during the generalization phase of the study required participants to apply the knowledge by learning to partition irregular shapes using unit square tiles.

Each individualized i-Ready™ lesson plan was comprised of three segments, an instructional tutorial, an opportunity to practice, and i-Ready™ lesson quiz (Curriculum Associates, 2014). The i-Ready™ lesson quiz served as the summative assessment that
assessed mastery of the lessons topics (Curriculum Associates, 2014). Participants had two opportunities to pass the lesson before the teacher was alerted that supplemental i-Ready™ material would be necessary. Typically, supplemental teacher materials and instructional worksheets were used to further explain a concept to a participant who was struggling, however, to maintain the validity of the study, the lessons were restarted for the participant to complete.

**Evaluation Methods**

This study evaluated the effectiveness of the i-Ready™ program and will further investigate the use of virtual math programs on improving the foundational math skills of partitioning rectangles and general shapes with unit square tiles in high school participants with ASD. An assessment was conducted to determine study participants who were below grade level and having difficulty understanding partitioning shapes. The following research questions were addressed:

Research Question 1: Will the use of a virtual math program improve the fundamental math skill of partitioning rectangles to measure the area with unit square tiles better than a traditional face to face didactic instruction?

Research Question 2: Will the use of a virtual math program assist the generalization of participants’ partitioning skills to measure the area of irregular shapes with unit square tiles better than a traditional face to face didactic instruction?

**Hypothesis**

It was hypothesized that the i-Ready™ program, as intended by the authors, would improve students’ computational performance on partitioning and measuring the
area of rectangles and irregular shapes with unit square tiles, following the intervention and generalization phases of the study in comparison to the baseline rates, indicating an improvement in their foundational math skills.

**Independent and Dependent Variables**

**Independent Variables**

The effects of two interventions, traditional didactic instruction and i-Ready™ virtual math program, were implemented to evaluate their impact on foundational math skills and they were the independent variables for the study. The didactic instruction, which was implemented first, consisted of teacher led, 30 minute, face to face lessons. During these lessons, a typical “I do, we do, you do” lesson structure was followed to teach participants about partitioning shapes. During the “I do” portion of the lesson, the teacher showed the participants how to partition a rectangle using unit square tiles. The teacher explained what partitioning was and demonstrated how to tile a rectangle with same size squares. The “we do” portion of the lesson required participants to work together with the teacher to partition a second rectangle example. Finally, during the “you do” part of the lesson, students were given a rectangle that they had to partition individually.

The second intervention used in this study was the i-Ready™ program, which provided individualized, virtual instruction to participants who had mathematical abilities that ranged from kindergarten to 12th grade (Curriculum Associates, 2014). This self-paced, math component of the virtual program was designed to improve the math skills of users by adjusting content and difficulty levels of virtual lessons to match the users’ comprehensive needs, while meeting the new Common Core State Standards (CCCS;
Curriculum Associates, 2014). The program used real world examples, personalized instruction, and virtual manipulatives, in addition to multimedia graphic design, to deliver math instruction. Participants had 30 minutes to complete the interactive, virtual geometry lessons to learn about partitioning and area.

**Dependent Variable**

The dependent variables used for this study was the percentage of correctly partitioned rectangles and irregular shapes in participants’ quizzes. After the conclusion of each didactic and i-Ready™, the teacher administered a quiz that assessed participants’ comprehension of the partitioning polygons. The quiz contained five problems randomly selected from a predetermined bank of 20 regular rectangles and 20 irregular shapes. Each problem contained a rectangle or irregular shape, participants had either 20 or 30 minutes, dependent upon the phase, to correctly determine the number of unit square tiles within the shape, based on the given dimensions. If problems were not completed in the assessment window, the remaining problems were considered incorrect.

The percentage of correct problems on quizzes across each phase were compared to the baseline rates of both the didactic instruction and i-Ready™ intervention to measure the improvement of participants’ foundational math skills. The teacher graded all quizzes where the percentage of correct problems on the quiz was determined by calculating the total number of correctly completed problems out of the five quiz problems given.

The quizzes for phase 1, 2, and 3 contained problems involving rectangles. The quizzes given during phase 4 included both rectangles and irregular shapes. Each problem was scored based on participants’ ability to determine the correct number of
same size squares used to tile the entire polygon. Each correct answer was worth one point of the five possible points that could possibly have been earned on a single quiz. All quizzes were graded by the teacher and grades were not shared with students. Problems not completed within the 20 minute assessment window during the didactic and i-Ready™ phases and 30 minute assessment window during the baseline and generalization phases, were considered incorrect.

The social validity of the i-Ready™ program was measured by the responses to a questionnaire (Appendix E). Following phase 3 of the study, the teacher provided the participants with a short, three question survey that evaluated their opinion of the i-Ready™ program and asked them to provide a more personal perspective of their exposure to the i-Ready™ program. The questions were specifically designed to be easily understood so that the participants could evaluate the virtual program on its ease of use, the ability of participants to maintain focus during lessons and the content delivery. The first question was used to determine if the participants actually enjoyed using the program. The second question was used to indicate whether this mode of instruction was effective for maintaining focus throughout the duration of the lesson. The final question was used to indicate whether the participants preferred learning from the teacher or the virtual i-Ready™ program.

**Research Design**

A concurrent, multiple baseline design, across the participants was used to determine the effectiveness of the two interventions, the didactic instruction and i-Ready™ program. Multiple baseline designs are frequently used in studies involving special education participants because each individual participant can be evaluated
separately to determine the effectiveness of an intervention based on individual outcomes (Horner et al., 2005). By using this design method, each participant’s quiz results on partitioning rectangles and measuring the area of irregular shapes with unit square tiles could be collected during each phase of the study. The individual quiz results obtained during the baseline phase were used to both establish initial patterns and evaluate the instructional strategies used for the remaining phases of the study.

A multiple baseline design that allows data collection before, during, and after an intervention was implemented (Murphy & Bryan, 2001). Although typically used to collect data across two or more subjects with similar behaviors or conditions, this type of design has been more common in studies regarding participants with disabilities due to its ability to easily accommodate small study groups, which allows for data to be easily compared between subjects (Barger-Anderson, Domaracki, Kearney-Vakulick, & Kubina, 2004).

Experimental control in multiple baseline designs is established when participants’ data indicate that there is a change in behavior when the intervention is introduced and removed (Horner et al., 2005). In this study, since the intervention phase required a skill to be learned and could not be removed, a staggered introduction of the intervention was used to show that whenever the intervention was introduced it produced a change in participants’ behavior (Horner et al., 2005).

Multiple baseline designs seldom pose any ethical concerns, since removal of the independent variable is not needed and only changes in one behavior are observed and documented. This design is frequently used when new skills are learned and study
participants are unable to return to their original baseline state and “unlearn” their new skills (Barger-Anderson et al., 2004).

Although an internal threat to validity may not occur, changes in the application of the independent variables, from didactic instruction to virtual instruction, could be a threat to validity due to maturation, since participants are exposed to similar materials in different formats (Barger-Anderson et al., 2004). The participants were exposed to the interventions over a two-month period of time, thus normal development may have occurred, since participants may not have matured at the same rate (Barger-Anderson et al., 2004). Exposure from the didactic instruction intervention could lead to unintended changes in the dependent variable if participants retain knowledge on partitioning as they transition from the didactic instruction intervention to the virtual instruction intervention. External threats to validity may also remain if the study results are not generalized for other future groups (Barger-Anderson et al., 2004). These threats to external validity can be minimized if detailed documentation is provided on the intervention, setting, and measures (Barger-Anderson et al., 2004).

The dependent variables in this study were the percentage of correctly partitioned rectangles during the baseline and intervention phases and irregular shapes during the generalization phase on participants’ quizzes, which were given at the end of each session, in each phase of the study. A quiz, which contained five problems on partitioning shapes using unit square tiles to determine the area, was distributed to the participants at the end of each lesson during each phase of the study to measure the participants’ achievement level for the session. Participants were introduced to each phase of the study individually, based on the results of their five-problem quiz scores. An
example of the quiz used for Phase 1, 2, and 3 is shown in Appendix C, while an example of the quiz used in Phase 4, the generalization phase, is shown in Appendix D. Each phase of the study is described below.

**Procedures**

**Phase 1: Baseline**

All participants began the study in the baseline phase, in which a five-problem quiz on partitioning rectangles was administered without any instruction or corrective feedback. Participants who received scores below 60% on their quizzes had the opportunity to continue to the next phase of the study, however, if participants received scores above 60% for more than two days during the baseline phase, they were automatically removed from the study, since they showed an initial understanding of the partitioning concept prior to the intervention implementation. Once baseline data collection began, participants with similar scores were selected every day of the study to proceed to the didactic instruction phase. The first two participants who demonstrated a consistent baseline trend below 60% moved to the didactic instruction intervention phase while the remaining participants stayed in the baseline phase. Baseline data continued to be collected on participants that remained in the baseline phase of the study.

**Baseline Data Collection.** Each student began the study by completing a five-problem, baseline quiz, which was used to establish the student’s basic capabilities on partitioning rectangles. The quiz consisted of partitioning rectangles into rows and columns, where participants had to identify the number of same size squares needed for the entire shape. The baseline quiz had to be complete within the 30 minute session and
was used as a measure to determine each student’s current knowledge on partitioning rectangles without any prompting or explicit instruction given in advance.

Participants who received a score equal to or higher than 60% were removed from the study, since their scores would have indicated that they had prior knowledge of partitioning rectangles. Each day of the study, two students were selected from the remaining participants to proceed to the next part of the study, the didactic instruction portion of the intervention phase. Participants who remained in the baseline phase after completing their daily baseline quiz had the opportunity to work on other math material, outside of the scope of the study, while waiting to proceed to the next phase of the study.

**Phase 2: Didactic Instruction Intervention**

Participants selected to proceed to the didactic instruction phase participated in small group instruction with two to three other students and the teacher. The teacher used a typical “I do, we do, you do” lesson structure for the 30 minute lesson on partitioning rectangles in a traditional face to face environment. In this lesson structure, the “I do” segment was introduced by the teacher and example problems were modeled to demonstrated how they should be solved. The teacher then worked together with the participants to solve additional examples during the “we do” segment of the lesson. Finally, the participants were expected to independently solve the example problems during “you do” segment of the lesson. Although this was not a one-on-one instruction, participants did have the opportunity to ask the teacher for help and get individual attention during their small group sessions. Verbal praise was given to any participant who had the correct answers during the “we do” and “you do” segments of the lesson.

After completing each lesson with the teacher, participants received a five-problem quiz
that had to be completed within 20 minutes to evaluate their comprehension of the content. Once stable performance was established over a period of at least three sessions, participants who received scores of 80% and above remained in the didactic phase until the generalization phase of the study, while participants who had a stable performance below 80% moved on to the i-Ready™ intervention for the next phase of the study. The didactic instruction intervention addressed only the calculations and algorithms for partitioning shapes.

**Didactic Instruction Data Collection.** After each lesson, participants were given a five-problem quiz, which had to be completed within 20 minutes, to measure what they had learned. Participants who scored at least 80% on two quizzes or more remained in didactic instruction and continued to be assessed until the generalization phase began. Their scores indicated that they were able to correctly comprehend how to partition the rectangles without requiring the virtual instruction.

**Phase 3: i-Ready™ Intervention**

Following phase 2, participants who performed below 80%, moved on to receive the i-Ready™ intervention phase until stable performance was established over a period of three sessions, indicated by five-problem quiz scores of at least 80%.

**i-Ready™ Data Collection.** The individualized lesson plans which lasted 30 minutes, were comprised of instructional tutorials, practice opportunities, and program generated assessments, and designed to teach and assess the participants newly acquired foundational math skills (Curriculum Associates, 2014). After each lesson, participants had 20 minutes to complete a five-problem quiz to determine their comprehension level. Participants remained in the i-Ready™ portion of the intervention phase until stable
performance of at least 80% was achieved over a period of three sessions, or the intervention phase of the study concluded and the generalization phase began. Participants whose scores indicated stable performance prior to the end of the intervention phase proceeded to the generalization phase of the study.

Participants who progressed to the i-Ready™ portion of the intervention phase of the study used the individualized lesson plans created by the program of instruction. The individualized lesson plans, comprised of virtual instructional tutorials, interactive practice opportunities, and program generated practice assessments, were designed to teach and assess the participants newly acquired foundational math skills (Curriculum Associates, 2014). Scores on the program generated practice assessments were only utilized by the participants as a tool for reflection and did not impact the scores of the five-problem quiz given at the end of each lesson.

During the lesson, participants not only learned how to partition shapes, they also observed practical uses for partitioning shapes in the real world and why it was a useful skill to have. The i-Ready™ program provided participants with the opportunity to use virtual manipulatives to assist in the partitioning. Participants also received immediate feedback, tips and corrective instructions by the program during the practice portion of the lesson, so that they knew where they made errors on each problem and how to correct their mistakes for future problems.

At the end of each lesson, participants took a five-problem quiz to determine their comprehension level. Participants remained in the i-Ready™ portion of the intervention phase until stable performance of at least 80% had been achieved over a period of three sessions, or the intervention phase of the study concluded and the generalization phase
began. Participants whose scores indicated stable performance prior to the end of the intervention phase proceeded to the generalization phase of the study.

**Phase 4: Generalization**

Once the intervention phase was complete, participants proceeded to the generalization phase of the study, which lasted for three sessions. During this phase, participants received a five-problem quiz during each session that required the application of their partitioning skills to determine the answers for more complex, irregular shapes. The entire length of the study was completed within approximately six weeks.

The generalization phase of the study began immediately after the participants either stabilized their quiz scores during the i-Ready™ intervention portion of the study or the intervention phase concluded. Three, five-problem quizzes were administered to the participants and assessed their ability to apply foundational skills on partitioning rectangles using unit square tiles to more complex shapes. The quizzes used for the generalization phase consisted of five irregular shapes, where participants had 30 minutes during the session to complete the problems correctly. Although it was predetermined that three quizzes would be given during the generalization phase due to the time constraints of the overall study, data should be driven by time and not limited by the study session. Time constraints limit the amount of data that can be collected since students with ASD require additional time to process and respond to questions.

**Participant Questionnaire**

A questionnaire with four questions using a five-point Likert scale was administered after the intervention to obtain the opinions of the participants who were
exposed to the i-Ready™ phase of the study. In order to obtain a perspective on the entire study and receive feedback on the virtual program, only participants that participated in both the didactic and i-Ready™ instructional phases were selected to take the survey. These participants were asked if they enjoyed using the program and if it helped them remain focused and if it prepared them for their session quizzes. The final question asked whether the participants either enjoyed working with the teacher during didactic instruction or enjoyed the virtual instruction using the i-Ready™ program. This question only gave the option of selecting either didactic or virtual instruction.

Data Analysis

As described in the research design, the participants’ five-problem quiz scores were collected during each phase of the study and plotted on a line graph showing the percentage of correctly partitioned rectangles and irregular shapes on participants’ quizzes. The line graphs of the plotted data were compared to analyze the participants’ performance during each phase of the study and the effectiveness of each phase of the intervention. Graphed data that displayed a stabilized score of 80% or above during the didactic instruction phase indicated that participants are receptive to face to face instruction and did not require virtual instruction to improve their partitioning and measuring skills. If graphed data revealed that stabilized scores increased to at least 80% after the i-Ready™ intervention was implemented, then the patterns indicated that the program did improve participants’ computational performance on partitioning and measuring the area of rectangles with unit square tiles in participants with ASD. If graphed data revealed that scores during the generalization phase of the study were at
least 80% after the intervention was implemented, then the patterns indicate that the intervention also improved students’ ability to generalize their partitioning skills.

Data may also indicate that further studies may need to be performed to determine if future use of the program could be expanded to a school-wide program that includes other areas of math, as well as elementary and middle school participants with ASD. This enables teachers to identify core math skills that participants may be struggling with at an earlier age and use the i-Ready™ virtual lessons as a means of improving comprehension in those areas. However, if the program is not successful, then the evaluation indicates that future purchase and use of i-Ready™ software may need to be reduced to only the diagnostic exams, so that teachers are able to identify areas that participants are having difficulty in and address them with didactic instruction instead.

**Conclusion**

The multiple baseline design enables the results of multiple participants’ exposure to the content with and without an intervention during several phases of the study. Collected data on exposure to the intervention can then be viewed over several sessions and easily allows for the comparison of data with and without the intervention for each student. Given that a single subject design might limit the evaluation of the intervention to a smaller number of participants, this research design provides useful data for future studies to determine if the i-Ready™ program would work on a school-wide scale. If data shows that the program is successful in improving the foundational math skills of participants, as well as improving their motivation, administration will more than likely purchase an i-Ready™ seat for every student in the school. For a case to be made for
school-wide implementation, additional research will be required for future studies on larger groups of participants.
Chapter Five

Findings and Discussion

The purpose of this study was to determine whether implementing the i-Ready™ program or using didactic instruction to learn about partitioning geometric shapes, was more effective with high school students that have hfa. This chapter examines the empirical findings organized by the research questions and study design discussed in Chapter 4.

Research Question 1: Will the use of a virtual math program improve the fundamental math skill of partitioning rectangles with unit square tiles better than a traditional face to face didactic instruction?

Research Question 2: Will the use of a virtual math program assist the generalization of participants’ partitioning skills to measure the area of irregular shapes with unit square tiles better than a traditional face to face didactic instruction?

Intervention Implementation

The study began three weeks after students returned to school from summer break and continued for 15 sessions. Per administration’s request, each session could only occur during the participants’ regular math class, which lasted for 50 minutes. After all of the study participants were trained on how to use the i-Ready™ components, the participants began the baseline phase of the study. Appendix B shows the progression of each participant through the four phases of the study. During this first phase, all of the participants received failing scores, between 0% and 20%, on their baseline assessment. After three sessions of failing baseline scores, two students, Student 1 and Student 2 were
selected randomly to proceed to the didactic instruction phase. Once in didactic instruction, Student 1 and 2 had stable scores over 80% and remained in didactic instruction until the generalization phase began.

Students 3, 4, and 5 were then placed in didactic instruction, where they scored between 0% and 20% on the session quizzes. Students 3, 4, and 5 then progressed to the i-Ready™ phase where they all showed improvement in their scores. Once placed in the generalization phase, none of the participants received a score higher than 0%. Appendix F shows the graphs of the quiz scores after each session during the course of the study.

**Student 1**

Student 1 remained in the baseline phase for three sessions. During the first session, Student 1 received a 20% on his first quiz. This was due to him calculating the perimeter instead of the area which happened to be the same value as the area. On the second quiz he received 0% and another 20% on his third quiz where he correctly partitioned one problem. Although Student 1 attempted to partition the shape, he calculated the perimeter by adding up the sides instead of determining the total number of unit square tiles within the shape. Since all of his scores were below 60% he remained in the study and was selected to progress to the didactic instruction phase.

After the first didactic instruction session, Student 1 comprehended the concept of partitioning shapes and received an 80% on the first didactic instruction quiz. Since Student 1 received a score of 80% or higher on the quiz, he remained in the didactic instruction phase where he received 100% on the remaining quizzes for the next five sessions.
Once Student 1 progressed to the generalization phase, he had difficulty correctly partitioning the more complex shapes and received a 0% on all of his quizzes.

**Student 2**

When Student 2 began the baseline phase, he did not partition the shapes at all. His response to the problems was to only add the numbers that were shown as the sides of the shapes. Student 2 remained in the baseline phase for three sessions and received a 0% on all three of his baseline phase quizzes. This participant was selected to progress to the didactic phase along with Student 1 for the fourth session.

Student 2 received a 0% on the first quiz in the didactic phase, where he continued his trend of solely adding the two digits shown as the side lengths of the shape. During the second session of the didactic phase, however, Student 2 began to understand that partitioning the shapes meant drawing in the number of unit square tiles indicated by the side lengths of the figures instead of adding them together. He received 100% on the quizzes in the next five sessions and remained in the didactic phase until the generalization phase began.

Student 2 also had difficulty during the generalization phase. He attempted to partition the shapes with unit square tiles but was confused on how many unit square tiles each side should have. He received 0% on all of his quizzes within this phase.

**Student 3**

When Student 3 began the baseline phase, where he remained for four sessions, he did not partition the shapes into unit squares at all. During the first quiz, Student 3 divided each shape in half horizontally and added the side lengths together to formulate his response. This trend of adding the side lengths continued for the duration of the phase
and Student 3 received 0% on all four quizzes. Student 3 then progressed to the didactic instruction phase with Student 4.

Student 3 also struggled with comprehension of the concept during the didactic phase. He received a 0% on all four of the quizzes he took during this phase. On the first quiz of the phase, Student 3 continued to add the side lengths together in order to calculate his response. On his second quiz of the phase, he attempted to partition the figures into unit square tiles, but then went back and erased all the lines he drew. Finally on the third quiz during the didactic phase, Student 3 partitioned the figures. Although the partitioning was incorrect, he understood the concept required to calculate his answer.

Student 3 successfully completed all components of the three i-Ready™ lessons he took during the 30 minute instructional period. It is evident that Student 3’s focus on completing the i-Ready™ lessons improved his understanding of how to partition shapes. After using the virtual program, Student 3’s quiz scores improved significantly. On the first and second quiz of the phase, Student 3 correctly partitioned all but one of the shapes and received an 80% on both quizzes. His scores continued to improve with the use of the i-Ready™ program since he received a 100% on the last quiz he took during the phase.

During the generalization phase, Student 3 did not know how to partition a shape that had more than two sides. He received 0% on all three of his quizzes during the generalization phase.
**Student 4**

Student 4 struggled throughout the entire study. During baseline phase, where Student 4 remained for four sessions, he did not partition any of the shapes and responded to each problem on the four quizzes he took with the answer “4”.

Student 4 remained in the didactic phase for three sessions. After progressing to the didactic instruction phase, Student 4 continued to respond with the answer “4” for all of the problems on his first quiz in the phase. During the second session in the didactic phase, he began to understand that partitioning meant to draw in the number of unit square tiles based on the lengths of the sides. Although Student 4 attempted to partition the shapes on the quizzes for the last two sessions, he drew in the incorrect number of squares for the sides and frequently miscounted the number of unit square tiles.

Student 4 progressed to the i-Ready™ phase, which assisted him in understanding what is required for partitioning shapes. He did not make the anticipated improvement to 80%, but he did show improvement in his quiz scores after using the program. Although Student 4 scored a 0% on his first quiz within this phase, the i-Ready™ program helped improve his score from 0% to 60% on his next three quizzes. Student 4 also completed all of the i-Ready™ lesson components, including the practice quizzes provided by the program. Even though Student 4 made significant improvements during the i-Ready™ intervention phase, he was progressed to the generalization phase after obtaining three stable quiz scores of 60%. In some quiz problems he drew the unit square tiles correctly but miscalculated how many there were while counting them. In other instances he only drew in the correct number of squares for one side of the shape and not the other. Since Student 4’s responses on the quizzes indicated that he understood the concept of
partitioning a rectangle into unit squares, but continued to make minor errors and miscalculations based on the number of tiles he drew. He may have been able to improve his quiz scores to 80% if he was provided with additional time to complete more sessions. Since Student 4 was unable to meet the 80% quiz score goal, he may have also needed another method of instruction, not presented in this study, that was more conducive to his learning needs.

Student 4 also had difficulty in the generalization phase. He tried to draw the unit square tiles, but did not know how to determine the number of squares required for each side of the shape. Student 4 frequently ran out of time trying to draw the unit square tiles and rushed to finish the remaining problems on his quiz resulting in a 0% for each of the three quizzes he took.

**Student 5**

Student 5 remained in the baseline phase for five sessions and received a 20% on the first session quiz. This was due to him calculating the perimeter instead of the area which was the same value as the area. Similar to other participants, Student 5 determined his answer by adding the sides of the shape instead of partitioning the shapes using unit square tiles. Student 5 did not partition any of the figures during this phase and received a 0% on the remaining four quizzes during the phase prior to progressing to the didactic instruction phase.

The didactic instruction did not improve Student 5’s partitioning skills. He remained in the didactic phase of the study for 3 session and continued to add the sides together to determine his answers to all of the problems. Student 5 received 0% on all three of the quizzes he took during the didactic instruction phase.
Progress on partitioning was not made until Student 5 began using the i-Ready™ program. Student 5 was able to consistently complete all the components of the i-Ready lessons during the 30 minute instructional session, however, the first quiz he took after the first i-Ready™ session showed his improvement increasing only from a score of 0% to 60%. Although Student 5 was unable to finish two of the problems within the allotted 20 minute timeframe for quizzes, the three he did complete were correctly partitioned into unit square tiles and had the correct number of total squares for the figures. If Student 5 was allowed additional time to complete his quiz, as indicated by his IEP, he most likely would been able to complete the last two problems and would have received a 100% on his first quiz during the i-Ready™ phase since he understood the concept of partitioning rectangles. The next three sessions he correctly partitioned all the figures and received a 100% on the final three quizzes in the phase.

During the generalization phase of the study, Student 5 shared the same difficulties as the other participants. He was unable to determine how many unit square tiles belonged on each side of the shape. He received 0% on his three generalization quizzes.

**Social Validity**

After the intervention was complete, Student 3, 4 and 5 received a four-question questionnaire on their experience using i-Ready™. The results of the questionnaire are listed in Appendix G. Student 3 responded that he enjoyed using the i-Ready™ program to learn and that he agreed that it helped him to remain focused during the lesson and prepared him for the session quiz. Student 3 selected that he preferred using the i-Ready™ program instead of working with the teacher.
Student 4 strongly agreed that he enjoyed using the i-Ready™ program to learn and agreed that the lessons did prepare him for his session quizzes. He did, however, remain undecided as to whether or not he remained focused during the use of the program, but noted that he preferred working with the teacher rather than the i-Ready™ program.

Student 5 also strongly agreed that he enjoyed using the i-Ready™ program to learn, in addition to strongly agreeing that it helped him remain focused and prepared him for the session quizzes. He did prefer working with the virtual program instead of working with the teacher.

**Discussion**

The objective of this study was to directly measure whether implementing virtual or didactic instruction was more effective with high school students with ASD, who were classified by the school as students with hfa, in learning about partitioning rectangles and applying partitioning skills to irregular shapes by comparing the effectiveness of the i-Ready™ program to didactic instruction. Both instructional methods provided the participants with modeled example problems, real world examples, the opportunity to practice newly learned partitioning skills and a reinforcement system. Each instructional method, however, proved to be effective in teaching skills necessary to partition rectangles, yet ineffective in teaching how to apply partitioning skills to irregular shapes, based upon the participant’s instructional needs.

The study began three weeks after students returned to school from summer break and continued for 15 sessions. The beginning of the school year was the best time to conduct the study. Students are still refreshed from summer, but have had time to settle
back into the cycle of coming back to school. It is recommended that future research be conducted during similar times of the year if possible.

Although the collected data indicated that the didactic instruction was not an effective instructional method for teaching all the participants rectangle partitioning skills (Appendix F), it was an effective method for Students 1 and 2. Once Student 1 and Student 2 had the opportunity to participate in the face to face group instruction with the teacher, their scores immediately began to improve from their baseline scores of 0% to a score of 100% on their five-problem quizzes by their second didactic instruction session and continued for the duration of the phase.

Didactic instruction did not offer any multimedia features or gaming techniques, however, it did provide the opportunity for participants to interact freely with the teacher during the small group instruction and participants could receive immediate feedback to all specific questions asked without having to go back and independently review the instructional material for answers. Students 1 and 2 did not need additional resources to help them remain focused on the content. They only needed the instructional tools necessary to understand the content, which were provided during the teacher’s lessons. Since these two participants could interact freely with the teacher, they were able to immediately ask a question when they were having difficulty and implement the changes to their calculations. This required the participants to have higher level thinking and the ability to know which questions to ask to improve comprehension, as well as how to self correct for future problems. The brief one on one attention given while the teacher was answering their specific questions and providing verbal praise was enough of a
reinforcement system to keep the two participants focused on learning, which was indicated by their participation throughout the didactic lessons.

Another trend that was clearly apparent in the collected data (Appendix F) was the effectiveness of the i-Ready™ program on improving the rectangle partitioning skills in three of the participants. During the didactic phase of instruction Students 3, 4 and 5 were unable to independently complete the problems during the “you do” segment of the lesson and did not understand how to partition the rectangles. All three of these participants received failing scores on their five-problem quizzes during the duration of the didactic instruction and required a different instructional method in order to successfully partition shapes. The three participants’ improvement during the i-Ready™ intervention phase could be attributed to both their increase in focus on content during the i-Ready™ lessons and an increase in their sense of preparation. All three of the participants who progressed to the i-Ready™ phase successfully completed all lesson components on partitioning rectangles while using i-Ready™ as the mode of virtual instruction. The data collected (Appendix F) clearly shows the improvement that Students 3 and 5 had using the i-Ready™ program. Both participants had a trending score of 0% throughout the baseline and didactic phases of the study, however, they both attained mastery in their partitioning skills, with scores of 100%, immediately after beginning the i-Ready™ phase. Although Student 4 did not score as high on his quizzes after his virtual sessions, with a trending score of 60% correct during the i-Ready™ intervention phase, his scores were much higher than his trending 0% scores during the baseline and didactic instruction sessions, indicating that there was an improvement in his partitioning skills while using the i-Ready™ program as well.
Improved Focus

The effectiveness of virtual instruction has been shown to depend heavily upon the engagement of the student (Zhi-Hong et al., 2011; DiPietro et al., 2010; Gagné, Wager, Golas, & Keller, 2004; de Oliveira Malaquias et al., 2013; Tu, Sujo-Montes, & Yen, 2014; Vogel et al., 2006) and the presentation of problems in the gamification of instruction could directly impact the learner’s level of achievement. In Downey’s (2011) I-MMOLE framework, he found that the manner in which problems were presented was considered critical to gamification since the learner’s level of engagement could influence their interest in achieving their learning goals (Downey, 2011). This concept was also reiterated in DiPietro et al.’s (2010) research, who found that student success could be achieved by maintaining student engagement, as well as Moore and Calvert (2000) who measured student focus during virtual instruction at 97% during their research. Moore and Calvert’s (2000) research also showed that there was a direct relationship between the amount of time students remained focused on virtual instruction and achievement. As focus on virtual instruction increased so did the students’ achievement level (Moore & Calvert, 2000). In addition, research conducted by DiPietro (2010) showed that by making the content meaningful and providing students with ASD opportunities to relate with the content, improved both the students’ engagement and motivation (Moore & Calvert, 2000).

Engagement and motivation were not directly measured in this study, however, the research cited did have implications on focus and interaction of the subjects with the content, which was consistent with the social validity results from this study. The participants’ average score from the social validity results indicated that they “agreed”
with question two on the questionnaire, which asked if the participants remained focused
during the i-Ready™ intervention lessons (Appendix G). Participants’ focus during the i-
Ready™ intervention was also evident by their ability to remain on task during the
instruction in order to complete all the virtual components, including the practice quiz,
during the 30 minute lesson.

The improvement in the focus of the participants can be explained by i-Ready™’s
utilization of gamification techniques in conjunction with interactive lessons. The use of
enhanced audio combined with animated avatars, interactive games that incorporate real
world activities, and virtual manipulatives within the lesson were used as the attention
getters within the program. The use of the multimedia features not only helped
participants maintain focus on instruction, it also promoted user interaction within the
lesson while example problems were modeled, allowing meaningful opportunities for the
participants to relate to the content.

Improved Preparation

The third question on the social validity questionnaire, which asked if the
participants felt that the i-Ready™ lessons prepared them for their five-problem quizzes,
received an average response of “agree” (Appendix G). All three participants who were
exposed to the i-Ready™ intervention indicated that they believed the virtual program
prepared them for their five-problem quiz. The embedded self check system, a
component within the i-Ready™ program, is designed to improve students’
metacognition and help bolster their confidence throughout the lesson. These frequent
opportunities to assess their abilities within a safe environment could explain the reasons
participants indicated an improved sense of preparation after using the program. This also
lends itself to the self-determination theory (SDT) where students select experiences to fulfill the need to be successful within their academic environment and rely on themselves for their academic success (Denzine & Brown, 2015). By completing the i-Ready™ lessons and using the self check system embedded within the virtual program, participants are working on improving their partitioning skills by selecting an experience that they know is needed for them to be successful on the session quiz, thus giving them a sense of self confidence and preparation with the assistance of i-Ready™.

**Preference for Virtual Learning**

Virtual learning over face to face didactic instruction has been found to be the preference of students with ASD (Moore & Calvert, 2000). This can be explained as a result of the safe environment that is created within the program that allows students to practice their skills without experiencing any ridicule from others (de Oliveira Malaquias et al., 2013) and the unique instruction methods that can be fun and engaging to the student. The i-Ready™ program also provides the opportunity to improve time on task through two of the most important virtual instruction components necessary for students with ASD to learn, interaction of the learner with the program and individualized instruction in order to maintain student engagement and motivation.

The results from this study were inconsistent with the previous research, which indicated that if given the opportunity, students with autism would select virtual learning over didactic instruction (Moore & Calvert, 2000). Student 4, who struggled with comprehension of the content throughout the study, and Student 5, two of the three participants who had the opportunity to partake in both the didactic instruction and i-Ready™ instruction phase, indicated a preference for didactic instruction over virtual
instruction. Although the reason behind their selection is unknown, there are several possible explanations. The two participants could have selected didactic instruction since they knew their teacher would see the surveys and they did not want to upset her.

Another reason could be that the participants found comfort in having a teacher present so that they could ask questions when necessary. A third reason could also be that the questionnaire only allowed selection of the teacher or the virtual program and did not provide an opportunity for participants to select both.

One of the main differences in the instructional methods was the level of self-instruction required based on the presentation of the content. In didactic instruction, the teacher presented the examples in a traditional format, however, she was present and could answer questions immediately, however, participants needed to know which questions to ask to improve their comprehension and how to apply the answer to their questions to subsequent problems. This method of instruction would also be difficult for students that refuse to interact with others and don’t ask questions or do not want their peers to know that they don’t comprehend a concept. Although receiving immediate feedback from the teacher did not seem to help improve the five-problem quiz scores of the two participants that preferred didactic instruction, it added a second level of security if future problems or questions arose due to lack of comprehension.

The i-Ready™ instruction required more self-instruction, although the content was presented in a format which required more interaction with the program. Specific questions could not be asked during lessons, so participants would have to go back to review the lesson again or wait for the virtual self checks during practice portion of the lesson if they did not understand the content. This method of instruction is adequate for
students who prefer a more personal learning environment that does not require interaction with any of their peers. It does require students to remain focused on learning the content since the learning process through the program requires a significant amount of interaction with the content and the program.

Students 1 and 2 were successful during the didactic instruction phase and showed mastery in partitioning with multiple scores of 100% although they did not progress to the i-Ready™ phase of the intervention. A student who shows signs of higher level thinking and metacognition, in addition to being capable of learning without the need for multimedia features that provide additional support to remain focused, could successfully learn math with didactic instruction, if an explicit instructional approach is used. Information must be provided in chunks or modeled in a small group setting and students should be led through guided and independent practices (Hua et al., 2012). These measures were provided during the “I do, we do, you do” lesson structure during the didactic instruction explaining why Students 1 and 2 were able to achieve mastery without using the virtual program. Although they showed mastery in partitioning rectangles using only didactic instruction, it cannot be determined whether or not these participants would have also been successful with the i-Ready™ intervention based upon the design of the study.

**Application of Skills for Generalization**

All of the participants were successful in using either didactic or the i-Ready™ virtual instruction to master partitioning rectangles with unit square tiles, however, none of them were able to generalize their skills and apply them to partitioning irregular shapes. One limitation to the generalization phase of the study, was that once a
participant obtained a stable score over three sessions, data collection ended. Since all five of the participants obtained a stable score of 0% over three sessions, data collection ended after three sessions. Based on the scores of all the participants, it seemed unlikely that they would have improved their scores even if additional time was provided to them. Many of the participants were confused as to how to correctly partition a shape when opposite site showed missing lengths due to the protrusions of the shape.

Step by step instruction is a common method that has been successful in teaching math to students with ASD. Although students learn the process to solve a specific type of problem, however, this method does not help students develop strategic math skills for application problems. In a study, Hua et al. (2012) noted that teaching students how to manipulate strategies so that their skills can be applied to problems that differ from the modeled examples, assists the students in learning how to solve more complex problems that involve application of skills rather than a scripted solution. Although the i-Ready™ program attempted to provide real world application problems, the real world problems were similar to the models and did not require the application of the skill learned. This explains why the participants were able to partition the figures during the intervention phase, but had difficulty with the application of the skill with the more complex figures in the generalization phase.

As stated in in Chapter 1, EF skills are necessary to manage behaviors and make it for developing an action plan to solve a problem when these skills are not present. Generalization is important to a study because it shows strategies that help behaviors evolve beyond what was taught in a study using generalization strategies (Stokes & Baer, 1977). The generalization strategies are techniques that are used to help promote this
growth and improve the EF skills needed to problem solve. Although there are several generalization strategies, in this study, a train and hope approach was used where participants were taught how to partition rectangles during the intervention phases of the study and it was hoped that they would know how to apply their newly acquired partitioning skills to more complex, irregular shapes that also had missing sides (Stokes & Baer, 1977). This strategy can be effective in the general population, however, it is not often an effective strategy for individuals with ASD and other individuals with intellectual disabilities (Stokes & Baer, 1977). Since many students had difficulty determining how to partition an irregular shape that had missing sides, a plan should be implemented for future research that incorporates a natural progression to partitioning irregular shapes by training student to partition rectangles that are slightly modified with smaller protrusions and by giving the length of all of the sides. This would allow for a more efficient strategy for generalization, training with sufficient exemplars, to be used where participants were provided with variations of the slightly modified rectangle with the small protrusion that had a similar shape to the previously partitioned rectangles, but only had two sides with a slight protrusion. Since the i-Ready™ cannot be modified manually, suggestions can be made to the design team to include these types of problems in future versions of the program. Until the virtual program lessons are modified it is recommended that these strategies are taught during didactic instruction.

Implications for Practice and Recommendations

During this study, both the didactic and virtual instruction methods were successful in improving the rectangle partitioning skills of the participants. The success of the intervention was dependent upon each participant’s individual learning
requirements. Collected data revealed that the implementation of solely didactic or virtual instruction was unsuccessful in improving acquisition for all participants in the study.

The application of this study in a classroom would provide a teacher with similar data and valuable knowledge on the instructional requirements of individual students thus making future instruction more effective. A teacher would be able to use data to develop work stations, so that certain students would have the opportunity to either participate in small group or virtual instruction. Data could also be useful when assigning homework or extensions to a lesson. The teacher would know which student would be able to participate in a flipped classroom, where virtual instruction is provided for review at home and problems and questions are answered the following day in class for a deeper understanding of the content or a blended classroom environment. Although this data may provide initial direction on whether didactic or virtual instruction would be adequate for a student’s individual learning needs, future studies would be necessary to determine if these instructional methods continue to be effective when new standards are introduced.

Until research is conducted to determine if the effectiveness of the interventions continues over other math standards, it is recommended that an initial study be performed to provide a general idea as to which instructional methods students need, but to allow students to have access to multiple forms of instruction in the classroom in order to meet the needs of all students.

Teachers would appreciate the program’s ability to identify core math skills that students may be struggling with at an earlier age and prepare individualized i-Ready™ lessons as a means of improving comprehension in those areas. For students who
comprehend the content better through virtual instruction, teachers may want to provide specific lessons in areas where students have demonstrated a weakness as a homework exercise, so that students can continue to improve their foundational skills independently outside of class.

Although teachers must first be trained on the management of the i-Ready™ components, many instructors would appreciate the opportunity to track student’s comprehension and modify the level of instruction, based on the student’s progress on the virtual lessons. Purchasing the entire i-Ready™ program may not be conducive to an administrator’s budget, however, future purchase and use of i-Ready™ software may need to be reduced to only the diagnostic exams, so that teachers are able to identify areas that participants are having difficulty in and address them with didactic instruction instead. Future research should also be conducted to see if the program is as effective with elementary and middle school students as it is with high school students.

**Study Limitations and Future Research**

There were several limitations to this study that should be considered for the design of future studies. First, this study used a concurrent, multiple baseline design, where the study limited the evaluation of the intervention to a small number of participants. Although this study provided useful data, only a small sample of the student population participated in the study.

In order to determine if this program should be purchased on a school-wide scale, and to obtain a broader scope of the population, future studies should be conducted on a larger, more diverse study group to provide more valid data representative of the entire school’s population. Prior to investing in the virtual program school wide, consideration
should be given to including students from other grades in future research as well.

Participants in this study did not exhibit a history of severe behavior issues and had a level of maturity suitable for virtual instruction, however this may not be the case with all students, especially those who are in lower grades. The level of student focus required for the successful use of the i-Ready™ program would be impacted by any behavior issues or attention deficits exhibited by younger, less mature students.

Maturation of the participants also provided a limiting factor during this study. Didactic instruction proved to be successful for Students 1 and 2, the participants who remained in didactic instruction for the duration of the study, however, it was impossible to know if the i-Ready™ program would have been equally successful for them, since content cannot be unlearned. Future research can be conducted on these two participants using virtual instruction first instead of didactic instruction on a related math standard to determine if the virtual instruction was as effective as the didactic instruction for these participants as well.

The study was also limited by data collected and analyzed, since a single math standard on correctly partitioning rectangles and irregular shapes was the only standard studied. This math standard was selected since knowledge of partitioning shapes could be lent to improvements in both algebra and geometry. Students’ knowledge of partitioning is used as the foundation for identifying and understanding fractions an area that many students have difficulty in. When students can partition shapes into equal parts, they can easily comprehend and identify the fractional part of the shape, making it easier to visualize a fraction. Partitioning a shape into equal parts is also the foundational skill necessary for determining the surface area and volume of shapes. It is recommended that
future research also be performed on these math standards using the same participants to
determine if the foundational knowledge of partitioning using either a didactic or virtual
instructional method improved their skills. Future research should include the analysis of
data from studying multiple standards to determine if the effectiveness of an instructional
method remains constant for a participant over multiple standards. This would help
determine if the virtual programs’ effectiveness would extend beyond partitioning shapes
and is equally successful with other math standards in students who seem to perform
better when learning with virtual instruction.

Two separate questionnaires should also be provided for future studies. One
questionnaire for participants who completed the entire study and one questionnaire that
obtained the perspective of the participants who only participated in the didactic phase of
the study. This would allow for comparisons to be made on the participant level of
enjoyment for each phase as well as the level of focus and preparation for quizzes each
phase provided. Finally a change would be made in the final question for the participants
that completed the entire study to include the option of working with both the virtual
program and the teacher. Instead of limiting the participants’ choice to only one or the
other, some participants may have enjoyed both and the modification to the final question
would provide them the opportunity to express their preference for both.

Although the i-Ready™ program improved the participant’s ability to partition
rectangles using unit squares, none of the participants knew how to apply that skill to
partitioning irregular shapes during the generalization phase. The virtual program only
modeled problems similar to the examples and did not provide strategies as to how to use
partitioning skills on irregular shapes, leaving the participants to figure out how to
measure the irregular shapes on their own. These strategies, however, can be learned by using another generalization strategy that is more effective with the ASD population, training with sufficient exemplars (Stokes & Baer, 1977) in conjunction with a modification of the shapes used in the generalization phase problem bank. It is recommended that the irregular shapes are modified to include less complex figures that more closely resembled rectangular shapes and had all of the side lengths labeled.

In addition to modifying the generalization strategies, the study design should be modified to allow for more time during sessions and the overall length of the study. Although dependent variables should be measured using the same amount of time across phases, sessions were limited to the participants’ 50 minute math class. This only allowed for 20 minutes to complete the intervention five-problem quizzes after the intervention, as opposed to the 30 minutes that were provided to complete the five-problem quiz for both the baseline and generalization phases. The additional 10 minutes could have given participants, like Student 4, enough time to complete additional problems or go back to review their answers. It is recommended that future research should either include a longer length session in the research design or modify the allotted time for the five-problem quizzes to 20 minutes for all phases.

Motivation and engagement are key elements necessary for the success of instruction and could provide important data on the effectiveness of an intervention. Although motivation and engagement were not measured during this study, it is recommended that all subsequent studies include motivation and engagement as dependent variables. Engagement has been shown to be measured by the amount of uninterrupted time a student participates in instruction without distraction, and should be
measured as such during future research. Motivation should be separately researched to determine if the impact of verbal praise is as substantive as virtual praise. This study will help determine if it is the method of instruction that determines the achievement or the reward system provided that truly drives instruction. A similar study can be conducted using the i-Ready™ program with the token system toggled on or off. When the token system is toggled off, the teacher would provide verbal praise and when the token system is on, the students have the opportunity to use the video game feature with their accumulated tokens. Similar data can be collected with the five-problem quizzes after each virtual lesson, while engagement is measured as the amount of time the student stays on task. This would provide an effective method for determining the impact of verbal and social praise on both achievement and engagement.

For all future studies, the progression between all phases should be explicitly identified for the stabilized five-problem quiz results. The criteria or progression between the i-Ready™ instructional phase and generalization phase was three stabilized scores of 80% or more or the end of the phase. This criteria left it very unclear as to how long a participant actually had to reach their 80% goal. It is recommended that the criteria for progression between phases not exceed eight sessions per phase. This would provide enough time to identify any potential growth in achievement while placing some constraints on the study so that the study does not continue for months waiting for a participant to reach three stable scores of 80%.

The current criteria, however, was not followed for Student 4, who may have been able to reach the goal of three stable scores of 80% or higher during the i-Ready™ phase. Data collection for this phase ended after the participant received three stable scores of
60% instead of 80%. Based upon his progress, he may have been able to show additional improvement if he continued with additional sessions within the phase. Since Student 4 did show remarkable growth with the i-Ready™ instruction, even though he was not given enough time to reach the 80% goal, it is recommended that he continue using the virtual program for instruction.

**Conclusion**

The concurrent, multiple baseline design used in this study allowed the collected data of multiple participants’ exposure to the skill of partitioning shapes during several phases of the study to be viewed over several sessions and easily allowed for the comparison of data with and without the intervention for each participant. Data showed that the i-Ready™ program was successful in improving the foundational math skills of participants, as well as improving their motivation and engagement, however, the didactic instruction was also successful for some students who did not need to be addition measure to support their focus on instruction in order to learn. Future research, however, should be conducted on a larger more diverse study group that represents a true sample of the student population, as well as on multiple standards to determine the effectiveness of the i-Ready™ program across multiple mathematic concepts prior to purchasing and implementing the i-Ready™ program school wide. In order to address any issues with generalizing skill sets, research should also be conducted on whether programmed generalization strategies and using a train sufficient exemplar strategy improve performance on measuring the area of irregular shapes using unit squares.
References


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Appendix A

Needs Assessment Interview Questions for Students with ASD

1. Does your teacher use examples (3 or more) of the problems in math class?
2. Do the problems in your classwork look like the examples you went over as a class?
3. How do you feel when you complete classwork that has problems similar to the examples? Do you like it? Why or why not?
4. How do you feel about trying new problems that aren’t exactly like the examples?
5. Do you have to complete classwork with one or more other students?
6. When you have classwork to complete, do you like to work alone or with other students?
7. How do you feel about working the problems together with other classmates in a group?
8. Do you like math project and activities? If so, what about them do you like? If not, why not?
9. Do you use manipulatives to solve problems? How do you feel about using the manipulatives?
10. Does the teacher have competitions or races between students? What do you think about having races in math class? How do they make you feel?
11. If there are races, are there prizes? How does having a prize make you feel about the competition?
## Appendix B

**Study Design - Phase Progression**

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ST – Student Number  
BL - Baseline Phase  
D - Didactic Instruction Phase  
I – i-Ready™ Instruction Phase  
G – Generalization Phase
Appendix C

QUIZ EXAMPLE (Baseline, Didactic and i-Ready Phase)

INSTRUCTIONS: Fill the rectangles with unit square tiles based on the given lengths and widths of each rectangle. Determine the total number of squares in all.

1) Total squares: ______

2) Total squares: ______

3) Total squares: ______

4) Total squares: ______

5) Total squares: ______
Appendix D

QUIZ EXAMPLE (Generalization Phase)

INSTRUCTIONS: Fill the shapes with unit square tiles based on the given lengths and widths of each rectangle. Determine the total number of squares in all.

1) Total squares: ______

2) Total squares: ______

3) Total squares: ______

4) Total squares: ______

5) Total squares: ______
Appendix E

Questionnaire

To what extent do you agree or disagree with the following statements:

1. I enjoyed using the i-Ready program to learn.
   - Strongly Agree
   - Agree
   - Undecided
   - Disagree
   - Strongly Disagree

2. I remained focused during the i-Ready lesson.
   - Strongly Agree
   - Agree
   - Undecided
   - Disagree
   - Strongly Disagree

3. Overall, the i-Ready lessons prepared me for my quiz.
   - Strongly Agree
   - Agree
   - Undecided
   - Disagree
   - Strongly Disagree

4. Did you like working with the teacher or the i-Ready program?
   - Teacher
   - i-Ready Program
Appendix F

Graphed Data of Percent of Correct Quiz Responses
### Response to Questionnaire

<table>
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<th>Participant</th>
<th>Enjoyed Using i-Ready™</th>
<th>Helped Maintain Focus</th>
<th>Quiz Preparation</th>
<th>Prefer i-Ready™ over Teacher</th>
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<td>Student 5</td>
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<td><strong>AVERAGE</strong></td>
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<td><strong>4.00</strong></td>
<td><strong>4.33</strong></td>
<td><strong>No</strong></td>
</tr>
</tbody>
</table>

**Strongly Agree = 5**  
**Agree = 4**  
**Undecided = 3**  
**Disagree = 2**  
**Strongly Disagree = 1**
Curriculum Vitae

YOLANDA L. LANGHORNE

717-634-9085 | YLanghorne@yahoo.com
(b) November 28, 1976  Davenport, Iowa

CAREER OVERVIEW

Results-oriented, instructional leader with project management and civil engineering background. Proven track record in improving STEM skills of students including those with learning disabilities. Committed to increasing the foundational mathematical and science competency of students with the use of cutting edge instructional techniques and real world projects.

Areas of Expertise

- Instructional Design
- Online Educational Technology
- STEM Education
- Special Education
- Common Core Standards
- Brain Based Instruction
- Inquiry Based Instruction
- Personal Learning Environments (PLE)
- Data Driven Instructional Modification
- Virtual Instruction
- Project Based Learning (PBL)
- Experiential Learning
- Empirical/Theoretical Research
- 21st Century/Web 2.0 Tools

EDUCATION

Doctor of Education in Technology Integration, Johns Hopkins University, Baltimore, MD 2017

Related Coursework: Trends and Issues in Instructional Design, Message Design, and Online Learning, Instructional Message Design in Online Learning Environments, Instructional Design Theories and Models, Mind, Brain Science and Learning, Instructional Theory in Online Teaching and Learning, Leadership in Educational Organizations, Multiple Perspectives on Learning and Teaching Contemporary Approaches to Educational Problems, Evaluation of Education Policies and Programs, Power, Politics, and Policy in Education

Masters of Science in STEM Education, Johns Hopkins University, Baltimore, MD 2011

Bachelor of Science in Civil Engineer, Morgan State University, Baltimore, MD 1998
RESEARCH EXPERIENCE

Researched the contextual and theoretical foundations for implementing a virtual mathematics program, which strengthens core skills and provides an alternate educational system for students with autism spectrum disorder. Johns Hopkins University School of Education, Baltimore, MD 2013

Researched the social, cultural and political influences of equity and access to Kenyan girls' education and developed a theory of change for the Aga Khan Foundation, government officials and stakeholders use to improve the current conditions of Kwale's educational system. Johns Hopkins University School of Education, Baltimore, MD 2014

Coordinated global research efforts between Johns Hopkins University and the Aga Khan Foundation (NGO) to support the analysis and improvement of girls’ education in Kwale, Kenya. Johns Hopkins University School of Education, Baltimore, MD 2014

LEADERSHIP & MANAGEMENT EXPERIENCE

• Project Management with 8 years civil engineering experience for consulting firms.
• Coordinate and monitor design efforts between local and governmental agencies and sub-consultants.
• Lead and direct task managers to develop project designs within budget, schedule and project constraints.
• Monitor project coordination and design efforts among task managers and county agencies.
• Manage proposal preparation, contract bidding, permit acquisition and status report documentation.
• Train new hires and junior staff on design software.

RELATED EXPERIENCE

Math Department Chair for the Autism Center, The Children’s Guild, Chillum, MD Aug 2014 – Present
Transformed the Math Department into a technology-enhanced educational environment for high school students, resulting in an academic growth in math competency of 1 to 2 years in students.
• Develop and implement life skills and finance curriculums for diploma track students with Autism Spectrum Disorder (ASD).
• Receive high evaluation marks for creative instruction, engaging lesson planning and technological implementation.
• Train and mentor department members on professional growth opportunities, current trends in pedagogy and technology.
• Lead professional development sessions on technology integration and pedagogy.
- Maintain an accurate inventory of materials and order supplies necessary to support instruction.
- Expand current curriculum and adapt it to meet students’ needs while adhering to Common Core Standards.
- Modify all high school IEPs and attended all IEP meetings.

Adjunct Mathematics Professor, University of Phoenix, Columbia, MD Apr 2014 – Present
Provide college level mathematics instruction to a cadre of adult learners as part of their general math education requirements (hybrid courses).
- Serve as the Lead Discrete Mathematics instructor and ranked as one of the top 5 math professors by students.
- Develop and manage syllabus materials relative to learning objectives.
- Facilitate class instruction in accordance with course goals and objectives.
- Evaluate student performance and monitor progress through student data tracking.
- Course instruction: MTH 208 College Algebra I, MTH 209 College Algebra 2, MTH 210 Discrete Mathematics

Mathematics & Physics Instructor, Prince George’s County Public Schools, Upper Marlboro, MD Aug 2012 – Jul 2014
Math and science instruction to high school-aged students within a public school system. Devised alternate approaches to present lessons that increased student understanding. Implemented several project based learning techniques to provide students with alternate strategies for academic growth.
- Courses Taught: Data Analysis, Algebra I, Geometry and Physics.
- Provided (in) formal counseling/mentoring to students.
- Implemented Project Based Learning (PBL) techniques.
- Collaborated with special educators and staff learning specialists.
- Tracked student data and designed individualized student data tracking measures.
- Developed individual learning plans (ILP) students and differentiated instruction for IEPs.
- Designed hands-on mathematical investigations that incorporated real life contexts.
- Incorporated virtual instruction, I-pads/tablets, SMART boards, TI-85 calculators, 21st Century / Web 2.0 tools.

High School Instructor for STEM AP Computer Integrated Mechanical Engineering course, which modeled and analyzed assembly and manufacturing processes.
- Certified Project Lead the Way (PLTW) engineering instructor.
- Integrated Autodesk CAD instruction with robotics and automation to design factory cells.
• Incorporated manufacturing strategies and philosophies in lessons to maximize manufacturing system’s efficiency.
• Instructor for both G & M coding and CAM numerical coding for CNC machinery.
• Wrote grants for STEM projects and assisted in the program certification.

Mathematics Instructor, Baltimore City Public School System, Baltimore, MD Jun 2007 - Apr 2012
Designed and implemented curriculum for Algebra II, Advanced Math and AP Probability and Statistics classes.
• Utilized inquiry based learning, cooperative education, differentiated instruction, experiential and discovery learning.
• Implemented cross-curricular lesson plans and real world projects.
• Modified instruction based on individual learning plans (ILP) for each student.

PREVIOUS EXPERIENCE

Project Manager, Civil Engineering, Baltimore, MD Mar 1999 - Jun 2007
Served as lead water resources engineer on several engineering projects including design-build and retrofit project.
• Coordinated design efforts governmental agencies and sub-consultants, design teams and subcontractors.
• Monitored project coordination amongst task managers and county agencies.
• Directed and trained junior engineers on efficient design methods that maintained budget, schedule and project constraints.
• Prepared cost estimates, progress reports, and contract bidding/permit documents.
• Conducted floodplain studies, produced stormwater management and drainage reports and experienced in both SWM and E&S permit acquisition.
• Performed hydrologic and hydraulic analysis.

PROFESSIONAL DEVELOPMENT PRESENTATIONS

Maximizing Technology Use in the Classroom
Technology Integration: Apps for Instruction
Virtual Math Manipulatives
Smartboard 101
Classroom Management with PBIS