EFFECTS OF DIRECT INSTRUCTION ON ACQUISITION OF EARLY ELEMENTARY MATHEMATICAL VOCABULARY BY STUDENTS WITH AUTISM

by

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ABSTRACT

DAWN ROBIN PATTERSON. Effects of direct Instruction on acquisition of early elementary Mathematical vocabulary by students with autism. (Under the direction of LYNN AHLGRIM-DELZELL)

Education in American schools is driven by the No Child Left Behind Act (2001) with the Individuals with Disabilities Education Improvement Act (2004) ensuring that educators provide students with disabilities a grade-aligned education. Recently, the Common Core State Standards (CCSS) have been adopted as a way to provide consistency of content for students across the U. S. One priority component established in the CCSS is for vocabulary instruction to occur across content areas. Understanding effective methods for teaching mathematical vocabulary to all students is needed, especially students with severe disabilities. Research has identified Direct Instruction (DI) effective for teaching students with severe disabilities components of literacy; however, no research exists on how to teach mathematics vocabulary to young students with autism. The purpose of this research was to determine if DI is an effective method for teaching early elementary mathematical vocabulary to students with autism. Results indicated that DI shows promise with students possessing prerequisite skills and learning behaviors, such as attention and engagement, when introducing new information. However, some students continue to require explicit, systematic instruction in a one-to-one format to make progress with novel skills. Information gained from this research suggests that DI in small group may be effective during maintenance and generalization for young students with autism. Additionally, when teaching new skills to students with autism, it is necessary to begin at their current level of communication.

DEDICATION

This dissertation is dedicated to my entire family and many friends. The endless encouragement and patience I received from all of you have made this possible. Knowing that all of you understood my passion for this helped me better accept the many sacrifices I made. Most importantly, thank you Rhonda, for living this with me. I could have never taken the first step if it were not for your encouragement, nor finished without your undying support. My sister Diane, thank you for being my cheerleader. Andrew, thank you for sharing yourself with me for the past 20 years and remaining my constant inspiration, and Linda, thank you for believing in me and trusting me to guide your son through his life. My friend, Christy, this journey brought us together and for that I will always be thankful. My nieces and nephews, move forward confidently and don't let anyone else ever set your limitations. Finally, my sister, Tracey, I felt you there beside me every step of the way and my mom, without your unconditional love and the freedom to be happy, I would have never succeeded; I know you are both squeezing me tightly.

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CHAPTER 1: INTRODUCTION

Educational reforms have intended to develop the quality of education to meet the needs of the diverse student populations in K-12 public schools (Borkowski & Sneed, 2006; Wetherill & Applefield, 2005). Since the first public education school was established in 1635, and the instatement of compulsory education in 1642 for the New England colonies, the goal of education has been to teach students to read and write, and to prepare them to be self-sufficient adults (Bowles & Gintis, 2011). For centuries, this was the guiding force for the general student population; those that were capable of learning using common teaching practices. Students that required atypical or specialized instruction to learn were often omitted from the compulsory schooling already established. Students who could not acquire the information using standard procedures were determined to be unteachable. Not until 1975, with the passing of PL 94-142, the Education of All Handicapped Children Act, were individuals with disabilities included in the educational rights arena. With this ground-breaking legislation, all children were now eligible for a free and appropriate education in American classrooms. As the needs of American culture changed, so did the educational requirements from local, state and federal agencies. Currently, the No Child Left Behind Act (NCLB, 2001) serves as the overriding legislation for educating all children in American schools with the Individuals with Disabilities Education Improvement Act (IDEIA, 2004), which outlines the additional requirements for students with disabilities.

In 2001, NCLB established that all children, including those with disabilities were to receive an equitable education measured by annual achievement standards. Aligning with these mandates, the reauthorizations of the original special education law, PL 94-142 (i.e., the Individuals with Disability Education Act; IDEA 1997, IDEIA, 2004) mandated that all students with disabilities, including those with moderate-to-severe disabilities, have access to the general education curriculum (Browder, Wakeman, Flowers, Rickelman, Pugalee, & Karvonen, 2007) giving these students an equitable education as their general education peers. The two laws mandate that state departments of education and school systems provide this subset of students an academically-based, age-appropriate, education from highly qualified teachers (Wakeman, Browder, Meier, & McColl, 2007). This set the stage for a new framework for teaching students with developmental disabilities, including those with autism. In the past, educators of students with disabilities have focused on developmentally appropriate academic and/or functional life skills for these students as their core curriculum. Now it is necessary for educators to learn how to adapt the breadth and depth of information without compromising the content necessary to receive passing scores on annual state assessments.

In decades past, teachers in general education classrooms have been provided with specialized curricula that address the critical information to teach their students and guide them through content. Special education teachers have not had this luxury. They have had to sort through grade-level curricula to identify and adapt priority elements in order to develop individualized lesson plans for students of multiple grade levels.

Understanding how to make the requirements of NCLB (2001) fit into the demands of special education has been the result of extensive research (e.g., Browder, Gibbs, Ahlgrim-Delzell, Courtade, Mraz, & Flowers, 2009; Collins, Evans, Creech-Galloway, Karl, & Miller, 2007; Jimenez, Browder, Spooner, & DiBiase, 2012; Lemons, & Fuchs, 2010; McDonnell, Johnson, Polychronis, & Risen, 2002) and scholarly writing (e.g., Browder & Cooper-Duffy, 2003; Browder, Flowers, Ahlgrim-Delzell, Karvonen, Spooner, & Algozzine, 2004; Browder, Spooner, Wakeman, Trela, & Baker, 2006; Flowers, Wakeman, Browder, & Karvonen, 2009). Knowing what and how to teach students with developmental disabilities has lead to the development of a few quality curricula over the past decade such as: *Early Science Curriculum* (Jimenez, Knight, & Browder, 2012), *Early Numeracy Curriculum* (Jimenez, Saunders, & Browder, 2013), *Edmark Reading Print* (Austin & Boekmond, 1990), *Accessible Literacy Learning Reading Program* (Light & McNaughton, 2008), The *Early Literacy Skills Builder* (Browder, Gibbs, Ahlgrim-Delzell, Courtade, & Lee, 2007). Each of these curricula provide special education teachers with the information and framework on how to teach grade-level academic content to students with developmental disabilities, while focusing on the content centrality of the concepts. Although this is an exceptional step forward for special education teachers, much research is still required. It is evident that there is a continuous need to know what and how to teach students with developmental disabilities.

The above-mentioned curriculum is an initial contribution by scholars to meet the demands of educational reform for students with developmental disabilities. Chiefly, the foundation for each of the curriculum is based on research verifying effective practices for students with developmental disabilities. As researchers continue to better understand the effectiveness of these tools and the focus of legislation, revisions to the curricula will be necessary. For example, the recent adoption of the national Common Core State Standards (CCSS) may require revised editions of previously published curricula.

The CCSS are the most recent attempt to provide a more uniform education nationally, for all students, including those with developmental disabilities by providing consistency of content for a mobile America. As the needs of society change and as advancements in education occur, policies are continually amended. From the onset of public education, scholars have pursued effective learning practices and developed curricula for students in an attempt to meet the demands of society and educational regulations set forth by the federal government.

Despite the fact that the education of students is placed in the hands of state and local educational agencies, the federal government continues to institute the laws pertaining to educational standards for students. As mentioned above, two of the most recent critical regulations impacting students with disabilities are NCLB (2001) and IDEIA (2004). The overlying components of NCLB (2001) indicate that students with disabilities (a) be included in accountability standards, (b) by making adequate yearly progress, (c) on year-end standardized assessments for students in grades three through eight and at least one assessment year in grades 10 through 12, and (d) with the use of evidence-based practices (Browder & Cooper-Duffy, 2003). These components of NCLB were then followed up with the alignment of IDEIA (2004) by providing students with disabilities (a) access to the grade-level standards, (b) in the least restrictive environment, (c) with year-end testing consisting of modified or alternative assessments (Wakeman, Browder, Meier, & McColl, 2007); therefore, establishing compliance with legislation. It has taken nearly a decade of research to understand how to integrate these two laws into educational practices for students with developmental disabilities (Browder, Gibbs, Ahlgrim-Delzell, Courtade, Mraz, & Flowers, 2009; Collins, Evans, Creech-Galloway, Karl, & Miller, 2007; Jimenez, Browder, Spooner, & DiBiase, 2012; McDonnell, Johnson, Polychronis, & Risen, 2002).

As the federal government strives to improve the quality of education to meet the needs of all students, these educational reforms perpetuate the need for ongoing research to close the gaps leading to effective educational practices. The CCSS are a set of national objectives clearly communicating student expectations at each grade level. In the past, each state determined priority components to guide instruction of students at each grade level and therefore established their own set of grade-level content standards. In an effort to (a) provide consistency of education across state lines, (b) integrate concepts across content areas, and (c) identify the most critical skills and knowledge required for students to be prepared for post school outcomes, a group of stakeholders developed the CCSS in English language arts and mathematics (Wasiams, 2012).

With the recent adoption of CCSS by 45 states and three U. S. territories (i.e., American Samoa Islands, October 2012; Common Core Standard Initiatives [CCSI], 2012) students across the U. S. are currently affected by the changes in grade-level content standards, including those with developmental disabilities. One critical change has been the process of embedding literacy into all content areas, primarily vocabulary development and comprehension. The CCSS now indicate that educators provide adequate instruction to ensure that students have a clear understanding of core content vocabulary and can demonstrate comprehension of that vocabulary by reading, writing, speaking and using the language (National Governors Association Center for Best

Practices, NGACBP, Council of Chief State School Officers, CCSSO, 2010). One example of this is the very specific vocabulary used in mathematics; traditionally, students were taught how to execute the skills of mathematical terms. Now all students are required to have a clear understanding of this vocabulary by reading, writing, speaking, and using the language. This practice continues to meet the demands of previous legislation (i.e., NCLB, 2001, IDEIA, 2004) informing state departments of education that all students, including students with developmental disabilities are entitled to an equitable education, aligned to grade-level standards.

Prior to the adoption of the CCSS, preliminary research was conducted to determine if students with developmental disabilities could learn grade level material using various systematic instructional procedures. Some of these included system of least prompts for literacy components (Browder, Lee, & Mims, 2011; Mims, Browder, Baker, Lee, & Spooner, 2009; Minoravic & Bambara, 2007; Spooner, Rivera, Browder, Baker, & Salas, 2009), constant time delay for literacy (Alig-Cybriwsky, Wolery, & Gast, 1990; Mechling, Gast, & Krupa, 2007), science (Jimenez, Browder, Spooner, & DiBiase, 2012;), social studies (Head, Collins, Schuster, & Ault, 2011; Johnson, McDonnell, Holzwarth, & Hunter, 2004; Ross & Stevens, 2003), and mathematics (Frederick-Dugan, Test, & Varn, 1991; McDonnell, 1987). Another method of systematic instruction that has received little attention in the field of developmental disabilities is Direct Instruction (DI). Research on using DI has been focused on employing specifically designed English language arts Direct Instruction curriculum (i.e., *Reading Mastery* [Engelmann & Bruner, 1995]; *Corrective Reading* [Engelmann, Haddox, Osborn, & Hanner, 1998]; *Language for Learning* [Engelmann & Osborn, 1999]) with students with developmental disabilities

(Allor, Mathes, Roberts, Jones, & Champlin, 2010; Flores, Shippen, Alberto, & Crowe, 2004; Gersten & Maggs, 1982; Maggs & Morath, 1976; Riepl, Marchand-Martella, & Martella, 2008). Furthermore, scant research is available using DI as an instructional method for teaching students with developmental disabilities discrete components of literacy such as prepositions (Hicks, Bethune, Wood, Cook, & Mims, 2011) or other core content material such as science (Knight, Smith, Spooner, & Browder, 2011). This research provides that DI is an effective method for teaching literacy through the use of a designated curriculum, teaching discrete components of literacy, and science concepts; however, there is no available research identifying DI as an effective method for teaching mathematics to young students with autism. With mathematics as one of the core content areas of instruction and one of the two academic contents measuring annual yearly progress, there is an urgent need to determine effective procedures for teaching grade-level mathematical vocabulary to students with severe disabilities including those with autism. In an effort to combine the most recent legislation, including the adoption of the CCSS and the importance of vocabulary development, it is necessary to extend investigations exploring the use of DI to teach mathematical vocabulary. Therefore, it is important to understand how this most recent educational reform can be implemented in special education classrooms across the U. S. It is necessary for researchers to set the groundwork to continue to close the research-to-practice gap.

The primary purpose of this study is to determine to what extent early elementary (i.e., kindergarten to second grade) students with autism can learn core content vocabulary through the use of DI. Limited research currently exists on using DI to teach core content vocabulary to students with autism (Knight, Smith, Spooner, & Browder, 2012); however, DI has been validated as an effective method for teaching students with autism vocabulary as a component of literacy development (Allor, Mathes, Roberts, Jones, & Champlin, 2010; Flores & Ganz, 2009).

The current study will extend and build upon previous research by using DI to teach core content mathematical vocabulary to students with autism. The following research questions drive the investigation:

1. What are the effects of Direct Instruction on the reading of core content mathematical vocabulary on early elementary students with autism?
2. What are the effects of Direct Instruction on the maintenance of acquired mathematical vocabulary on early elementary students with autism?
3. What are the effects of Direct Instruction on the generalization of acquired mathematical vocabulary on early elementary students with autism?
4. To what extent do teachers and parents feel instruction in mathematical vocabulary has benefitted student learning?

Delimitations

This study examined the effects of using DI to teach early elementary students with autism mathematical vocabulary through the use of a single-case research design. There are several delimitations to this investigation that define critical features of this investigation. First, this investigation was conducted with three students and one researcher. The nature of single-case research lends itself to a small number of participants and therefore limits the generalizability of the results to the population of students with autism (Gast, 2010). Second, the participants in the study represent a very small sample of students with autism; therefore, extending the results to students with other disabilities should be done with caution. Third, the participant group is comprised of early elementary (i.e., kindergarten to second grade) students. Fourth, the investigation took place in a separate room within an elementary school located in one of the largest urban school systems in the southeastern U. S. Finally, the researcher served as the interventionist, so it is impractical to determine the extent to which a typical teacher would obtain the same results.

Definition of Terms

For the purposes of this investigation the following terms are defined. These terms are generally consistent with those used in special education research related to providing students with severe disabilities a free and appropriate education as determined by federal mandates.

Autism: A developmental disability, apparent before the age of three, characterized by uneven development in social interactions, and communication, including behaviors that are stereotypical and repetitive often restricting learning (Center for Disease Control and Prevention, 2008).

Common Core State Standards: A collection of the essential skills that all students in the 45 participating states need to know in preparation of career and college readiness (NGACBP, CCSSO, 2010).

Developmental Disability: "A severe, chronic disability which is attributable to a mental and/or physical impairment, is manifested before the person attains age 22; is likely to continue indefinitely; results in substantial functional limitations in three or more of the following areas of major life activity: self-care, receptive and expressive language, learning, mobility, self-direction, capacity for independent living and economic self-sufficiency; and reflects the persons need for special services that are lifelong or extended duration and are individually planned and coordinated" (Handlemann, 1986, p. 153).

Direct Instruction: A model for teaching that uses explicit, sequenced, and scripted instruction developed by Siegfried Engelmann and Wesley Becker. The model of Direct Instruction (DI) used in the investigation is based upon the instructional design principles developed by Siegfried Engelmann and Douglas Carnine (Engelmann & Carnine, 1991; Marchand-Martella, Slocum, & Martella, 2004).

Explicit Instruction: "involves carefully designed materials and activities that provide structures and supports that enable all students to make sense of new information and concepts" (Heward, 2006, p. 198).

Literacy: An understanding of words and concepts that comes from an integration of the written, oral, and spoken language (Vacca, J., Vacca, R., Gove, M., Burkey, L., Lenhart, L., & Mckeon, C., 2006).

Low-incidence Disabilities: A group of individuals with disabilities that represents less than one percent of the population. Individuals with moderate, severe, and profound disabilities are grouped within this term. Also included are those with autism, and multiple disabilities (i.e., physical disabilities, severe behavior disorders, sensory impairments; Collins, 2007).

High-Incidence Disabilities: A large group of individuals with mild disabilities who are capable of receiving their education with minimal support. The majority of these students require accommodations and adaptations while focusing on grade level academics to attain a high school diploma (Collins, 2007).

Model-Lead-Test: A teaching format in which "…the teacher first demonstrates how to do the new skill so that the students have no difficulty understanding exactly what the new skill looks like" (i.e., model). Then, "the teacher practices the skill with his or her students until they are able to do it without him or her" (i.e., lead). Lastly, "the teacher monitors students as they do the skill independently" (i.e., test, Bursuck & Damer, 2007, p. 16).

Model-Test-Independent test: A teaching format in which the teacher designs all instances of the routine to follow the same set of steps (Carnine, 1980). Initially the teacher provides the students with a verbal model of the response (i.e., model). Then the teacher observes as the students respond chorally (i.e., test). Lastly, the teacher checks the response of each individual student (i.e., independent test).

Read: "To look at and understand the meaning of letters, words, symbols, etc.; to read words of (a book, magazine, etc.); to speak aloud the words of (something written)" (Merriam-Webster, 2014). To verbally identify the word followed by touching the image that represents the word.

Severe Disabilities: Students who are significantly challenged in general learning ability, including personal and social skills, exhibit uncommon behavior characteristics, and require assistance and ongoing support from individuals without disabilities. The use of the general term of severe disability refers to categories of individuals that include those students diagnosed with moderate, severe, and profound intellectual disabilities (IQ ≤ 55), autism spectrum disorders, and multiple physical or sensory disabilities with an onset prior to age 18 (Westling & Fox 2009).

Systematic Instruction: An extremely organized, structured, and consistent form of instruction designed to utilize error manipulation, response prompting, stimulus modification, and reinforcement strategies to teach chained or discrete responses to individuals (Collins, 2007; Snell, 1983).

Vocabulary: Knowledge of words and word meanings both orally and in print (National Reading Panel, NRP 2000).

CHAPTER 2: REVIEW OF LITERATURE

Overview

The literature review for this chapter examines factors that are most important to the development of mathematical vocabulary for students with autism. This chapter reviews the relevant literature on professional and content standards, Direct Instruction, vocabulary, and autism. Together these tenets are the foundation of the current intervention which served as a practice for teaching mathematical vocabulary to students with autism. The chapter concludes with a summary of the literature to support the contributions of Direct Instruction to the field of special education.

Professional and Content Standards

Teaching has become an increasingly more complicated profession. To meet the demands of today's diverse student population, in 2008, the Interstate Teacher Assessment and Support Consortium (InSTAC) revised the professional and content teaching standards to reflect the expectations of teachers at all levels, from novice to accomplished. These new standards were developed to meet the needs of today's learners with a focus on cross disciplinary skills that include problem-solving, critical thinking, creativity, and communication. The recently established standards concentrate on the accountability and infrastructure necessary to build and support the new vision of teaching. A group of stakeholders including teachers, teacher educators, researchers and state policy makers developed the new standards to align with other national and state documents. The InSTAC model standards are compatible with the recently released Common Core State Standards (CCSS) for students in mathematics and English language arts (ELA), National Board for Professional Teaching Standards, National Council for Accreditation of Teacher Education, National Staff Development Council, and Interstate School Leader License Consortium (Franz, Hopper, & Kritsonis, 2007). This integrated approach provides consistency of information for education professionals at all levels.

Ten professional standards have been grouped into four general teaching standards including (a) the learner and learning, (b) content, (c) instructional practice, and (d) professional responsibility. The overriding message emphasizes that learning the targeted information begins with the learner and learning focuses on learner development, learning differences, and learning development to determine if the instruction has been effective. Content focuses on subject matter knowledge and application of the information. Instructional practice requires that teachers understand and integrate assessment, planning for instruction, and instructional strategies. The professional responsibility category includes professional learning and ethical practices and leadership and collaboration (CCSSO, 2011).

The revised standards have a strong emphasis on integration of concepts across content areas and collaboration among professionals. There is a need to embed literacy into all content areas and to diversify instructional procedures to meet the needs of all learners. Educators are directed to focus on individual needs while advancing learner knowledge. This current framework sets the standard for all learning in schools.

Common Core State Standards

The CCSS provide education agencies with a unified scope and sequence to English language arts and mathematical content. They are aligned to international benchmarks with a consistent, clear understanding of what students are expected to learn. This national framework of specific grade-level objectives was developed to ensure that today's students receive a quality education with real world application to ensure that progress is made to succeed in college and the workforce (NGACBP, CCSSO, 2010). Although the CCSS are available in all fundamental content areas (i.e., ELA, mathematics, science, social studies) federal regulations have set ELA and mathematics as the priority areas of study for third through eighth grades as dictated by achievement testing regulated by NCLB (2002).

English language arts standards are divided into four strands (a) reading, (b) writing, (c) speaking and listening, and (d) language (NGACBP, CCSSO, 2010). Within each of these strands it is evident that a strong foundation in ELA leads to success across all content areas; therefore, it is necessary to not only be able to read and to understand the concepts presented (NRP, 2000) but to also understand the terminology and vocabulary specific to the content (Knight, Smith, Spooner, & Browder, 2012; Simmons, et al., 2010; Taboada, Bianco, & Bowerman, 2012). Vocabulary is one component within the language strand; however, vocabulary development extends across all four strands and is inseparable from learning (NGACBP, CCSSO, 2010). Vocabulary development is a critical indicator in the disparity of academic achievement (Baumann & Kame'enui, 1991; Becker, 1977; Stanovich, 1986) therefore signifying a need for purposeful and ongoing attention to vocabulary (Hayes & Ahrens, 1988). Making progress in vocabulary must include relevant context and flexible use (NGACBP, CCSSO, 2010).

Students build vocabulary by hearing, seeing, and reading words which can be learned through either informal or formal instruction. Words can therefore be divided into three tiers of word models (Beck, McKeown, & Kucan, 2008); word levels are dependent upon common usage. Tier one words are those used in everyday conversation and do not require formal instruction such as happy and car; children learn these within daily interactions and conversations with others. Tier two words are general academic words that require formal instruction. Tier two word instruction includes an understanding of root words and the use of context clues; these words are those used by mature language users and those found in written text (e.g. persevere, eloquent). Tier three words are particularly content specific and necessary for understanding new concepts such as biology or geometry. These words require formal instruction within the particular subject matter with opportunities to maintain and generalize the usage within conversations. Examples of tier three words include osmosis within the context of biology and transversal within the context of geometry. Using vocabulary specific to a particular topic or content area has been identified as domain-specific words (Beck, McKeown, & Kucan, 2002; 2008). By providing instruction with tier two and tier three vocabulary, a bridge between ELA and other content areas, such as mathematics, can be established. For students with severe disabilities, the foci for vocabulary instruction typically targets tier one words, those words that have functional application and are used regularly (Leaf, Sheldon, & Sherman, 2010; Taylor, DeQuizno, & Stein, 2012) examples of these include dog, sock, star, bike. Students with severe disabilities often learn nouns or words with concrete referents such as saddle, pickle, carrot (Dittlinger & Lerman, 2011). This study will focus on teaching tier two and tier three vocabulary.

In addition to the intense focus on CCSS in ELA, the NGACBP, CCSSO (2010) have identified that CCSS in mathematics must be coherent and succinct to eliminate "a mile wide and an inch deep" philosophy. With fewer standards, the CCSS focuses on the processes and proficiencies in mathematics education outlined by the National Council of Teachers of Mathematics (NCTM) and supported by the National Research Council's (NRC) mathematical proficiencies (NRC, 2001a). The initial focus, especially for elementary students, is the process; to connect the standards for mathematical practices to the standards for mathematical content (NGACBP, CCSSO, 2010). Before the students can begin to understand the content they need to recognize the (a) need to solve the problem, (b) understand the vocabulary involved, (c) rationalize the information provided and provide proof of understanding, and (d) equate the concept to real world applications. If these procedures are weak, students may resort to rote application of procedures limiting their ability to generalize concepts and practices; therefore, impeding mathematical achievement.

Mathematics

Teaching mathematics is a fundamental component of education and is considered "one of the oldest and most continuously pursued of the exact sciences" (Burton, 1997, p. 31). The focus of mathematics has evolved over the past 5000 years, from notched wolf bone, through Medieval and Renaissance periods, to the modern period emphasizing the need for computation and problem-solving (Burton, 1977). This pursuit of mathematics instruction led mathematical reform into the 21st century. When Sputnik launched in 1957 much controversy of mathematical education in the United States arose, resulting in the need for reform. Additionally, *A Nation at Risk* (1983) further criticized the state of

American education, which in turn resulted in the need for further improvement (Hofmeister, 2004). Both post Sputnik and *A Nation at Risk* attempts at transformation were merely reactive and did not produce a comprehensive analysis of the revisions that needed to be made in mathematical education. In 1989, the National Council for Teachers of Mathematics released *Curriculum and Evaluation Standards for School Mathematics* resulting in a substantial change to mathematical curriculum in schools (Dossey, Halvorsen, & McCrone, 2012).

National Council of Teachers of Mathematics. The National Council for Teachers Mathematics (NCTM) is a professional organization established in 1920 and has become the world's largest organization dedicated to mathematics education (NCTM, 2013). Since its inception, the NCTM has undergone many revisions to its framework. In 1944, the organization established a more formal framework for math education with a focus on algebraic concepts. Grades one through six were identified as the critical math learning years; a more systematic format replaced informal teaching methods. At this time, many of today's standards, (a) number and computation, (b) geometry in everyday life, (c) graphic representations, and (d) introduction of essential elementary algebra were introduced (NCTM, 2013).

In 1989, constructivist influences led to an emphasis on problem solving, which replaced the focus on direct instruction and rote learning with exploration and understanding (Hekimoglu & Sloan, 2005). The algebraic focus remained constant with a concentration on patterns and the cumulative property in the early elementary grades. At this time high standards were established for all students to meet, where closing the achievement gap became a priority through outcome-based education. The *Standards* provided a framework for math educators and soon became the basis for many math curricula. At this point the introduction of mathematics communication was initially emphasized and continued to be addressed in the subsequent revisions, including the revision in 2000 (Hekimoglu & Sloan, 2005).

The *Principles and Standards for School Mathematics* (NCTM, 2000) provided further clarity and balance; these revisions replaced all previous publications and remain in existence today. The new *Standards* were organized around six principles (i.e., equity, curriculum, teaching, learning, assessment, technology) within the following five content areas (a) numbers and operations, (b) algebra, (c) geometry, (d) measurement, and (e) data analysis and probability. This refinement improved educators understanding of the priority components of teaching mathematics to early elementary students and has served as the basis for mathematics curricula. In addition, NCTM, through collaboration with mathematicians, researchers and teachers, included five processes necessary for a comprehensive understanding of mathematics including (a) problem solving, (b) reasoning and proof, (c) communication, (d) connections, and (e) representations. Learning mathematics was no longer limited to solving an equation. Mathematics was now a process of making connections to the real world and understanding the vocabulary involved (NCTM, 2013).

Through the years NCTM has continued to develop priority components to enhance the learning of students. Most recently, NCTM developed more specific links between curriculum and anticipated outcomes by adding *Curriculum Focal Points for Prekindergarten through Grade 8 Mathematics: A Quest for Coherence* (Dossey, Halvorsen, & McCrone, 2012). Prior to this point the breadth of mathematics was extensive, with little depth. Now educators have a clear understanding of the priority concepts for each grade level while ensuring cohesiveness through the grade-level advancements. The goal is for students to establish a meaningful foundation, life-long proficiency and the desire to practice and apply mathematics to daily life. The NCTM emphasizes the critical need for including the processes (i.e., communication, reasoning, representation, connections, and problem-solving) throughout *Curriculum Focal Points*. The current revision emphasizes reform-based mathematics where students are responsible for their own learning by developing reasoning, learning problem-solving, and making connections. Conversely, more traditional, explicit teaching systematically directs students through the learning processes to build on previously attained skills (Hudson, Miller, & Butler, 2006). Developing mathematical vocabulary is an integral element for students to expand and understand their math knowledge.

Reviewing the revisions of the 2000 NCTM standards and the guidelines of the CCSS, there is an overlap between the two; where NCTM has highlighted the need for students to communicate about mathematics and the CCSS ensures that instruction in content vocabulary is embedded into lesson planning. In an effort to understand effective methods for incorporating these elements into math instruction, recent research has investigated the use of mathematical literacy (Capraro & Capraro, 2006), journaling (Kostos & Shin, 2010; Lim & Pugalee, 2004), and specifically designed curriculum using Direct Instruction procedures (Chard, Baker, Clarke, Jungjohann, Davis, & Smolkoski, 2008) for regular classroom implementation.

Math Vocabulary for Typically Developing Students

Scant research has been conducted on mathematical vocabulary for typically developing students. Incorporating vocabulary instruction into mathematical lessons is an undeveloped area of research and little is known about the effects vocabulary instruction has on attaining math concepts. The majority of research conducted on the topic is qualitative in nature, with some investigations combining descriptive statistics with qualitative themes. In a mixed-method investigation employing a single group pre-, posttest design, Capraro and Capraro (2006) used a mathematical storybook reading as a warm-up and closure activity to a geometry lesson. Using statistical analysis from pre- and posttesting and qualitative analysis from 105 sixth grade student communications, students in the experimental group who received the warm-up and closure activities outperformed the control group. The experimental group gained a better understanding of the geometrical vocabulary through the characterization of the terms, therefore, establishing an increased foundation for correct responses to test questions. In this study, the warm-up and closure storybook reading gave students an opportunity to have informal discussion about the characters (i.e., Geo of Metry, Lady Di of Ameter) and their task in the story, which assisted with vocabulary acquisition.

Another opportunity for students to use mathematical vocabulary in a more directed learning method has been investigated in journaling. In two research studies (Kostos & Shin, 2010; Lim & Pugalee, 2004), embedding vocabulary instruction into mathematics lessons increased students' vocabulary usage, thereby, establishing a better understanding of mathematics. In both studies the authors used qualitative research methods to determine if students would include mathematical vocabulary to explain the problem-solving process required for assigned math equations. In a qualitative study, Lim and Pugalee (2004) provided 12, middle grade students with a rubric and specific instructions on how to complete a journal entry. After receiving narrative feedback on entries, student's use of mathematical vocabulary increased from the first half of the year to the second half of the year based on two work samples selected by individual students. Students indicated that the writing process helped them better understand the content and skill acquisition process. Similarly, Kostos and Shin (2010) conducted a mixed methodstudy that incorporated math journaling into mathematical instruction and a single group pre-, posttest design to improve 16 second grade students' understanding of mathematical concepts. By collecting data from (a) pre and post test, (b) math journals, and (c) teacher-researcher's reflective journal, the team determined the instruction on optimal mathematical communication when responding to math equations, and improved students' mathematical thinking. Comparable to the middle school students, narrative, instructional feedback was given to each student’s journal response. In both investigations, student’s mathematical vocabulary usage increased with journal writing and the students also indicated that journal entries were beneficial to their own self-actualization of skill acquisition.

Another qualitative investigation examined the effects of a researcher-made graphic organizer called the Personal Math Concept Chart, on a group of elementary-aged students. In this study, Friedman, Kazerouni, Lax, and Weisdorf (2011) developed the Personal Math Concept Chart to integrate mathematical vocabulary into geometry lessons. While employing the assigned mathematics curriculum, the four teachers used (a) pre and post written descriptions of geometric shapes, (b) anecdotal student classroom mathematical conversations, and (c) surveys to determine that the Personal Math Concept Chart increased student's use of mathematical vocabulary during conversation with students indicating a favorable response to the graphic organizer.

In contrast to the constructivist-type learning applied to story reading, journaling, and graphic organizers, Chard, Baker, Clarke, Jungjohann, Davis, and Smolkoski (2008) investigated the effectiveness of a newly designed curriculum for kindergarten students, *Early Learning in Mathematics* (*ELM*) program. This explicit curriculum focuses on building number sense while integrating activities to develop mathematical vocabulary. Results of the quasi-experimental investigation indicated the students in the *ELM* program significantly outperformed the control group students on the *Stanford Early School Achievement Test-Fourth Edition* (Harcourt Brace Educational Measurement, 1996). Although this research did not investigate mathematical vocabulary exclusively, the outcomes suggest there is promise that embedding vocabulary instruction into curriculum can be effective in building kindergarten students understanding of mathematics.

Additionally, in a randomized control trial study the *ELM* program was further investigated to determine its effectiveness with kindergarten students identified as at-risk for failure in mathematics (Clarke, Smolkowski, Baker, Fien, Doabler, & Chard, 2011). Results indicated a significant difference in the performance of at-risk students in experimental and control groups, with at-risk students in the explicitly taught *ELM* program outperforming the no-risk, experimental group. Despite the fact that the two *ELM* program studies do not specifically measure gains in vocabulary usage, the studies do provide promise regarding embedded vocabulary during explicit mathematical instruction for kindergarten students.

From this review it is apparent that focusing on mathematical vocabulary instruction for typically developing students is in the early stages of investigation. The limited research available indicates that journal writing, read-alouds, and graphic organizers have a direct impact on the acquisition of mathematical vocabulary for elementary and middle grade students, coupled with the *ELM* program having an indirect influence when vocabulary is embedded into explicit instruction for kindergarten students. Applying mathematical vocabulary into problem-solving, communication, and reasoning demonstrates students' abilities to develop a deeper understanding of mathematical content by using higher level cognitive skills. Journaling gives students a process to analyze and evaluate their learning, whereas graphic organizers assist with building an understanding of vocabulary to therefore apply it in communication. Nevertheless, it is critical, especially at the foundational level, that students are specifically taught mathematical vocabulary in a way that it can be remembered.

The Value of Direct Instruction

Direct Instruction (DI) is an explicit systematic instructional procedure developed to increase student engagement therefore leading to improvements in student achievement (Stein, Carnine, & Dixon, 1998). Through the use of careful program design, organized instruction, and specific student-teacher interactions, DI has successfully incorporated multiple opportunities for students to remain actively involved by responding during lessons (Watkins & Slocum, 2004). By interacting with stimuli such as choral responding to the teacher or pointing to materials, the student is demonstrating engagement (Cooper, Heron, & Heward, 2007). Furthermore, Moore (1986) stated, "Direct Instruction attempts to ensure that what is intended to be learned is learned" (p. 206). The instructional procedures of DI include scripted lessons and students responding in unison through the use of frequent questioning and specific, constructive feedback. Extensive research has been conducted to determine the effectiveness of DI in mathematics (e.g., Kame'enui, Carnine, Darch, & Stein, 1986; McKenzie, Marchand-Martella, Moore, & Martella, 2004) and literacy (e.g., Kamps, Abbott, Greenwood, Wass, Veerkamp, & Kaufman, 2008; Stockard & Engelmann, 2010) through formal curriculum and informal curricula (e.g., Fallon, Light, McNaughton, Drager, & Hammer, 2004; Flores & Ganz, 2009; Ganz & Flores, 2009).

For decades, DI has been the foundation of many educational curricula. In 1968 components of DI were first introduced to the educational arena by Engelmann and Carnine through *Direct Instruction System for Teaching Arithmetic and Reading* (DISTAR; Carnine, Silbert, Kame'enui, & Tarver, 2010). Since the initial presentation of DISTAR, several other curricula have evolved in ELA (e.g., *Reading Mastery*, [Engelmann & Bruner, 1997]; *Journeys*, [Engelmann, Engelmann, & Seitz-Davis, 2000]; *Horizons*, [Engelmann, Engelmann, & Seitz-Davis, 1998]; *Corrective Reading*, [Engelmann, Haddox, Osborn, & Hanner, 1998]; and *Spelling Mastery*, [Dixon, Engelmann, & Meier, 1998]) and mathematics (e.g., *Essential for Algebra*, [Engelmann, Engelmann, & Kelly, 2007]; *Connecting Math Concepts*, [Engelmann & Carnine, 1992]; and *Bridge to Connecting Math Concepts*, [Engelmann, Engelmann, Kelly, & Carnine, 1995]). The primary goals of DI are to provide a cohesive system for gaining and classifying knowledge structures and to link that information to instructional procedures.

DI should include many specific details such as, (a) non-examples along with examples, (b) very clear wording, (c) examples that are most alike with very similar non-examples, (d) progression to incorporate examples that are more different from each other than they are similar, and (e) test with examples that are different from each other. A variation of examples and non-examples fosters the ability for students to generalize the information taught reducing rote memorization. Generalizability is an important factor in DI (Moore, 1986). More specifically, DI provides carefully designed, explicit instruction concentrating on content and explicit, systematic instruction to produce the most efficient learning for students (Watkins & Slocum, 2004).

Direct Instruction and Literacy

With the specific, systematic structure of DI, evidence has demonstrated success in literacy development for students of all ages. Based on the principles of DI, reading curriculum, such as *Reading Mastery* (Engelmann & Bruner, 1995), has been developed to methodically teach components of reading to students. In a recent quasi-experimental study, Stockard and Engelmann (2010) investigated the effects of *Reading Mastery* on early elementary students from two geographical regions, the Pacific Northwest and the Midwest. Using subtests (i.e., Letter Naming Fluency, Initial Sound Fluency, Nonsense Word Fluency and Oral Reading Fluency) from the common ELA *Dynamic Indicators of Basic Early Literacy Skills* (*DIBELS*, Good & Kaminski, 2002) assessment, students in the intervention groups from both geographical locations significantly outperformed students in the control group on the Nonsense Word Fluency subtest from kindergarten to third grade. Notably, at the end of third grade those students receiving instruction from the DI curriculum, *Reading Mastery*, continued to score higher than the control; however, the range of scores between the cohorts (i.e., one cohort received whole language in kindergarten, a second and third cohort received only *Reading Mastery* from kindergarten to third grade) decreased as the three cohorts reached third grade. These results suggest that incremental, explicit teaching, especially related to phonemes, is critical to thoroughly developing reading; from phonemes to comprehension, especially in the early grades. This study suggests that the DI reading curriculum, *Reading Mastery*, was effective for early reading development of students in kindergarten through third grade.

An additional quasi-experimental study by Kamp, Abbott, Wass, Veerkamp, and Kaufman (2008) conducted a two year investigation, beginning in kindergarten, examining the effects of DI as a reading intervention for students requiring the most intensive reading support, those most at risk for reading failure. In this study, the researchers collected data from students randomly assigned to four different reading groups, *DI*, *Guided Reading*, *Programmed Reading*, and *Open Court* (i.e., *Reading Mastery* [Engelmann & Bruner, 1995]; *Early Interventions in Reading* [Mathes & Torgesen, 2005]; and *Read Well* [Sprick, Howard, & Fidanque, 1998] respectively). Based on the Nonsense Word Fluency and Oral Reading Fluency subtests from the *DIBELS* (Good & Kaminski, 2002) and the Word Attack, Word Identification (grade 1) and Word Identification, Passage Comprehension (grade 2) subtests of the *Woodcock Reading Mastery Test-Revised* (Woodcock, 1998), students in the DI intervention group made the most notable gains across all four subtests. This research further supports the methods employed in DI for early elementary students and highlights the effectiveness of explicit instruction in comparison to other curricula for students at risk for reading failure.

The two previously mentioned studies are a mere sampling of the evidence behind DI and its explicit methods for teaching literacy skills to young learners. Using similar curricula and assessment measures makes it easier to analyze the research to pursue future research endeavors. In both studies multiple year research was paired with the *Reading Mastery* (Engelmann & Bruner, 1995) curriculum to determine the effectiveness of DI for teaching reading to early elementary learners. Both studies employed quasi-experimental procedures; however, Stockard and Englemann's (2010) investigation used three cohorts of large reading groups for three years in two geographical regions while Kamp et al. (2008) compared small groups of students at risk for reading failure in the same school for two years. When comparing results of the same measures (i.e., NWF, ORF) students receiving consistent instruction from *Reading Mastery* (Engelmann & Bruner, 1995) exclusively made the greatest overall gains. Interestingly, Stockard and Englemann determined that if students received instruction in an alternate curriculum (e.g., Whole Language) in kindergarten followed by DI (e.g., *Reading Mastery*) in grades two and three the gap can gradually closed.

Direct Instruction with Low-incidence Disabilities

Direct Instruction research has also been targeted with students with disabilities. Kinder, Kubina, and Marchand (2005) conducted a literature review to determine the effectiveness of special education and DI. In the review from 1979-2004, the team located more research conducted on students with high-incidence disabilities (i.e., 37), than low-incidence disabilities (i.e., eight). Overall, DI was determined an effective method for all students with disabilities. Of the eight studies located, disabilities of participants included mental retardation, traumatic brain injury, autism/moderate intellectual disability, and intellectual disabilities, ranging in age from six to 16. Specific DI programs in math (i.e., *DISTAR Arithmetic* [Engelmann & Carnine, 1975], *Corrective Math* [Engelmann, Carnine, & Steely, 2005]) and reading (i.e., *Language, Reading Mastery* [Engelmann & Bruner, 1992]) were examined, identifying the overall effectiveness of DI curricula for students with low-incidence disabilities. Interestingly, the researchers identified two themes from the located research on students with low-incidence disabilities, (a) professional's low expectations and (b) the use of less sophisticated intervention of this group of individuals; however, this literature review suggested that when explicit instruction is delivered systematically with research-based methods, students with low-incidence disabilities can learn more advanced information. This literature review served as a spring board for additional research focused on DI methods to teach reading to students from one of the subgroups within the low-incidence grouping, moderate-to-severe disabilities.

Since the literature review was conducted, Fallon, Light, McNaughton, Drager, and Hammer (2004) investigated the effects of DI on single-word reading skills of children requiring augmentative and alternative communication. Five students aged 9-14 years with congenital speech impairments receiving educational services in a separate classroom setting were taught phoneme matching, telescoping/blending, and single-word reading through the use of the model, prompt, check, DI method. Results from the multiple probe across subjects, single-case design, indicated a functional relationship between DI methods and single-word reading. All students met criteria for all trained words and maintained at least 80% of taught words after a two-month period; however, only one participant met criteria for novel words in generalization.

In another study, Flores and Ganz (2009) investigated the effects of DI on reading comprehension for two students with autism spectrum disorder (ASD) and two students with developmental disabilities. By breaking reading comprehension into smaller chunks (a) picture analogies, (b) deductions, (c) inductions, and (d) opposites, the researchers employed a DI method of model, prompt, check during group instruction including all four students between the ages of 10 and 14 years. Results from the multiple probe across behaviors, single-case design indicated a functional relationship between DI methods and subcomponents of advanced reading comprehension. All students met criteria for all categories of instruction with no overlapping data points and continued maintenance of skills.

Furthermore, Ganz and Flores (2009) investigated the effectiveness of DI to teach three boys aged 10-11 years with mild-to-severe autism to identify vocabulary using objects. By modifying the *Language for Learning* (Engelmann & Osborn, 1999) script, results from the changing criterion, single-case design indicated 90% of nonoverlapping data points. A functional relationship was established between the materials and DI, with replication across participants and sets of materials followed by maintenance of skills beyond formal instruction; therefore, implying modified DI curriculum as a highly effective instructional method for students with autism.

Lastly, Thompson, Wood, Test, and Cease-Cook (2012) investigated the effectiveness of *Connecting Math Concepts Level B* (Engelmann, Carnine, Kelly, & Engelmann 2003a, 2003b) to three elementary students (i.e., ages six to eight years) with ASD. This single-case study examined the effects of exercises, conducted in a one-to-one format, from the math curriculum to teach time telling to the five-minute increment.

Results indicated a functional relationship between the intervention and student skill acquisition. One student met criteria; however, all three students improved time telling skills and fell within the range of chronologically-aged peers. Maintenance data was collected and suggested that students can maintain skills for up to 25 probes following intervention with minimal skill loss as time progressed; whereas, generalization data revealed limited results. As one the first studies investigating DI as a method for teaching a specific math skill (i.e., time telling to the five-minute increment), the authors suggested that DI may be an effective method for this specific skill to elementary-aged students with ASD and recommended future research on the use of DI to teach other mathematical concepts.

Despite the fact that three studies investigated the effects of DI on various reading elements, (a) phoneme matching, telescoping/blending, and single word reading (Fallon et al., 2004), (b) reading comprehension (Flores & Ganz, 2009), and (c) vocabulary (Ganz & Flores, 2009), similarities between the investigations such as age span of participants (i.e., 9-14 years old) and instructional procedures (i.e., model, prompt, check) can lead researchers to draw conclusions about DI. However, the different disability groups represented result in the need for further research on DI for individuals of different ages within these disabilities (i.e., congenital speech impairments, autism, developmental disability). The research suggests that specific scripts from DI curricula can be adapted to meet the learning needs of students with low-incidence disabilities and that the signature components of DI can be employed for students with autism and other specialized learning needs to gain literacy skills. Additionally, with the limited results of the one study that examined the effects of DI on time telling with elementary-aged participants (i.e., 6- 8 years old) with ASD (Thompson, et al. 2012), further research is necessary to determine the effectiveness of DI to teach components of the CCSS, especially as vocabulary is integrated into mathematics. This research established the use of DI as a promising method for teaching reading and mathematics to students with low-incidence disabilities.

Importance of Teaching Vocabulary

As early as 1925, vocabulary has been documented as a critical need in reading and education (Whipple, 1925). Vocabulary is central to comprehension (Chall, Jacobs, & Baldwin, 1990; Comely & Azevedo, 2007; Fien, Santoro, Baker, Park, Chard, Wasiams, & Haria, 2011; Stahl & Fairbanks, 1986) both reading and listening comprehension, and has been identified by the NRP (2000) as one of the five components to teaching literacy. Many sources have identified the value of vocabulary instruction as an integral part of academic instruction for all students (Gonzalez, Pollard-Durodola, Simmons, Taylor, Davis, Kim, & Simmons, 2011; Jimenez, Browder, Spooner, & DiBiase, 2012; NCTM, 2012; NGACBP, CCSS0, 2010; NRP, 2000; Simmons, Hairrell, Edmonds, Vaughn, Larsen, Wilson, Rupley, & Byrns, 2010). Teaching new words for the purpose of receptive and expressive word building has received considerable attention (Beimiller & Boote, 2006; Coyne, Simmons, Kame'enui, & Stoolmiller, 2010; Maynard, Pullen, & Coyne 2010; Zipoli, Coyne, & McCroach, 2011) for students with very diverse learning needs. Although there are numerous methods available for teaching vocabulary to students, the NRP (2000) summarized these into five instructional categories (a) explicit instruction, (b) implicit instruction, (c) multimedia methods, (d) capacity methods, and (e) association methods. Explicit instruction is the process of giving students specific words, definitions, and other attributes of words to be taught and learned by the student, such as DI. Implicit instruction consists of students deriving meaning of new words based on the information read within a specific context, such as exposure to new words while reading to then develop a meaning based on the information within the text. Multimedia methods involve using other modes such as technology, graphic representation, organizers, or through other senses such as the sense of touch employed in American Sign Language. Capacity methods are the process of employing repetitive practice to increase the exposure to multiple words and to make reading automatic, such as repeating targeted words within the content area taught and embedding the words into other content areas. In the association method students are expected to draw connections from their current knowledge and apply that information to what the new word, such as, using word bases to develop a core understanding of new vocabulary. Regardless of the model selected, it is critical that students acquire new vocabulary on a regular basis and make connections to real world applications.

Vocabulary and Literacy

Vocabulary instruction is essential in the early years. Students arrive to school with varying ranges of vocabulary (Biemiller & Slonin, 2001) depending upon the exposure these students have had to rich vocabulary in the home from experiences, conversation, and story readings (National Early Literacy Panel, 2008). One suggested approach for students to acquire vocabulary is through literacy. In preschool and early elementary grades, vocabulary instruction occurs during read alouds; in this method vocabulary instruction can include explicit or implicit methods.

Christ and Wang (2012) conducted a study using explicit instruction. Using a case study, qualitative method of 14 Head Start preschool students, the researchers measured the acquisition of theme-based vocabulary words by calculating students continued use of the targeted words during "buddy readings." After conducting formal literacy instruction, including explicit instruction of targeted vocabulary, the students were placed into carefully constructed student dyads to measure their understanding of the taught words. In these "buddy readings" students would re-read, talk about pictures, and extend discussions about the story. After coding the video recorded sessions the researchers identified that students demonstrated an increase in the explicitly taught vocabulary by correctly using the words during 93% of the dyad interactions. This research suggests that when young students receive specific vocabulary instruction they can maintain and generalize the new words during semi-contrived settings.

In another study, Hindman, Wasik, and Erhart (2012) used a quasi-experimental single group pre-, posttest design, qualitative design to evaluate the use of explicit and implicit instructional methods on vocabulary acquisition of 153 Head Start preschool students during story book reading time. During explicit instruction teachers systematically introduced the targeted word prior to reading the story, gave the students an age-appropriate definition, and gave an example of how the word is used in a sentence. During implicit instruction, teachers would not preteach specific vocabulary. Instead, while reading the story the teacher would point to something on the page that represented a word when an unfamiliar word appeared in the story. This procedure is called gloss over. To quantify the impact of the explicit instruction, the researchers collected pre and post test measures of the *Peabody Picture Vocabulary Test III* (Dunn &

Dunn, 1997). Results indicated more robust vocabulary development from explicit instruction, especially for students with the lowest pretest scores, than implicit instruction. These results indicate the importance and need of explicit instruction for early learners, especially those at risk.

In a third study, Zipoli, Coyne, and McCroach (2011) compared the effectiveness of explicit instruction (i.e., semantic vocabulary review), implicit instruction (i.e., embedded vocabulary review), and no vocabulary review for 80 kindergarten students at risk of reading failure using a within subjects design so that all students received all three conditions. The authors administered a pretest prior to any instruction and posttest scores after each type of vocabulary review to identify student vocabulary acquisition from a researcher-developed *Target Word Knowledge* measure to determine the more effective practice. The results indicated a significant difference in word learning when semantic instruction was purposefully integrated into vocabulary instruction. Semantic instruction included in-depth review of each word (i.e., reintroduction, explained, and discussed) with explicit emphasis on semantic features, association during extension activities, and subsequent storybook readings. Embedded review included reintroduction, pronunciation, definition, and additional presentation in an anchor sentence from the book. Researchers indentified semantic related word review as the most effective procedure with students learning nearly twice as many words than in the embedded condition; however, embedded word review was identified as more time efficient for both teachers and students. Results suggest that despite the additional time required, explicit instruction is the more effective procedure for teaching vocabulary to kindergarten students at risk of reading failure.

Each of these studies supports the need for explicit instruction when teaching new vocabulary to young students at risk for reading failure. Head Start students were the targeted population in two studies (Christ &Wang, 2012; Hindman, Wasik, &Erhart, 2012) for teaching vocabulary explicitly; however, Hindman included implicit teaching methods to compare the more effective teaching method for this group of students. Furthermore, Zipoli, Coyne, and McCroach (2011) compared explicit and implicit teaching methods with older students only to come to the same conclusion. Interestingly, Christ and Wang examined practical application of vocabulary through student's use of vocabulary when retelling or discussing stories with peers; whereas, Hindman and Zipoli analyzed formal measures to determine acquisition of vocabulary. Moreover, Zipoli included a third component of the NRP (2000) instructional categories, association, in their instructional package to build capacity in vocabulary development for kindergarten students. Adding association to the investigation may have influenced the research outcomes but it is important to remember that systematic and explicit instruction was the primary instructional method. These three research studies suggest that explicit instruction is effective in teaching vocabulary to young students (i.e., 3-6 years old), which can also improve listening and reading comprehension skills.

Vocabulary and Reading Comprehension

Vocabulary remains an essential requirement of reading; however, in late third grade and early fourth grade the focus begins to shift (Biemiller, 2005). By fourth grade students are reading to learn; therefore, learning vocabulary for reading comprehension is critical to ongoing learning. Researchers have attempted to identify the connections between vocabulary development and reading comprehension.

In one study examining the effects of contributing factors on reading comprehension, Comely and Azevedo (2007) employed a path analysis of a direct and inferential mediation model of five factors hypothesized to play a part in reading comprehension. These factors included background knowledge, inferences, reading comprehension strategies, vocabulary and word reading (i.e., fluency). Based on reading data gathered from 177 ninth grade students from all ability levels, analysis was conducted to determine the strongest predictor on reading comprehension. Results indicated vocabulary and background information had the greatest direct impact on reading comprehension. Vocabulary had an indirect effect as a mediator between comprehension and word reading and background information. The authors concluded that students with limited background information, word reading, inferential and vocabulary were at a disadvantage in reading comprehension. This research suggested the value of vocabulary instruction and background knowledge as fundamental components to reading comprehension.

In another study examining the correlation between vocabulary and comprehension, Yovanoff, Duesbery, Alonzo, and Tindal (2005) investigated the relationship between three (i.e., fluency, vocabulary, comprehension) of the five essential NRP (2000) components of reading for students in fourth to eighth grade. Using alternate form tests, results indicated a moderate correlation (r = .48 to .66) between vocabulary and reading comprehension for fifth, sixth, seventh and eighth grade students on both forms; however a disparity of results occurred on the two forms for fourth grade students (i.e., Form A, r = .63; Form B. r = .35). Despite the researchers' attempts to control for remarkable differences between groups such as employing descriptive statistics to identify outliers, the inconsistent results could not be explained statistically. The investigators suggested that a pivotal change occurs in fourth grade. As students continue to improve fluency and learn vocabulary, fourth grade students are transitioning from learning how to read, to reading to learn. These results further support the need for ongoing vocabulary instruction in the late elementary grades where learning to read is transitioning to reading to learn.

In a third study, McKeown, Beck, Omanson, and Pople (1985) evaluated the method of instruction and the frequency of encounters to determine their effect on reading comprehension. In a quasi-experimental investigation the researchers analyzed the effects of the number of word encounters (i.e., how often a word is appears in instruction) and the method of instruction on vocabulary knowledge, fluency, context interpretation, and story comprehension. Researchers used 24 words equally divided into three encounter levels (i.e., high-12, low-4, no encounter-0) paired with three instructional methods including: (a) traditional, which simply used definitions and word associations, (b) rich, which further elaborated word meanings and diverse perspectives, and (c) extended/rich, which added extension activities beyond the classroom on 169 fourth grade minority students during 12, 30 minutes lessons. Overall, results indicated improvements in all areas for high encounter words; whereas, fluency of access and story comprehension were impacted the most extended/rich instruction. Furthermore, the more encounters students had with words and the more extensive the instructional method, had the greatest effect on students' word knowledge, fluency, context interpretation, and story comprehension.

In another study, Fien, Santoro, Baker, Park, Chard, Williams, and Haria (2011) investigated the effects of supplemental small group instruction on vocabulary development and reading comprehension. In the randomized control study of 106 low-vocabulary first grade students, the researchers provided two additional, twenty minute, small group reading instruction time for eight weeks. By using explicit, systematic instructional practices such as preview and review with the small groups aligned with the whole group curriculum, the experimental students made significant improvements and outperformed the control group on vocabulary and expository story retell. These results suggested that explicit, systematic small group instruction not only increases vocabulary skills but improves the ability to retell expository information from a story.

All these studies investigated the effects of vocabulary on reading comprehension with each confirming that vocabulary development plays a critical role in reading comprehension. Three of the studies (Comely & Azevedo, 2007; McKeown, Beck, Omanson, & Pople, 1985; Yovanoff, Duesbery, Alonzo, & Tindal, 2005) examined the impact of vocabulary on older students (i.e., fourth to ninth grade), when students are applying reading to gain knowledge; thereby, resulting in the need for ongoing vocabulary instruction to facilitate comprehension. Vocabulary instruction is especially critical with younger students (Fien et al., 2011) as they are still developing their reading skills by demonstrating comprehension through retells. Vocabulary is a necessity to comprehension; therefore, instruction is continual and with direct, systematic instruction (Fien et al., 2011; McKeowen, et al., 1985), students gain the ability to increase their learning from both narrative and expository text. Academic content such as social studies, science and mathematics typically employ expository text and includes vocabulary from the three tiers of word models (Beck, McKeown, & Kucan, 2002; 2008). By using direct, systematic instruction with text that is laden with tier two and three, reading comprehension is facilitated. This need for vocabulary acquisition is especially necessary to understand concepts in core content areas.

Vocabulary and Core Content

Teaching vocabulary within specific content areas provides students with a deeper understanding of instructional material. Without a thorough understanding of the words students are merely skimming over content. Literacy is embedded into all areas of education and should not be limited to ELA. It is evident that each content area has priority vocabulary (i.e., tier two, tier three) that must be taught for students to understand the material presented.

In a two-part non-experimental study, Taboada, Bianco, and Bowerman (2012) examined the effect of vocabulary development of English language learners (ELL) on the comprehension of fifth grade science content after allotted preview time and vocabulary instruction was provided in comparison to English only speakers. Results indicate that general vocabulary development is a significant predictor in reading comprehension of ELLs and has a greater impact on reading comprehension than for English only learners.

In another study, Simmons, et al. (2010) investigated the effects of two explicit instructional procedures with 904 fourth grade social studies students. After teachers received training in the two experimental procedures, students were randomly assigned to one of the three conditions: content vocabulary, content reading comprehension, or control. Both experimental procedures employed an instructional vocabulary component of content specific words. However, the content vocabulary group extended explicit vocabulary instruction to include capacity and association methods, where as the content reading comprehension group received explicit vocabulary instruction followed by question asking instruction. Results indicated improvements for both experimental groups; however, the content vocabulary group outperformed the content reading comprehension group on the curriculum-based measures and the end of year, grade-level social studies assessment. Furthermore, the content vocabulary group was observed generalizing vocabulary across content areas. These results suggested that explicit multi-categorical instructional procedures focusing on vocabulary to improve comprehension are critical to promote fourth-grade students' understanding of social studies content concepts, and that vocabulary continues to facilitate reading comprehension and understanding across content areas.

In a third study, Gonzalez, et al. (2011) examined the acquisition of science and social studies content vocabulary and content comprehension of 148 preschool students. Researchers compared two instructional methods employed by teachers randomly assigned to either an experimental and control group. The experimental group provided explicit vocabulary instruction with extended word use embedded into the lesson during shared reading time focusing on science or social studies content (e.g., Earth-land and water, live and go). Teachers in the control group continued to employ the regular procedures and received no instructional guidance. Results on pre and posttest standardized measures indicated no significant differences between the groups. Further examination of the results, however, indicated significant differences in vocabulary and comprehension of younger students in the experimental group. Comparable to the results of research conducted in other preschool classrooms (Hindman, Wasik, & Erhart, 2012; Zipoli, Coyne, & McCroach, 2011). These results suggested that explicit instruction for preschool-aged children is valuable for vocabulary development and employing these methods can improve content comprehension as early as age three.

The reviewed research provided implies that students of various ages, fifth grade, fourth grade and preschool age, receiving explicit instruction with embedded capacity and association methods, develop a stronger comprehension of core content. Despite the fact that specific curricula are not as readily available for preschool students as it is for K-12 students, the focus on vocabulary remains a consistent need. The value of tier three vocabulary instruction continues to be supported in science and social studies content not only in the upper elementary grades but also for students as young as three. Students of all learning needs, such as ELL, (Taboada, Bianco, & Bowerman, 2012) benefit from specific vocabulary instruction; therefore, it is necessary for teachers to have a clear understanding of effective methods to teach students. By using explicit teaching practices, students build a stronger understanding of vocabulary in core content areas, including mathematics.

Vocabulary and Mathematics

The importance of teaching content-specific vocabulary to students in general education classrooms with a variety of learning needs continues into mathematics (Capps & Cox, 1991; Kovarik, 2010; Noel, 2009). Research has demonstrated that vocabulary in science and social studies is necessary for students to comprehend the specific contextual concepts. Many of the vocabulary words in science and social studies can be embedded into daily conversation (e.g., erosion, pollution, thermometer, and friction); therefore giving students extended opportunities to build capacity with the vocabulary. In mathematics the vocabulary can serve multiple functions and have multiple meanings, some words are homonyms (Adams, Thangata, & King, 2005; Thompson & Rubenstein, 2000) such as sum/some, for/four, and weight/wait or homographs such as formula, power, and degree. Numerous words are specific to mathematical concepts; however, as with science and social studies vocabulary, they can be used in daily conversations about mathematical situations (Bay-Williams & Livers, 2009; Thompson & Rubenstein, 2000) including words such as correlation, parallel, and range. Furthermore, mathematical vocabulary can be used in an elite conversation exclusive to those operating deeply within a mathematical context (Pierce & Fontaine, 2009) including words such as denominator, exponent, congruent, and polynomials. Each of these examples not only provide words within each of the three word tiers, but also exhibits the depth of tier three words and the complex nature of math vocabulary for students; further supporting the call for action by NGAC, CCSSO for vocabulary across content areas and the NCTM recommendation for communication in mathematics.

As early as 1993, researchers identified the need for teaching mathematical vocabulary to students (Kidd, Madsen, & Lamb). After 25 deaf high school students received a mean score of 46% on a multiple choice mathematics test, it was evident to the researchers that formal vocabulary instruction must become an integral part of math lessons. Regardless of the students' communication abilities, it was apparent that mathematical vocabulary was complicated and critical to understanding the content. This early investigation provided a foundation for the value of math vocabulary instruction for all students.

In a qualitative study, Carter and Dean (2006) investigated the use of explicit vocabulary instruction, comparable to that used during ELA lessons, on the comprehension of math content for 14, middle school-aged students. Through the use of explicit instructional methods to explicitly teach mathematics vocabulary, reading and comprehension during the three-week summer intervention program students exhibited notable improvements in math content. After reviewing 72 audio taped lessons researchers indentified student progress by the student's ability to explain concepts to others and their overall proficiency in math concepts; therefore, supporting the need for explicit instruction with mathematical vocabulary.

In another study, Shamir and Baruch (2012) investigated the effects of employing mathematical vocabulary instruction through the use of e-books using a randomized control group design. By using explicit instruction embedded with media methods (i.e., e-books), four to seven year old children at risk for learning disabilities in the experimental group made significantly greater improvements in math concepts. With vocabulary focusing on essence of numbers and ordinal numbers further investigation determined that students with low verbal ability demonstrated the most significant growth. This research suggested that early elementary students, especially those with limited verbal skills, can benefit from explicit instruction with embedded media methods to improve mathematics concepts.

Notwithstanding the extremely limited research available on teaching mathematical vocabulary, this review of the literature reveals the importance of teaching math vocabulary to students as critical in developing contextual concepts, especially for students with special learning needs. By employing explicit instruction with embedded media, students can develop a deeper understanding of the information. Since the 1989 NCTM revisions prioritizing mathematical communication into instruction, relatively little research has been conducted to identify effective instructional methods in how educators can shift this theory into practice. Research continues to identify vocabulary instruction as a critical need to comprehension (Comely & Azevedo, 2007; Gonzalez, et al., 2011; McKeown, Beck, Omanson, & Pople, 1985; Simmons, et al., 2010; Taboada, Bianco, & Bowerman, 2012; Yovanoff, Duesbery, Alonzo, &Tindal, 2005), especially for students that have challenges with learning (Christ & Wang, 2012; Kidd, Madsen, & Lamb, 1993; Shamir & Baruch, 2012; Zipoli, Coyne, & McCroach, 2011).

Vocabulary and Students with Severe Disabilities.

Instructional content for students with severe disabilities is grounded in general education content (IDEIA, 2004; NCLB, 2001). Likewise, instructional methodology for students with severe disabilities can be drawn from that in general education classrooms, especially those used with struggling learners. From the previously described information, researchers have learned that vocabulary can be taught using (a) explicit, (b) implicit, (c) multimedia, (d) capacity, and (e) association methods; however, it appears that when the learners without disabilities are young and /or learning information for the first time, explicit instruction has been the most effective. This continues to be true for students with severe disabilities; however, as the literature reveals, students with severe disabilities often require more explicit instruction, such as prompting procedures, to promote learning. The following review of the literature on teaching vocabulary to students with severe disabilities was conducted to determine if the same instructional patterns holds true.

In 2006, Browder, Wakeman, Spooner, Ahlgrim-Delzell, and Algozzine conducted a literature review to categorize research on the five components of literacy identified by the NRP (2000) for students with moderate and severe disabilities. Of the 128 articles located, the authors indicated that the most research had been conducted in sight word acquisition, with a focus on functional sight words, not core content vocabulary. This review also revealed that little research has been conducted to measure comprehension. Since 2006, additional research on the acquisition of literacy skills for students with severe disabilities has been conducted. Researchers have used various research-based methods to determine effective instructional strategies for literacy (Collins, Evans, Creech-Galloway, Karl, & Miller, 2007; Coyne, Pisha, Dalton, Zeph, & Smith, 2010; Hudson & Test, 2011; Jimenez, Browder, Spooner, & DiBiase, 2012; Knight, Smith, Spooner, & Browder 2012; Leaf, Sheldon, & Sherman, 2010; Lemons & Fuchs, 2010; Minoravic, & Bambara, 2007; Spooner, Rivera, Browder, Baker, & Salas, 2010) with a focus on vocabulary development including comprehension.

One procedure used to teach components of literacy is read-a-louds, also referred to as story time and story-based lessons. This procedure often targets vocabulary development and comprehension skills within the context of a book reading. To identify the research-base on using book reading to teach literacy, Hudson and Test (2011) conducted a review of the literature to determine if story-based lessons could be identified as an evidence-based practice using the quality indicators developed by Test et al. (2009), for students with extensive support needs (i.e., students with intellectual disabilities, autism, or multiple disabilities). Results indicated that six of the 10 studies located focused on listening comprehension, reading comprehension, and vocabulary met the criteria suggesting a moderate level of evidence; therefore, implying that educators can implement this method to advance literacy in students with extensive support needs.

Similar to procedures in the studies conducted with Head Start students, using explicit instruction during story-time is also an effective method for teaching vocabulary and comprehension skills to young students. The literature review described above continues to support these practices with students that have individualized learning needs. One of the studies included in the aforementioned literature review focused on meeting the needs of a Latina student with an intellectual disability (Spooner, Rivera, Browder, Baker, & Salas, 2010). This single-case study determined that culturally relevant stories are effective to teach pre-emergent literacy, vocabulary and comprehension development for the student. Similarly, Coyne, Pisha, Dalton, Zeph, and Smith (2010), employed explicit instruction embedded with media methods (i.e., e-books) to develop vocabulary and comprehension in students with significant intellectual disabilities. Using story books is only one procedure that has been effective for vocabulary and comprehension instruction to students with very specific learning needs. In addition to teaching vocabulary and comprehension, benefits of storybook readings are numerous including serving as a model for fluency and as a connection to science and social studies content.

Other explicit procedures using systematic instruction such as (a) system of least prompts, (b) no-no and simultaneous prompting (c) constant time delay, and (d) Direct Instruction have been employed to teach vocabulary and comprehension to students with severe disabilities. Systematic instruction is another explicit procedure for teaching vocabulary and comprehension to students with severe disabilities. Systematic instruction is the process of analyzing the learning objective to small incremental components and providing specific prompts, materials, and instructional format as needed for the students to make progress (Collins, 2007). Many antecedent prompting procedures are used with individuals with severe disabilities as a form of errorless learning. Some of these include system of least prompts, simultaneous prompting, and time delay. In a study using single-case design, Minoravic and Bambara (2007) used the system of least prompts (i.e., gesture, verbal, model, physical) to teach adults with severe disabilities to read and comprehend job related vocabulary to increase their level of independence while at work. Initially the adults learned to read the words; however, they required additional explicit instruction to comprehend and generalize the words within the context of their jobs. This study highlighted not only the importance of learning relevant vocabulary, but also that explicit instruction can be valuable for individuals with severe disabilities at all ages.

Simultaneous prompting was examined in the following two studies. In one study using single-case design, Leaf, Sheldon, and Sherman (2010) investigated the effects of no-no prompting and simultaneous prompting on teaching discrete vocabulary building skills to three young students (i.e., three to five year olds) with autism. Results indicated systematical use of no-no prompting was more effective for teaching specific vocabulary skills such as objects (e.g., baby, spoon), pictures (e.g., green light scissors), or numbers. Researchers suggested that differential consequences (i.e., "no-no" for incorrect response, reinforcement for correct response) and the need for students to attend to materials (i.e., visually discriminate) to elicit a response leading to reinforcement, may have contributed to the overall effectiveness of no-no prompting. This research highlighted critical factors when teaching students with autism, differential consequences, visual discrimination, and individualized instruction based on students current level of performance.

Similarly, simultaneous prompting was researched to determine its effectiveness to teach core content vocabulary and word comprehension to students with severe disabilities was demonstrated through the use of a modified Direct Instruction model (Collins, Evans, Creech-Galloway, Karl, & Miller, 2007). This single-case investigation compared the rate of acquisition between functional and core content vocabulary using simultaneous prompting in special education and general education classrooms with four older students (i.e., aged 9-19 years). Instructors employed three different instructional packages, (a) massed trials (repetitive instruction on all words within 1-3 minutes by the special education teacher) in special education classrooms, (b) distributed trials (instruction provided on 2-3 words, when naturally occurring breaks occur within the 45 minute class time by the special education teaching assistant) in general education settings, and (c) embedded trials (instruction provided in a naturalistic manner by the general education teacher) in general education classrooms. Criteria of 100% on each targeted word were met for all three instructional packages; however, on average, students met criteria in fewer sessions with functional words. Additionally, the three older students met criteria in fewer sessions during the embedded trial sessions and maintained the acquired words across time. This research not only examined the effectiveness of explicit instruction for this population, but also provided evidence that students with severe disabilities can make progress with core content within an inclusive general education classroom.

Time delay is another type of systematic instruction that uses a specific antecedent prompting procedure to teach students either chained or discrete skills. There are two types of time delay, progressive and constant. The following two studies investigated the effects of constant time delay (CTD) on core content vocabulary. In a single-case study, Jimenez, Browder, Spooner, and DiBiase (2012) also conducted research in the general education classroom. The group investigated the use of peer-mediated embedded instruction paired with CTD to teach science vocabulary and comprehension to three, sixth grade students with severe disabilities. Results indicated that constant time delay was an integral component of students' attainment of vocabulary and word comprehension across three science units.

Additionally, Morrison (2011) employed CTD in a single-case design study to teach six tenth grade students with severe disabilities mathematical vocabulary. The dissertation research targeted math vocabulary from the tenth grade geometry text book glossary. Through the use of CTD, the three participants in the verbal group met intervention criteria; whereas, the three participants in the nonverbal group did not. Furthermore, the three verbal participants were able to maintain the acquired mathematical vocabulary but demonstrated variable generalization. This research indicated that individuals with severe disabilities, who are verbal, including one participant with autism, can learn grade level math vocabulary using CTD when delivered in a one-to-one format. Despite attempts to individualize instruction to meet the needs of the nonverbal learners, the author attributed several factors to the lack of progress. Some examples include: research environment, intervention sessions, reinforcement schedule, content, response modes, and communication competence. Results from this dissertation indicated a need to determine effective methods for teaching mathematical vocabulary, especially for students that are nonverbal.

Lastly, in another single-case study focusing on science, Knight, Smith, Spooner, and Browder (2012) investigated the effects of DI (i.e., model, lead, test) on the acquisition of science vocabulary with three elementary students with autism. Through the use of objects representing science concepts (e.g., wet, living, light), the students attained the ability to identify science concepts from three sets of materials consisting of five concepts per set. On average, the participants required 18 sessions for concept set 1, 13 sessions for concept set 2, and 14 sessions for concept set 3. This investigations included three generalization components, one, to determine if the students could indentify concepts with different materials, two, to use pictures in place of objects, and three, to use the materials in a science experiment focusing on simple machines. The students were only able to generalize to novel objects; however, they were unable to apply the concepts with objects during the science experiment or generalizing the concept objects to pictures.

Research examining effective methods for teaching students with severe disabilities core content vocabulary continues to unfold. There is evidence that explicit instruction is effective in a variety of forms such as large group (Collins, et al., 2007; Jimenez et al., 2012), small group (Knight, et al., 2012), or a combination of the two (Jimenez, 2012). Explicit instruction can consist of various prompting methods such as (a) system of least prompts (Minoravic & Bambara, 2007), (b) simultaneous prompting (Collins, 2007; Leaf, Sheldon, & Sherman, 2010) and (c) CTD (Jimenez, 2012; Morrison, 2011) and DI (Knight, et al., 2012). The majority of the research occurred with older students with severe disabilities (Collins, 2007; Jimenez, 2012; Minoravic & Bambara, 2007; Morrison, 2011), and two targeting young children with autism (Knight, 2012;

Leaf, et al., 2010). The lack of progress in learning geometry vocabulary with the group of students that were non verbal (Morrison, 2011) and the inability of the early elementary students to generalize science concepts to pictures, suggested that communication level may be a critical component when teaching vocabulary to students with severe disabilities.

This literature review highlighted the need for explicit instruction for teaching students with severe disabilities; including those with autism, grade level core content vocabulary (i.e., ELA, science, mathematics). The research suggested that explicit instruction is effective in general education classrooms with reliable peers (Jimenez, et al., 2012); however, it is necessary for instructors (i.e., peers, teachers) to receive training in the instructional methods (Jimenez et al., 2012). Furthermore, research suggests more efficient learning occurs in the special education classroom (Collins, et al,, 2007; Jimenez, 2012) with grade level content occurring in either small group (Knight, 2012) or a one-to-one instructional format (Leaf, et al., 2010; Morrison, 2011). Additionally, the lack of progress in learning vocabulary (Morrison, 2011) or generalizing concepts (Knight, et al., 2012) suggests that communication level may play a critical role in acquisition of skills.

Each of these investigations demonstrates that explicit systematic instruction employed through many methods are effective for teaching individuals with severe disabilities components of literacy such as vocabulary and reading comprehension (Coyne, Pisha, Dalton, Zeph, & Smith, 2010; Spooner, Rivera, Browder, Baker, & Salas, 2010), especially when the targeted words are functionally relevant (Minoravic & Bamabara, 2007) and comprehension of those words is included in the instructional procedures (Jimenez, Browder, Spooner, & DiBiase, 2012; Knight, Smith, Spooner, & Browder, 2012). As the review of the literature demonstrated, vocabulary reading is not exclusive to ELA but is necessary in all content areas (Jimenez, et al.; Knight et al.; Morrison, 2011). Research also reveals that students with severe disabilities can learn core content vocabulary in different settings (Collins, Evans, Creech-Galloway, Karl & Miller, 2007; Jimenez, et al., 2012). As more is learned about how students with severe disabilities learn, student expectations have gradually increased by assuming the least dangerous assumption (Jorgensen, 2005). It is evident that students with severe disabilities can learn core content vocabulary when explicit teaching methods are employed; however, there is limited research available in teaching content specific vocabulary (i.e., science, math) to students with severe disabilities.

Constant Time Delay and Autism

Time delay is a form of systematic instruction that employs very specific antecedent prompting procedures to elicit correct responding. Research has established that time delay is an effective and efficient practice for teaching discrete skills with a variety of students with disabilities. Time delay is a method of errorless learning that encourages students to respond correctly; thereby, accelerating the rate of acquisition (Schuster et al., 1998). Instructional trials with time delay involve simultaneous pairing of the antecedent stimulus (i.e., task directive, "Read this word" as word card is presented) and the controlling prompt (i.e., prompt, "Two"); whereas, the controlling prompt remains the same throughout all training (Snell & Gast, 1981). Time delay refers to the lag between antecedent stimulus and the student response. The controlling prompt is initially provided with a zero second delay between the antecedent prompt and correct response. After student obtains 100% accuracy during zero-second delay, subsequent trials add time between the antecedent prompt and response. Based on knowledge of the student, the instructor determines the time delay between the antecedent stimulus (i.e., directive) and the student's response before the controlling prompt is provided (Snell & Gast, 1981). In constant time delay (CTD) this time between the antecedent prompt and student response is held constant across instructional sessions. In progressive time delay the time between the antecedent stimulus and correct response is progressively increased. The goal is to give the student enough time to respond without producing prompt dependence or incorrect responding with reinforcement contingent upon correct response within the allotted amount of time. The carefully planned explicit instruction attempts to provide errorless learning (Westling & Fox, 2009). In order to deter incorrect responding, the instructor response blocks or interrupts the student by providing the controlling prompt; thereby, inhibiting incorrect responses. This is known as a prompted correct response. The presence of reinforcement for correct responding leads to the increase in probability that correct responding will occur in the future. The key elements to CTD are the use of, (a) an antecedent stimulus, (b) a consistent controlling prompt, (c) multiple trials of errorless instruction, and (d) the immediate change from zero second trials to the CTD (Collins, 2007).

For approximately the past 40 years, researchers have examined the effects of time delay for teaching students with severe disabilities. In 2009, Browder, Ahlgrim-Delzell, Spooner, Mims, and Baker conducted a literature review determining that time delay was an effective evidence-based practice for teaching picture and word recognition to students with severe disabilities. Of the 22 experiments identified, eleven met the quality indicators (Horner, et al., 2005) for constant time delay using single subject research. Furthermore, only one of the 11 studies involved students with autism (Mechling & Gast, 2003). In this study, the researchers investigated the use of CTD and a simulated multi-media program to teach three students to read words on grocery store aisle signs to locate items. The multiple probe across three sets of associated word pairs design was used to teach the students ages 12-18, one with autism, to locate familiar items in the grocery store. Results determined that all students attained and generalized the desired reading skill, with the student with autism demonstrating the greatest overall growth in generalization; therefore, indicating that CTD is effective for teaching functional word reading an older student with autism.

In addition to the evaluation of time delay procedures conducted by Browder and colleagues, Walker (2008) conducted a literature review specific to the use of time delay and students with autism. This review established that CTD was an effective method for teaching various skills including numeral identification (Ault, Wolery, Gast, Doyle, 1988), social skills (Dipipi, 2001; Nientimp & Cole, 1992) leisure skills (Wall & Gast, 1997; Wall, Gast, & Royston, 1999) and independent living skills (Gardill & Browder, 1995; Hughes, Schuster, & Nelson, 1993; Morse & Schuster, 2000; Norman, Collins, & Schuster, 2001; Winterling et al., 1992). Interestingly, from the 10 studies published in the 20-year time span (i.e., between 1985 and 2005) only one focused on an academic skill and none incorporated reading. Since this review of the literature, research investigating the effects of CTD related to reading for students with autism has expanded. In one study, this systematic instructional method was successful with teaching product label reading to two women with autism aged 23 and 24 (Dogoe, Banda, Lock, &

Feinstein, 2011). In this study, the women were taught to read, define, and explain three sets of functional word pairs using a 5s delay for each component. Both participants met criteria and were able to generalize the skills to the product labels; however, generalization to different environments was not achieved within the time parameters of the study.

In another study, the use of CTD was employed in combination with a TEACCH (Treatment and Education of Autistic and related Communication handicapped CHildren) model classroom in a single-case AB design (Kurt & Parsons, 2009). The authors found that CTD was effective in teaching a variety of individualized skills to three students ages 12-14; however, only one student was taught a reading related skill (i.e., correctly identifying picture of fruit when word paired with verbal name of fruit was stated). Results suggested that when employed to teach individualized academic skills CTD can be effective in combination with other research-based methods

Additionally, Ledford, Gast, Luscre, and Ayres (2008) found CTD effective in teaching community based words to six students between the ages of five and nine. Moreover, this multiple probe design study employed three dyads of students to determine that small group learning promoted incidental observational learning of students with autism.

Lastly, CTD with embedded DI components was employed in a treatment package to teach the science concept of convection to three middle school students with autism and intellectual disabilities (Knight, Spooner, & Browder, 2013). Using a multiple probe design to teach seven vocabulary words and definitions the five phase instruction included (a) CTD; (b) examples and nonexamples with model, lead, test; (c) graphic organizers; (d) teaching using multiple exemplars; and (e) connecting concepts to the big idea. This research found CTD effective in teaching students science content.

The information gathered from the literature reviews (Browder, et al., 2008; Walker, 2008) and the more recent research (Dogoe et al., 2011; Knight, et al., 2013; Kurt & Parson, 2009; Ledford et al., 2008) suggested that CTD is an effective practice for teaching students with autism functional and academic reading skills. Only one study, Knight, et al. incorporated content specific vocabulary. More research needs to be conducted investigating the use of systematic instruction, including CTD, in all content areas. Furthermore, only one of the discussed studies included the use of CTD with young students with autism (i.e., between the ages of five and 9; Ledford et al., 2008). With this in mind, it is evident that more research needs to be conducted examining effective methods for teaching grade level content vocabulary to young students with autism.

Autism

In 2014, the Center for Disease Control established that one in 68 children are identified with autism spectrum disorder (ASD). According to the Diagnostic and Statistical Manual of Mental Disorders: DSM-V, there are two primary symptoms that must be present for an individual to be diagnosed with ASD, these include: (a) persistent deficits in social communication and social interactions across contexts; and (b) restricted, repetitive patterns of behavior, interests, or activities. Furthermore, both of these symptoms must be present in early development and must cause clinically significant impairment in social, occupational, or other important areas of functioning and are not otherwise explained by an intellectual disability (American Psychiatric

Association, 2013). Unlike individuals with intellectual disabilities that display more even delays across many areas, individuals with an ASD are affected at varying degrees in each of these symptoms. Although the indicators of an ASD described in the DSM-V appear somewhat broad, social relatedness and restricted interests are general qualities that separate into more specific characteristics on a continuum. A non-exhaustive list of characteristics include: (a) limited or no speaking ability, often compounding into problematic behaviors that serve as functional communication (Chiang, 2008; Hanley, Jin, Vanselow, Hanratty, 2014; Wacker, et al., 2013); (b) lack of executive functioning, including lack of planning, organizing, and self-regulating (Hedvall, Fernell, Holm, Johnels, Gillberg, & Billstedt, 2013; Verte, Geurts, Roeyers, Oosterlaan, & Sergeant, 2006); (c) issues with sensory integration, including under and/or over-arousal in each of the five senses (Fazlioglu & Faganm 2008; Pfieffer, Koenig, Kinnealey, Sheppard, & Henderson, 2011; (d) self-stimulatory behaviors (Duker & Rasing, 1989; Powers, Thibadeau, & Rose, 1992), and (e) psychomotor coordination resulting in limited verbal and motor imitation (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Mostofsky & Ewen, 2011). With each individual with autism affected at varying degrees by these characteristics and others, meeting the needs of those diagnosed with an ASD are indeed very unique.

For teachers, these individualized needs often present many challenges throughout the school day (Iovannone, Dunlap, Huber, & Kincaid, 2003), especially for young students (i.e., six-12 years) as they are transitioning to new environments and becoming acquainted with new people (Wilkinson, 2014). Just as each person with autism possesses specific characteristics on a continuum within ASD symptomatology, educational services are also available on a continuum to meet those needs. The majority of students with ASD receive educational services in the eligibility category of autism; with each making progress at their own pace (NRC, 2001b). Educating students with autism is a comprehensive task that must include ongoing instruction in academics, communication, socialization, adaptive behavior, and reduction in inappropriate behaviors; therefore teaching students with autism requires methodical, consistent, systematic instruction (NRC, 2001b). Considering the spectrum of the disorder and the variability of skills within each person, 34.1% of students with autism between the ages of six and 21 are assigned to highly specialized classroom settings consisting of a low student to teacher ratio (U. S. Department of Education, 2013). Even with the identified ratios, the unique learning needs of these students often results in challenges for teachers when teaching academics, especially one of the foundational components of education-- reading. Many individuals with autism present as hyperlexic, the ability to identify words by decoding strings of letters; however, they lack comprehension skills (Nation, Clarke, Wright, & Williams, 2006). Despite these challenges, Vacca (2007) indicated that students with autism can learn to read in a way that is meaningful to them such as, including images to give words meaning.

Through the use of images the words are more than visual configurations of letters, the string of letters are associated with relevant information; therefore assimilating comprehension at some level. In a literature review identifying research focusing on reading comprehension for students with ASD, Chiang and Lin (2007) located 11 studies between 1986 and 2006 that met inclusion criteria. Seven of the 11 studies targeted sight words with comprehension while six studies focused on functional skills (Collins &

Stinson, 1994; Eikeseth & Jahr, 2001; McGee, Krantz, & McClannahan, 1986; Mechling & Gast, 2003; Mechling, Gast & Langone, 2002; Rehfeldt, Lattimore, & Stromer, 2003) and only one study targeted academic reading (Williams, Wright, Callahan, & Coughlan, 2002). Each of the seven studies employed one-to-one instruction with the students.

Since 2006, the research on reading for students with autism has increased to include investigations examining the differences in learning between typically developing students and students with autism (Brown, Oram-Cardy, & Johnson, 2013; Gabig, 2010; McDuffie, Yoder, & Stone, 2006) and developmental characteristics assisting with emergent literacy (Lanter, Watson, Erickson, & Freeman, 2012). According to the research conducted, there is overall variability in early reading skills between typically developing and children with autism. Children with autism are similar to young typically developing children in the need for visual referents when learning new words (McDuffie, Yoder, & Stone, 2006) and in word reading abilities (Nation, Clarke, Wright, & Williams, 2006). The difference arises in the acquisition of phonological awareness skills in learning to read (Gabig, 2010); students with autism are less able to use phonological awareness when reading unfamiliar words. Furthermore, there are more notable differences in reading comprehension between the two groups, especially when social world connections, such as remaining engaged to surroundings and experiences throughout the day, were restricted (Brown, Oram-Cardy, & Johnson, 2013). Additionally, language impairment plays an integral role in emergent literacy (Lanter, Watson, Erickson, & Freeman, 2012). The variability in the development of language skills of children with autism impacts the development of reading skills including new vocabulary, specific to academic content.

There is some single-case research to identify effective methods to teach students with autism to read. Crowley, McLaughlin, and Kahn (2013) found DI in (a) one-to-one setting, with flashcards; (b) immediate error correction; and (c) a model, lead, test method and embedded drill and practice to build accuracy and fluency effective in teaching two seven year old students to read Dolch Pre-primer words. Dittlinger and Lerman (2011) investigated effective practices for teaching word identification to young children with autism (i.e., three, four, nine years old) in a one-to-one setting using four different sets of materials, (a) word only cards with no previous picture association, (b) word only cards with previous picture association, (c) word with picture card, and (d) picture only card. Results indicated word only cards with no previous picture association as the most effective set of materials.

Contrary to the extensive research conducted with individuals with autism in one to one settings, Taylor, DeQuinzo, and Stine (2012) determined small group settings an effective method for teaching word identification to three young children with autism (i.e., between the ages of three and five years old). By employing (a) explicit instructional procedures including older peer models with autism and embedding reinforcement for correct responding and attending, and (b) incidental learning young students with autism accurately echoed peer responses and identified words. Furthermore, results from maintenance data indicated students retained more words taught in the explicit instruction condition than those incidentally learned, implying that explicit instruction is continues to remain a critical component for individuals with autism.

An investigation conducted by Mims, Lee, Browder, Zakas, and Flynn (2012) further indicates the need for explicit instruction in group settings, especially as it relates to learning core content vocabulary. Using a treatment package (e.g., CTD for vocabulary, adapted text with task analysis, and system of least prompts), to teach grade-level literacy skills researchers individualized instruction within five small group settings (i.e., two to three students) for 14 middle school students with severe disabilities, including nine with autism. Statistical analysis conducted on the group, using pre and posttest scores, determined significant gains in two (i.e., vocabulary and comprehension of familiar text) of the six dependent variables. This research suggested small group settings employing explicit instruction with embedded individualized targets can improve vocabulary acquisition for students with autism.

One-to-One vs. Small Group Format

The limited research provides promise for effective teaching practices in either one-to-one or group formats for students with autism; however, much more research is needed. Research has identified instruction in a one-to-one format for individuals with autism effective for teaching: (a) adults (i.e., 23- 24 years old), product warning labels using CTD (Dogoe, Banda, Lock, & Feinstein, 2011); (b) middle school students (i.e., 10- 14 year olds), vocabulary with objects using DI (Ganz & Flores, 2009), and science concepts using CTD (Knight, Spooner, & Browder (2013); and (c) young students (i.e., three to nine year olds), vocabulary related skills using no-no prompting (Leaf, Sheldon, & Sherman, 2010), Dolch pre-primer words using DI (Crowley McLaughlin, & Kahn, 2013), and word identification with different sets of materials using explicit instruction (Dittlinger & Lerman, 2011). Additionally, research has indicated small groups consisting of two to four students effective for teaching: (a) middle school students (i.e., 10- 14 year olds), reading comprehension using DI (Flores & Ganz, 2009), literacy skills

(Mims, Lee, Browder, Zakas, & Flynn, 2012), and (b) young students (i.e., three to nine year olds), community-based words using CTD (Ledford, Gast, Luscre, & Ayres, 2008), science concepts with objects using DI (Knight, Smith, Spooner, & Browder, 2012), and word identification using explicit instruction (Taylor, DeQuizno, & Stine, 2012). Furthermore, all but one study (Kamps, Leonard, Potucek, & Garrison-Harrell, 1995) from the literature reviews (Chiang & Lin, 2007; Walker, 2008) was conducted in a one-to-one format. Research on students with autism in small group settings is in the early stages of investigation.

One study on student engagement during a routine academic lesson conducted by, Carnahan, Musti-Rao, and Bailey (2009) employed a single-case, reversal design (i.e., ABCAC) to determine the effectiveness of interactive materials paired with music on engagement during group shared-story time. Outcomes from the two early elementary, school-aged students with autism were very different. One student's level of engagement ranged from 20% during baseline and increased to 80% during the interactive musically-based phase. A second student with autism maintained a variable rate of engagement (i.e., range 60%-100%) across both conditions. This uneven skill development may present challenges with group instruction.

Summary

Research on teaching reading to individuals with autism dates back to 1974 (Blumberg, 1974; Williams, 1974) and continues to unfold. Research focused on teaching functional word reading (Collins & Stinson, 1994; Eikeseth & Jahr, 2001; McGee, Krantz, & McClannahan, 1986; Mechling & Gast, 2003; Mechling, Gast & Langone, 2002; Rehfeldt, Lattimore, & Stromer, 2003) and content word reading (Crowley, McLaughlin, & Kahn, 2013; Dittlinger, & Lerman 2011; Mims, Lee, Browder, Zakas, & Flynn, 2012; Williams, Wright, Callahan, & Coughlan, 2002). Some of the most recent research was conducted in a small group setting (Kinght, Smith, Spooner, & Browder, 2012; Taylor, DeQuinzo, & Stine, 2012), but most research has been conducted in one-to-one formats. Each of these investigations makes a valuable contribution to understanding effective methods for teaching students with autism to read vocabulary.

Additionally, understanding the disparities between similar-aged typically developing children and children with autism (Brown, Oram-Cardy, & Johnson, 2013; Gabig, 2010; Lanter, Watson, Erickson, & Freeman, 2012; McDuffie, Yoder, & Stone, 2006) provides researchers with greater depth of knowledge, especially when word identification is a strength for some children with autism (Gabig, 2010; Nation, Clarke, Wright, & Williams, 2006). Furthermore, recognizing that characteristics of autism have an effect on vocabulary development (Brown, Oram-Cardy, & Johnson, 2013) provides essential information for researchers.

Teaching components of reading is a critical need in education (NRP, 2000) and ensuring vocabulary instruction leading to comprehension is embedded into all core-content areas is essential (NGACBP, CCSSO, 2010). This review of the literature on vocabulary instruction across all content areas reveals the scant research available teaching mathematical vocabulary, especially for students with severe disabilities. The need for additional research in teaching mathematical vocabulary to students with severe disabilities is critical to meet the needs of these individuals to be productive citizens alongside their typically developing peers.

Purpose of the Current Study

The purpose of this research is to examine the effects of using DI to teach mathematical vocabulary to early elementary students with autism. The research on this topic is limited. While the review of the previous research provides the foundation to begin this research investigation, it fills a gap by combining what we know about DI, content-related vocabulary instruction, comprehension, and small group instruction for students with autism.

The current study will extend and build upon previous research by using DI to teach core content mathematical vocabulary to students with autism. The following research questions drive the investigation:

1. What are the effects of Direct Instruction on the reading of core content mathematical vocabulary on early elementary students with autism?
2. What are the effects of Direct Instruction on the maintenance of acquired mathematical vocabulary on early elementary students with autism?
3. What are the effects of Direct Instruction on the generalization of acquired mathematical vocabulary on early elementary students with autism?
4. To what extent do teachers and parents feel instruction in mathematical vocabulary has benefitted student learning?

CHAPTER 3: METHOD

In this study, the researcher examined the effects of DI on the acquisition of early elementary mathematical vocabulary for students with autism. The independent variable in this study was the instruction that followed DI procedures with use of either examples and non-examples or taught definitions of the targeted vocabulary. The dependent variable was the number of correct responses during probe trials conducted at the beginning of each session. A multiple probe across word sets design with replication across participants, including randomization components were used to determine the effectiveness of DI procedures on student's identification, comprehension, maintenance and generalization of early elementary mathematical vocabulary.

Participants

This study consisted of several different types of participants; these included students, teachers, the researcher and the second observer. Each participant played a different role in the research investigation. The students were the participants of the research investigation, the teachers completed a social validity questionnaire, the researcher conducted the intervention, and the second observer assumed the role of an objective party to ensure credibility, reliability and validity of the investigation.

Students

The researcher used a purposive process to select three students with a special education eligibility of autism receiving their education in a separate classroom setting to serve as the research participants. Due to the learning needs of the students the Individualized Education Program (IEP) team determined that in order for progress to occur through CCSS it was necessary for each of the students to receive their education in a classroom setting that consists of (a) a low student to teacher ratio (i.e., 7:2), (b) consistent routines, and (c) extreme structure, with instruction broken into small incremental lessons. Each of the participants received 80% or more of their education among other students with autism. Eligibility for the research investigation included (a) an educational eligibility of autism on the IEP, (b) a consistent observable response mode, (c) follow the K-2 Common Core Extended Content Standards as indicated on their IEP, (d) capable of attending to task for 15 minutes, (e) exhibit small group learning behaviors, (f) exhibit audible one to two word utterances, and (g) have parental consent. Based on knowledge of the specific classroom arrangements within the school system, a district level administrator recommended the site. This was one of two locations with the highest number of students enrolled in separate classrooms for students with autism. The following participants met the eligibility criteria.

Tom. Tom was a 7-year-old African-American male with autism. According to teacher report, Tom's overall adaptive behavior was in the low-average range, his cognitive abilities were "very delayed," and his overall speech language skills were significantly below average. Tom was able to answer simple familiar questions, follow routine directions, and make simple requests. Tom’s speech was very difficult to understand because he typically mumbled and spoke using a low volume. Tom was unable to identify letters or numbers; however, when letters and numbers were presented visually during a computer activity, he accurately identified them with a memorized song.

Tom could label multiple animals. During reading instruction with Edmark™ Tom had difficulty remaining focused. Tom has had no previous experience with DI methods and group instruction primarily consisted of SMARTBoard™ activities.

Rick. Rick was a 5-year-old African-American male with autism. According to teacher report, Rick's overall adaptive behavior was in the low-average range, his cognitive abilities were noticeably lower than chronologically-aged peers, and his speech language skills were significantly below average. Rick uses a gesture such as a head nod to answer questions and point in the direction of a desired object. He had poor articulation, Rick used close approximations to words, often omitting the first or last sound of the word (e.g., ook for look, etc.) and he usually ran many words together when communicating. He followed directives; however, he inconsistently made requests, such as asking for help when needed. Rick inconsistently identified letters A-D, he was unable to identify letter sounds and numbers. Rick had not received reading instruction from a formal curriculum and has had no previous experience with DI procedures. Group instruction has been conducted employing a SMARTBoard™

Roger. Roger was 6-year-old Latino male with autism. According to teacher report, Roger's cognitive development was equivalent to a 21 to 36 month old, his adaptive behavior skills are equivalent to a 30 month old, and his speech-language skills were equivalent to a 24 month old. Roger was very vocal and used gestures such as pointing when communicating. He typically followed directions and routinely made verbal requests. Roger also used close approximations to words and had difficulty making specific letter sounds (i.e., l, qu, r) and when he used full sentences many of the words run together. Roger identified all alphabet letters and letter sounds, he expressively identified numbers 1-10. His formal reading instruction followed the Edmark™ reading program and he read approximately 20 nouns, 10 words, 10 adjectives, and color words. He had no previous experience with DI methods and group instruction had been conducted while sitting at his individual desk during morning SMARTBoard™ activities.

Researcher

The researcher was a doctoral student in the final phase of her doctoral studies with 14 years experience teaching students with autism and highly qualified certification in General Curriculum and Elementary Education along with additional certifications in Severe and Profound disabilities and Birth to kindergarten. The researcher was unfamiliar with each of the participants.

Second Observer

The second observer for this study was a full time second year special education doctoral student with nine years experience working with students with moderate-to-severe disabilities. This person was a member of the research team. The second observer served as an objective participant to ensure procedures were followed as planned and to eliminate any possibilities for researcher bias in implementation through the use of a treatment integrity checklist, and in data collection through the use of an inter-rater data collection checklist. Scores from these documents are recorded in the results section.

Setting

The investigation took place in an elementary school in a large urban school district in the southeastern United States (i.e., 18th largest in the U.S., 2009-2010). The total school population was approximately 500 students with 68 students eligible for free and reduced-priced lunch (Common Core of Data, 2013).

All intervention sessions took place at a small table located in a separate room within the school building (e.g., faculty lounge or therapy room) between 8:00 and 9:00 a.m. daily.

Procedure

The following section provides a clear explanation of the study including materials, a thorough explanation of the interventions including the independent and dependent variables, research design, and data collection procedures. Providing specific information about the study allows for replication to allow for further generalization of practice and adds to the body of research for effective practices to teach math vocabulary to early elementary students with autism.

Materials

The materials were items that can be easily assembled by a teacher who has access to a computer, printer, 3x5 note cards, and a laminator. A specific description of the word selection process and materials follows.

Vocabulary words. The list of vocabulary words was assembled from the K-2 Extended Common Core Standards developed by a professional team within the school system. These were words used by all special education teachers in the school system who teach students with moderate and severe disabilities in a separate classroom setting. The vocabulary list consisted of 89 words (see Appendix A for math vocabulary list) from each of the four domains identified by the NCTM and Common Core State Extended Standards including: (a) counting/cardinality/numbers and operations (n = 41), (b) geometry (n = 15), (c) measurement and data (n = 29), and (d) operations and algebraic thinking (n = 4). Each of these words were printed with black ink using a 36-

point comic sans MS font, cut out and glued to a 3x5 note card. To ensure durability each of the word cards were then laminated and cut out.

Word selection. A word selection phase was employed to identify a list of unknown words for each of the participants. A secondary list of common unknown words to all three participants was then produced. At this time any unknown words from the operations and algebraic thinking was combined into the counting/cardinality/numbers and operations domain. From this list, a mathematics expert from the university was consulted to identify six words from each domain (i.e., counting/cardinality/numbers and operations, geometry, measurement and data) equaling a total of 18 target vocabulary words.

The following is a detailed description of the word selection process. Prior to the word selection process, the researcher shuffled the cards creating a random order and divided them into three equal groups (i.e., 30, 30, 29). During the selection process, the researcher and one participant sat side-by-side with the researcher facing the classroom while the participant sat facing the wall to minimize distractions. Due to the large number of words in each group, the word selection process was conducted in three different segments for each participant, with each participant receiving the same set of word groups as the prior participant until all three participants had completed all three groups of word cards. During the word selection process, the researcher gave the directive, “Read this word” and waited three seconds for the participant to respond. If the participant correctly identified the word, it was placed in the known pile. If the participant did not identify the word, the researcher then incorporated a comprehension screening by asking the participant, “What does (eight) mean?” and waited three seconds for a response. If the participant gave part of the meaning, the word was placed in the known pile. If the participant did not respond or gave an incorrect response, the word was placed in the unknown pile. Participant responses were recorded on a data sheet using a "+" for known words and a "-" for unknown words. The participant only received a "-" if he could not read and give a definition for a word. This procedure was used for each participant. A set of vocabulary words was compiled based on the common unknown words of all three participants.

Word sets. From the word selection process, three sets of six words each was established by taking each wordset and reducing it to six. First, all number words larger than five were omitted. Once words six through thirty were removed from each wordset, the researcher categorized the remaining words by standard. Second, the researcher selected three words from each standard, ensuring that each began with different letter sound to control for overgeneralization of word reading during intervention. Then, random selection was employed from an EXCEL™ random generator program by assigning each word a number and inputting those numbers into the program to assign instructional order of the words in each set. Including a randomization component to the study strengthens the research results to draw causal inferences and generalize the results to individuals with similar characteristics (Kratochwill, Hitchcock, Horner, Levin, Odoms, Rindskopf, & Shadish, 2010).

Next, images or definitions were assigned to each word (see Appendix B for sources), ensuring that each pair of words (i.e., 1, 2; 3, 4; 5, 6) had one definition word and one image word. Finally, the word sets with definitions and images were approved by the university math expert with revisions made as needed.

Research Implementation

The following section provides a detailed description that was used by the researcher during each intervention. After identifying 18 common unknown words (i.e., three sets of words consisting of six words per set) for the three participants and receiving validation of the words from the university level mathematics expert, the researcher conducted a baseline phase, intervention phases, maintenance phase, and generalization phase. Data were collected from video recording of each session. Most sessions consisted of probe trials and intervention trials.

Baseline. Baseline data were collected with each participant during one-to-one trials. First, the researcher shuffled the targeted set of word cards then stated an attentional cue, “Get ready,” before beginning the baseline trial. Individual word cards were presented at eye level to the participants paired with the directive “Read this word” for each the words in the specific wordset. This process was completed with each participant first with wordset one, then wordset two, and finally wordset three. The participants were given a break between each wordset. No indication of correct or incorrect response was given to the participants. Participants only received praise for remaining engaged and in their seats. When stability of data points were established across the three participants across a minimum of three consecutive days, the participants began intervention the following day.

Probe Trials. To ensure the current level of understanding for each participant probe trials were conducted in a one on one format prior to intervention on the targeted wordset. Probe trials for non-targeted word sets were conducted intermittently to ensure current levels remained constant from baseline. Probe trials were conducted following the exact procedure of baseline. First, the participant was directed to "Read this word," if the participant correctly identified the word, the follow-up question, "What does ____ mean?" Correctly identifying and comprehending the word signified reading. Results of probe trials determined the targeted word for each session. Once a participant read the targeted word for three consecutive sessions the next word was introduced during that intervention trial. Once a participant met criteria on a wordset, maintenance probes were conducted once every five calendar days. Two separate generalization probes were conducted intermittently to establish that each participant could read the words when presented differently. Print generalization, changed the words to a green, Arial narrow, 44 font presented individually on 3 x 5 plain white index cards. Print generalization also used similar but different images, also presented in individual plain white 3 x 5 notecards. Book generalization embedded the words into sentences in a story book. All probe data were graphed.

Data Collection. Data were collected for reading words during probe trials. After a participant correctly identified the word within the three second time allotment and demonstrated comprehension of the word within the three second time allotment, a "+" was recorded for correct responding. If the participant was unable to identify the word and/or comprehend the word within the designated amount of time, the researcher recorded "-" for an incorrect or no response. Data were collected during baseline word reading (i.e., identification/comprehension), maintenance, and generalization probe trials. The data were graphed daily to monitor participants' progress, and to determine mastery of the targeted mathematical vocabulary words. Mastery criteria were met when a participant correctly read (i.e., identified/comprehension) five of the six words in the wordset over three consecutive sessions.

Data were collected using the results of the daily probe sessions described in baseline. All data were collected and graphed by the researcher. Decisions regarding student progression through the intervention were based on the graphed data.

Intervention one. Each participant entered intervention one, as a group of three, at the same time. This intervention targeted two words simultaneously, one definition and one image word, per session using Direct Instruction. As participants began to acquire word reading by identifying and comprehending the designated vocabulary words as indicated by a stable change in trend or level of three graphed data points (Kratochwill, et al., 2010) by all three participants, additional words were introduced into intervention until all six words in the set were taught.

Direct Instruction

In this study DI was conducted in a small group format consisting of three participants. During the intervention phase a DI script was used to ensure fidelity of intervention. The participants acquired word reading by identifying and comprehending vocabulary words. Identification is defined as correctly stating the word printed on the card when presented. Comprehension is defined as correctly touching an image representation of the word or correctly stating the definition provided. Direct Instruction employs both maintenance and generalization of taught skills to confirm acquisition. The following section consists of a thorough explanation of each phase along with clear identification of the dependent and independent variables.

Reading vocabulary words. During the group intervention for the vocabulary words, the researcher followed the DI script (see Appendix C for script). The intervention included word identification and word comprehension. Word identification consisted of three components for each vocabulary word: (a) model, (b) test, and (d) independent test. During the model component, the researcher began with an attentional cue directed at all three students simultaneously, “Get ready” followed by the instructional cue, “This word is (eight).” During the test component, the researcher stated, “Read this word” and gave the participants three seconds to respond chorally, followed by immediate feedback. If the participants responded correctly the researcher affirmed the answer with “Yes, (eight)”. If the participants responded incorrectly or two or more participants had no response, the researcher used an error correction procedure of simply stating, “This word is (eight)” and then reiterated the statement, “Read this word”. The researcher again waited three seconds for a response and again followed the procedure listed above. If the participants continued to respond incorrectly or have no response, the researcher used the designated procedure with each individual participant until the participants responded correctly. After each participant answered correctly, the researcher conducted the independent test component. At this time, the researcher returned to the first participant and delivered the directive, “Your turn" paired with a gesture of pointing toward the participant, followed by "Read this word” as the word card was presented at eye level in front of the participant and waited three seconds for the participant to respond. The researcher then followed the same procedure for each of the remaining participants. If at any time during the independent test a participant responded incorrectly or had no response, the researcher returned to the model component immediately followed by the independent test.

Comprehension consisted of two variations, one using definition and one using examples and nonexamples. For the math vocabulary words that were assigned definitions (e.g., set), the intervention consisted of the same three components as the word identification component: (a) model, (b) test, and (d) independent test. During the model component, the researcher stated an attentional cue directed toward all three participants simultaneously, “Get ready” followed by the model component, “(Set) means a group of items belonging together.” This definition was written on the back of the word card with embedded picture symbols (Mayer-Johnson™). During the test component, the researcher asked, “What does (set) mean?” and gave the participants three seconds to respond chorally, followed by the appropriate feedback. If the participants responded correctly the researcher affirmed the answer with “Yes, (set) means a group of items belonging together.” If the participants responded incorrectly or had no response, the researcher used an error correction procedure of simply stating “(Set) means a group of items belonging together” and then repeated the question, “What does (set) mean?” The researcher again waited three seconds for a response and again followed the procedure listed above. If the participants continued to respond incorrectly or have no response, the researcher used the designated procedure with each individual participant until the participants responded correctly. After each participant answered correctly, the researcher conducted the independent test component. At this time the researcher returned to the first participant stated, "Your turn" paired with a pointing gesture and asked, “What does (set) mean” and waited three seconds for the participant to respond.

For those words taught with images the following three components were employed for each vocabulary word: (a) model, (b) lead, and (d) test. During the model component, the researcher shuffled the five cards and placed them on the table, three examples and two nonexamples. The researcher began with an attentional cue, "Get ready" and then pointed to each image card while stating "This is (8), this is not (8), this is not (8), this is (8), this is (8)" while pointing to each specific image card (see Appendix D for list of nonexamples for each targeted word). During the model component the participants were expected to look at the specific image cards as the researcher pointed to them.

During the lead component, the researcher gave the directive, "With me," as she pointed to each specific card and provided the correct statement for the designated card, "This is (8), this is not (8), this is not (8), this is (8), this is (8)" while the participants chorally made the correct statement with the researcher.

During the test component, the researcher shuffled the cards and spread them across the table and stated an attentional "Your turn" paired with a pointing gesture toward the participant. The researcher then pointed to the card on the far right side of the designated participant stating "This is _____" and waited three seconds for the participant to respond. If the participant responded correctly, a validation statement of "Yes (eight) or (not eight)" depending on the image card to which the researcher pointed. If the participant responded incorrectly, the researcher provided an immediate error correction, "This is (eight) or (not eight)." The researcher then restated the directive "This is ____" while pointing to the same card. Once the participant correctly answered that image card, the researcher continued with each of the remaining cards for the testing component.

After the first participant completed the test component, the cards were reshuffled and placed in a row across the table in front of the next participant. The same procedure was followed for the remaining two participants. As the group met criteria for each of the words in the wordset, the specific procedure was used for each word until participants were reading all the mathematical words in the wordset.

Intervention two. The following revisions were made to intervention one to elicit progress for all three participants. The number of targeted words taught per session was reduced from two to one. Word cards were incorporated into comprehension component. Edible reinforcements were added for correct responding during testing components and on a two-minute variable ratio for sitting behavior. To reduce the number of targeted words, the researcher began with the first word generated from EXCEL™ random generator and progressed through each targeted word in sequential order as participants met criteria.

Word cards were incorporated into comprehension component for definition and image words. For definition words, during the model component the researcher held the word card beside the definition card while stating the definition. The word card remained with the definition card during the test component. During the independent test, the definition card was removed. For image words, the word card was placed on the table above the image. For example, during model component, “This is (8)" the word card (eight) was placed above the (8) card for participants to see the word (eight) and (8) went together. For images that did not match the word, the word card was withdrawn. This process continued with each of examples and nonexamples for image words.

Edible reinforcement was given to each participant for correct responding during intervention in the testing component. For example, as the researcher affirmed the correct response, "Yes, (eight)." the participant was given a small piece of the chosen reinforcer. To reinforce sitting behavior during intervention the researcher used a *MotivAider*®. The device was set for 120-second variable vibration. Prior to intervention beginning, the researcher turned the device on ensuring that edible reinforcers were readily available. During intervention, the *MotivAider*® vibrated indicating time to distribute reinforcement to participants that were sitting in chairs. The reinforcement was paired with a verbal statement such as "Good sitting." or "I like the way you are sitting."

Intervention three. Based on the graphed data from probe sessions, Tom and Rick were unable to make progress with DI instruction; it was necessary to include one-to-one supplemental instruction. After 17 sessions of DI, one-to-one instruction of CTD was added to Tom and Rick's instructional sessions. The following is a thorough description of CTD procedures.

Constant Time Delay

To further meet the individualized needs of the participants, a supplemental intervention was required for Tom and Rick. Direct Instruction procedures were replicated as closely as possible during constant time delay trials. CTD trials began with three sessions of zero delay teaching. During this time the researcher began by shuffling the word cards followed by an attentional cue, "Get ready." The researcher then stated, "Read this word." and immediately provided a model by stating the word. The researcher then waited three seconds for the participant to respond by imitating the model. If the participant correctly stated the word within the allotted time, the researcher affirmed the response with "Yes (eight)." If the participant responded incorrectly or did not respond, the researcher provided an error correction procedure of, "This word is (eight)." followed by the initial statement of, "Read this word." and again waiting three seconds for the participant to respond. This procedure was employed until the participant correctly identified the word. Comprehension followed identification of the targeted word. The researcher shuffled the three cards, one example and two nonexamples and placed them on the table. The researcher held the word card at the participants eye level and asked, "What does (eight) mean?" and immediately modeled the correct response of touching the example card with numeral 8. The researcher's finger remained on the card for three seconds waiting for the participant to respond. If the participant responded incorrectly or did not respond, the researcher picked her finger back up and stated, "This is (eight)." while physically assisting the participant to touch the image example card. The researcher removed the participant’s finger from the card and redelivered the question, "What does (eight) mean?” followed by an immediate model. When the participant correctly responded within the three-second delay, the researcher affirmed the correct response with "Yes, (eight)." If the targeted word was a definition word, the researcher began with the same question, "What does (set) mean?" followed immediately with the definition, "(a group of items belonging together)." The researcher waited three seconds for the participant to respond. If there was an incorrect response or no response, the researcher stated, (set means a group of items belonging together). When the participant correctly responded within three seconds the researcher affirmed the response with "Yes, (set means a group of items belonging together)." This procedure continued for each of the remaining words in the wordset using a zero second delay to teach mathematical vocabulary word reading.

After three sessions of zero second delay, procedures for a three second delay for correct responding was implemented. The exact same procedures from zero second delay were used during these trials, however, the participants had three seconds to provide the correct response before prompting occurred. If a participant required two or more prompts to correctly respond to a word during identification or comprehension the word was placed at the back of the pile during the session and retaught with intensive instruction during the trial. More specifically, if Rick required two or more prompts to identify the word *Saturday*, that word would be retaught using three consecutive zero second delay rounds after Rick had an opportunity to respond to the other words in the wordset. This intensive round would then be followed by a three second round to ensure correct responding of *Saturday*. This process occurred separately for either identification or comprehension. Additionally, if a participant required prompting in the three second round for three or more words, the participant received instruction using zero second delay on the full set of words the following session. This process occurred separately for either identification or comprehension. Reinforcement continued for correct responding and remaining seated during instruction.

Intervention four. This intervention was added to facilitate comprehension for all participants. Based on the graphed data, Roger was the only participant making progress with reading image words. Anecdotally, Roger was identifying two definition words in wordset one but was unable to state the definitions during probe trials. Intervention Four changed all definition words to image words. All other revisions remained in place during

Intervention Four including, instruction on one word at a time, additional viewing of word card, reinforcement for correct responding during testing component and without prompting during CTD, reinforcement for sitting on a VR2 schedule, and supplemental CTD instruction for Rick.

Independent variable. The independent variable was the DI instructional package for each of the vocabulary words, which included supplemental CTD for Tom and Rick. The same procedure was followed for each of the targeted vocabulary words for each participant. Each session lasted approximately 10 minutes. A session consisted of the designated instructional procedure for each phase during group instruction.

Dependent variable. The dependent variable was the number of words read correctly during probe trials. The probe trials were conducted prior to the intervention trials using the procedures described in the baseline section.

Maintenance. After a participant met criteria in the intervention phase by correctly reading five out of six words across three consecutive data points, the words were moved into the maintenance phase. In maintenance, instruction no longer occurred for the vocabulary words in the wordset. Maintenance probes were conducted every five calendar days following the acquisition of the wordset. The maintenance schedule remained constant for each of the mastered word sets.

Generalization. Two generalization components were involved to ascertain the participants had a comprehensive understanding of the mathematical vocabulary. The first generalization component, called print generalization, consisted of different materials. The word cards were printed in green using an Arial narrow 44-point font. Images on the image cards were generated from Internet images. Each of the words and images were presented on individual plain white 3 x 5 note cards. Using the new sets of materials, generalization probes followed the exact same procedure as baseline probes with each session conducted in a one to one format. Each word reading generalization session was conducted in a one-to-one setting.

The second generalization component, called book generalization, consisted of reading math vocabulary words embedded into a sentence followed by selecting the correct image of the word read. More specifically, the researcher created a story using PowerPoint™. In the story, each targeted mathematical vocabulary word was embedded into one sentence within the story. The targeted word was in the same color green from the print generalization component while all of the other words were in black. For comprehension, three image cards were placed on the table between the laptop and the participant. Image card choices consisted of the original set of image cards used during intervention with one example and two nonexamples; however, only one distractor was used and the other nonexamples was an example for a different word. Each page had one sentence with one target mathematical vocabulary word in the sentence. A nonrepresentational picture was included on each page; this picture was only included to make the story attractive to the participant, not to assist with word comprehension. The researcher began the trial by pulling the story up on the computer and stated, "Let's read a story." Once the PowerPoint™ story was on the computer and the participant was sitting in the chair the researcher stated, "Get ready." The researcher read all of the words in black print. When it was time for the participant to identify a green word in the story the researcher pointed under the word and waited three seconds. After the participant read the target word, the researcher finished reading the sentence. The researcher then placed the example and nonexample image cards on the table pointed to the target word in the story and asked, "What does (____) mean?" and gave the participant three seconds to respond. No instruction occurred during generalization. After the allotted three second wait, whether the participant responded correctly or not, the researcher prompted the student to turn the page and the researcher continued reading the story. This process continued for each of the remaining pages of the story. Data collection remained the same. If the participant identified the word and the correct image a "+" for correct was scored, if the participant did not correctly identify the word or the correct image a "-" was scored.

Research design. A single-case, multiple probe across word sets with replication across participants (Gast, 2010) was used to examine the effects of DI on the acquisition of mathematical vocabulary during this study. Single-case research is used when the target population is of low prevalence with systematic delivery including replication across behaviors, participants or settings (Kratochwill, et al. 2010). Participants received instruction on mathematical vocabulary words until a change in level or trend was evident from the graphed data. Once a participant demonstrated mastery of a vocabulary wordset by correctly reading five of six vocabulary words on three consecutive probe sessions, instruction on the targeted wordset ceased and a new wordset was introduced. Maintenance data were collected for two weeks following intervention.

Procedural fidelity. To ensure the intervention was executed consistently and as planned, a second observer collected procedural fidelity data during a minimum 33% of all sessions. A procedural fidelity checklist (see Appendix E) was used for each component of the research (i.e., intervention, maintenance, generalization). Procedural fidelity was calculated by dividing the total number of items by the number of items presented correctly then multiplying that quotient by 100; scores of 90% or higher are acceptable.

Interobserver agreement. To ensure accurate data collection, the second observer collected interobserver agreement data (IOA) during each component of the research. The second researcher was trained by the researcher to collect data using the procedures described in the data collection section during a minimum of 33% of sessions. The results were compared line-by-line to the researcher’s results, and the number of agreements was calculated by dividing the number of agreements by the number of agreements plus the number of disagreements and multiplying the quotient by 100. An acceptable criterion for interoberserver agreement was set for 90%.

Social validity. Social Validity was measured by administering a questionnaire to stakeholders (i.e., teachers, parents, students). The questionnaire consisted of five questions using a rating scale of 1- 4, with 1 indicating *Not At All* and 4 indicating *Very Helpful*, for each question. This instrument gave the stakeholder an opportunity to share their opinion of the study (see Appendix G). One additional question was completed by the classroom teacher to measure their opinions about the practicality of this intervention and their interest in implementing it in the classroom. Social validity helped determine if the skills taught were relevant to student learning within the context of a typical day and the importance of the skill for the student’s future.

Two days after the research was completed, social validity questionnaires for teachers, parents, and students were printed and distributed. Teachers were given the hard copies and asked to answer the questions honestly and to the best of their ability. The teachers were asked to complete the questionnaires with the participants. This was done by reading each question aloud and pointing to each answer as they read it. The participants could then circle or touch their answer choice. If the student touched their answer choice, the teacher circled their response. The teachers sent the parent questionnaires home in the participant's book bags with a request to complete the questionnaire honestly and to the best of their ability. The teachers collected all questionnaires and returned them to the researcher.

Summary

In summary, this study employed a DI intervention package to teach 18 math vocabulary words to early elementary students with autism. A multiple probe across word sets with replication across participants was used to teach the participants to read, maintain, and generalize the words. Data were collected at probe sessions and graphed at the conclusion of each session. Progression to the next phase of the study occurred when the participants met criteria for each phase.

CHAPTER 4: RESULTS

Results for treatment fidelity and interobserver agreement are presented below followed by the results for each research question.

Procedural Fidelity

To ensure each participant received consistent instruction as planned across all phases of the research and to eliminate the potential for researcher bias in implementation, procedural fidelity was completed for each of the following phases, (a) word selection probe sessions, (b) baseline probe sessions, (c) probe trial sessions, (d) intervention sessions (i.e., 1, 2, 3, 4), (e) maintenance probe sessions, and (f) generalization probe sessions. Through the use of video recorded footage, the second observer viewed 34% of sessions evenly distributed across all phases of the research. Procedural fidelity was scored from a side-by-side comparison of checklists developed for each phase of the intervention. The overall range was from 83% to 100% and a mean of 99.6%.

Individual Phases. During word selection phase and baseline phase procedural fidelity was 100%. Probe trial sessions resulted in 100%. Data collected from the intervention phases resulted in an overall range from 83% to 100% with a mean of 98%. More specifically procedural fidelity from each of the specific interventions include: (a) Intervention 1, range 83% to 100% with a mean of 94%; (b) Intervention 2, range 92% to 100% with a mean of 98.5%; (c) Intervention 3, range 96.5% to 100% with a mean of

99%; and (d) Intervention Four, range was 100%. During the maintenance probe sessions results were 100% and generalization probe results was 100%.

Interobserver reliability was collected on the dependent variable, the number of words read correctly (i.e., verbally stated, comprehended through the use images) by the second observer. The second observer insured that all data was scored objectively to eliminate the potential for researcher bias. Thirty four percent of the sessions were scored including each phase of the research, word selection, baseline probes, intervention probes, maintenance probes and generalization probes. Overall interobserver reliability ranged from 83% to 100% with a mean of 99.8%.

More specifically, results from the word selection probes, baseline probes, and probe trials were 100%. Results from constant time delay ranged from 83% to 100% with an average of 98.7%. Results from maintenance and generalization probes were 100%.

Dependent Variables

Research Question 1. What are the effects of Direct Instruction on reading core content mathematical vocabulary on early elementary students with autism?

Results from each of phase are presented in Figures 1. Each graph shows the results of individual participants across phases including (a) baseline, (b) interventions (i.e., Intervention 1, Intervention 2, Intervention 3, Intervention 4), (c) maintenance, and (d) generalization. Data collected from the interventions provide mixed results on the effects of Direct Instruction and indicates the selection of teaching methods may need to be based on individual student needs.

Roger. During baseline, Roger's performance remained stable at zero correct for all six words in all three word sets. When each of the words was presented, Roger attempted to state a close approximation to a word (e.g., wagon, balloon) and would often repeat the same word when different word cards were presented. Roger displayed good attending skills by remaining in his chair during each session, and looking at the word cards; however, he was distracted by the video camera.

Wordset One

Intervention One. Results from five probe trial sessions during Intervention 1 remained at zero. During Intervention 1, Roger remained in his seat during instruction and echoed corrected responses immediately following the researcher and peers. Roger was highly distracted during this phase by Tom's out of seat behavior and would often make comments regarding the behavior. During intervention, Roger would turn his head to watch and listen to peers when they responded and follow along during the use of examples and nonexamples. Roger attempted to repeat definitions of words during intervention; however, due to his limited articulation the words were difficult to understand and correct syllables in the phrase were acceptable during the independent test component.

Intervention Two. Results from 22 probe sessions during Intervention 2 indicate an increase in reading early mathematical vocabulary. In session 13, Roger read the word *two* and met criteria (i.e., correct responding for three consecutive sessions) in three sessions. The rapid acquisition of reading *two,* validated the need to reduce the number of target words from two to one. In session five, the second word, *week*, was introduced. *Week*, a definition word, remained a target word for four sessions. During probe trial session nine, Roger verbally identified the word *week* but was unable to state the definition. The word *week* was placed on hold and was replaced with an image word, *Saturday*. Roger immediately read the word *Saturday* and met criteria in session 20. During probe trial sessions, Roger continued to verbally identify the word *week* but was unable to state the definition. In session 24, a definition word, *little,* was introduced. Roger was able to verbally identify *little* in five sessions; however, he was unable to state the definition during probe trials. To avoid frustration, after six probe trial sessions the word *little* was placed on hold. Roger was absent from sessions 28, 29, and 30. In session 31 the word *rectangle*, an image word was introduced. Criteria were met for rectangle in eight sessions. Due to Roger's inability to accurately produce some of his letter sounds, he had a difficult time saying the word rectangle. He often replaced the */r/* with */tw/* producing a word sounding closer to *triangle*. After repeated attempts to correct this and because Roger was consistently producing the same sounds the researcher began accepting *twangle* for *rectangle*.

Intervention Four. Results from data collected during 23 probe trial sessions for Intervention 4 indicate continued progress. Transition from Intervention 2 to Intervention 4 was seamless for Roger because the target was an image word. In session one of Intervention 4 Roger was able to read the word *week*; a word that was previously placed on hold because he was unable to produce the definition during probe trial sessions. Roger met criteria for *week* in session three of Intervention 4. Again, this rapid acquisition of a previous definition word validated the change in intervention. In session eight of Intervention 4, the word *equal* was introduced. With the transition to all words taught with images Roger met criteria for *equal* in six sessions. Roger's inability to articulate */qu/* caused *equal* to sound very similar to *little*; therefore impeding his rate of acquisition. Roger met criteria (i.e., 5/6) for wordset one in 46 sessions across three intervention changes. Roger was unable to read the word *little*; however, he continued to verbally identify the word during probe trail sessions.

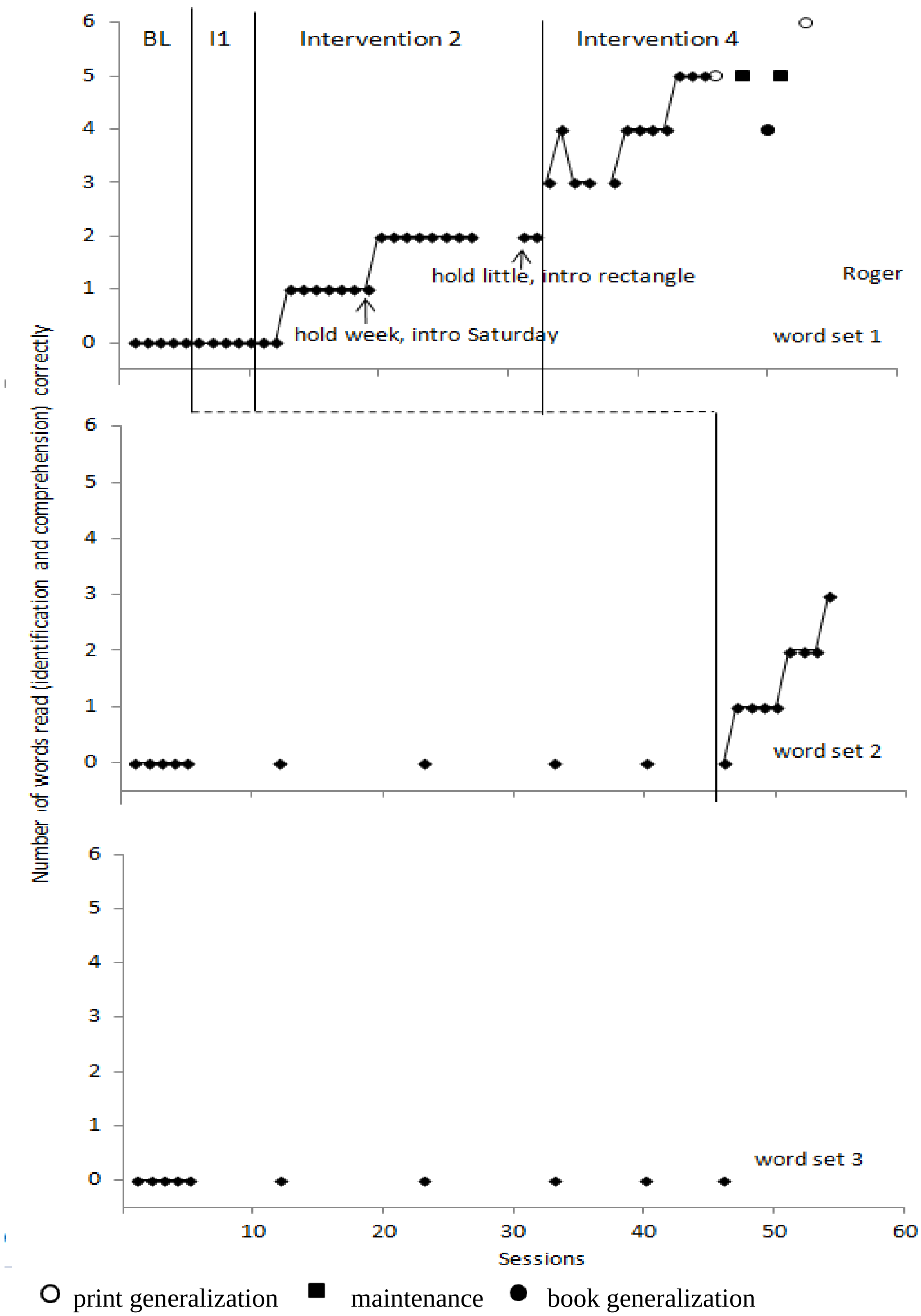

Figure 1a: Roger's correct responses across three word sets for probe sessions

Wordset Two.

Roger began intervention on wordset two during session 46. *Circle* was the first target word and Roger met criteria after three intervention sessions. Intervention on the second word, *set*, in wordset two began during session 49. Roger met criteria in five sessions. Due to the end of the school year and school wide accountability testing, intervention was terminated after session 55; however, Roger was absent from this session.

Attempting to average the rate of acquisition for words read in wordset one would provide misleading information, even with a seamless transition from Intervention 2 to Intervention 4. Data collection on early mathematical vocabulary reading exhibits promise in wordset two. The slope of acquisition was steeper in wordset two than in wordset one. Based on data collected from probe trial sessions, the average rate of acquisition for two words was four sessions. The study ended before wordset three began; therefore, there is no data for wordset three.

Tom. During baseline, Tom's performance remained stable at zero correct for all six words in all three word sets. Tom displayed good attending skills by remaining in his chair, looking at the word cards, and swiping his finger beneath each word as he attempted to identify each of the early elementary mathematical vocabulary words. Tom's verbal response to all of the words presented was either "dee," "pee," or "bee."

Intervention one. Results from five probe trial sessions during Intervention 1, remained at zero. Tom displayed the same responding behavior during probe trial sessions as he did during baseline probes. During intervention, Tom had a very difficult time remaining in his chair and engaged. He verbally echoed the correct responses of the researcher and peers; however, he was unable to respond correctly during the testing component of image comprehension (i.e., examples, nonexamples). Tom's off task behaviors resulted in the distraction of Rick and Roger during intervention.

Intervention two. Results from probe sessions during Intervention 2 remained at zero. The changes in the intervention (i.e., addition of edible reinforcement for in seat behavior on a VR2 schedule and correct responding) facilitated on task behavior for the first five sessions and decreased distractions for Rick and Roger; however, Tom's verbal responses during probe trial sessions remained the same. During intervention, Tom correctly echoed responses of the researcher and peers; however, he was unable to respond correctly during the testing component of image comprehension and required several error corrections.

Intervention three. Results from Intervention 3 continued to remain at zero. During probe sessions Tom's verbal responses remained consistent with those during baseline probes, Intervention 1 probes, and Intervention 2 probes. After session 29, during Intervention 3, Tom's teacher withdrew him from the research study. Tom was exhibiting a remarkable increase in out of seat behavior, which caused an extreme decrease in engagement. The same behavior was occurring in his regular classroom and his teacher was conducting intensive data collection sessions. At this time, Tom was also absent for six consecutive days. Attempts were made to collect probe data upon his return; however, out of seat behavior remained an issue resulting in the inability to complete the session.

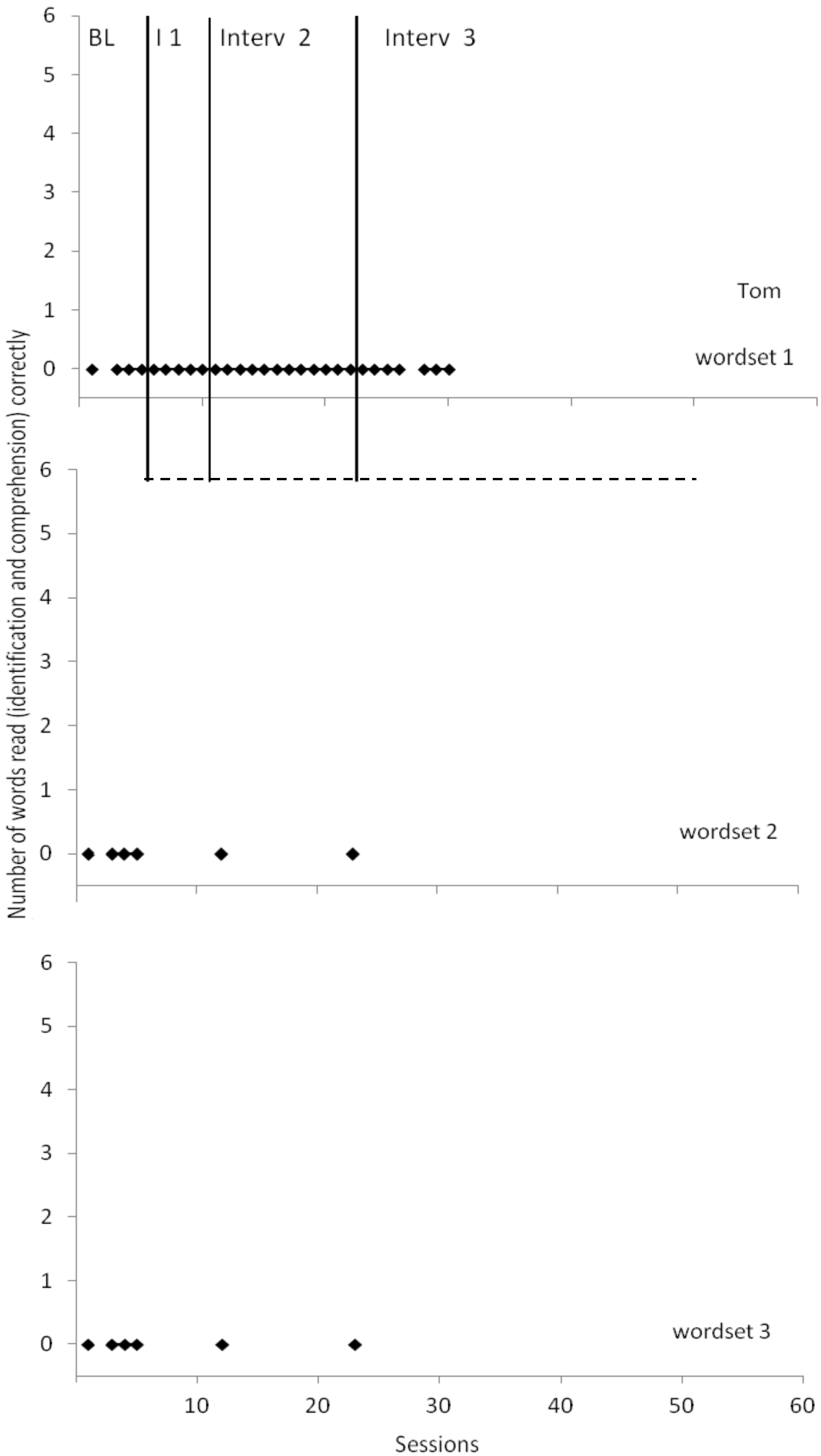

Figure 1b: Tom's responses across three word sets for probe sessions

Rick. During baseline, Rick's performance remained stable at zero correct for all six words in all three wordsets. When each of the words was presented, Rick attempted to state a close approximation to a word (e.g., pumpkin, apple, car, etc). Rick displayed good attending skills by remaining in his chair, looking at the word cards, and attempting to read each word as it was presented. Occasionally Rick engaged in self-stimulatory behavior such as flapping his hands in the air.

Intervention one. Results from five probe trial sessions during Intervention 1 remained at zero. During Intervention 1, Rick remained in his seat during instruction and echoed single word responses immediately following the researcher and peers. Due to his limited articulation, words and phrases were close approximations with phrases consisting of a comparable number of syllables more than specifically stated words. Rick continued to remain in his seat during instruction and would intermittently display self-stimulatory behavior. Rick required multiple error corrections during testing of image comprehension (i.e., use of examples and nonexamples).

Intervention two. Results from probe sessions during Intervention 2 remained at zero. The addition of edible reinforcement for correct responding and the decrease of target words from two to one improved Rick's ability to respond correctly during intervention. Rick required fewer error corrections during the testing component or image comprehension (i.e., use of examples and nonexamples). Rick was unable to retain this information over a 24 hour period to demonstrate correct responding during probe trial sessions.

Intervention three. Intervention 3 consisted of 10 sessions. Results from probe trial sessions during Intervention 3 indicated intermittent progress with reading the word *two*. Rick read the word *two* during six probe trial sessions; however, only sessions 32 and 33 consecutively. In Intervention 3 Rick was receiving intervention with CTD in a one-to-one format and DI in a small group.

Intervention four. Rick met criteria for the word *two* during the first session of Intervention 4 (i.e., session 33). Interestingly, this was three sessions after Tom was withdrawn from the research. Results from probe trial sessions indicated slow progress with CTD and DI. Rick continued to read the word *two* during four consecutive sessions. During session five of Intervention 4 (i.e., session 37), Rick did not read the word *two* but he correctly read the word *rectangle*. On session 38, Rick correctly read the words *two* and *Saturday* but did not read the word *rectangle*. On session 39, Rick correctly read *two* and *Saturday* again. On session 40, Rick read only the word *two*. Rick continued to read the word *two* for all of the remaining sessions. On session 49, Rick met criteria for the word *Saturday*. On session 48, Rick started reading the word *rectangle* again and met criteria for *rectangle* on session 50. On session 50, Rick started reading the word *equal* and met criteria for *equal* on session 52. The final intervention change to images only for comprehension increased the rate of learning for Rick.

Due to the end of the school year and school wide accountability testing, intervention ended after session 55. Rick was unable to meet criteria on wordset one; therefore, no maintenance or generalization probes were collected.

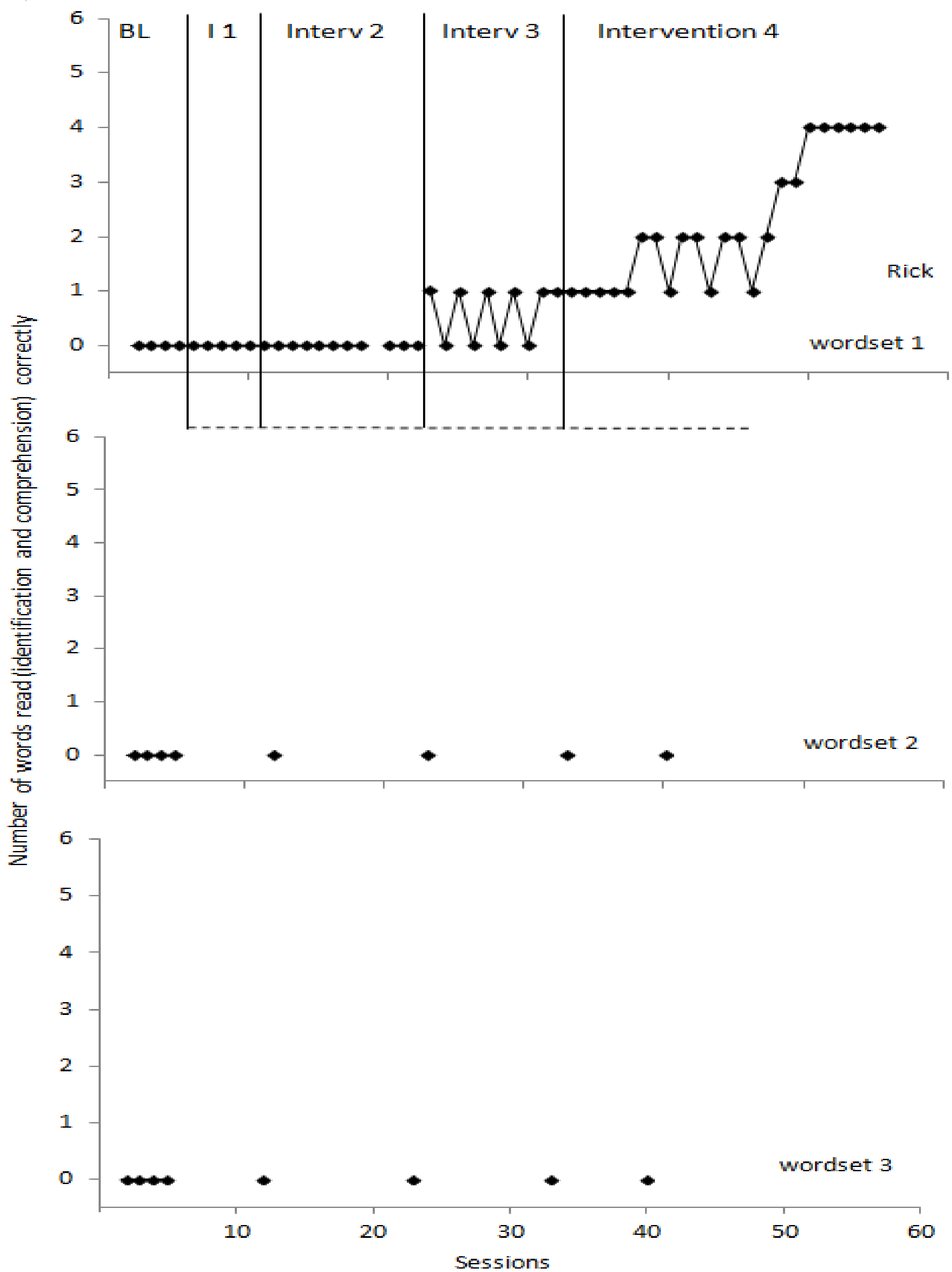

Figure 1c: Rick's responses across three word sets for probe sessions

Based on the graphed data from the CTD sessions (Figure 4), Rick's rate of progress increased during Intervention 4. With CTD intervention, Rick quickly learned that each of the words had meaning; however, it was difficult for him to identify the words over a 24-hour period. By the sixth session of Intervention 4, Rick met criteria (i.e., 5/6 correct) for comprehension of the math vocabulary words in wordset one. In the second probe session of Intervention 4 (i.e., session 33), Rick correctly touched six images for each of the six words; however, he was only able to verbally identify one word in this same CTD session with a 3-s delay. Throughout the CTD interventions Rick consistently comprehended more words than he could identify. This is a clear indication that images facilitate understanding for Rick.

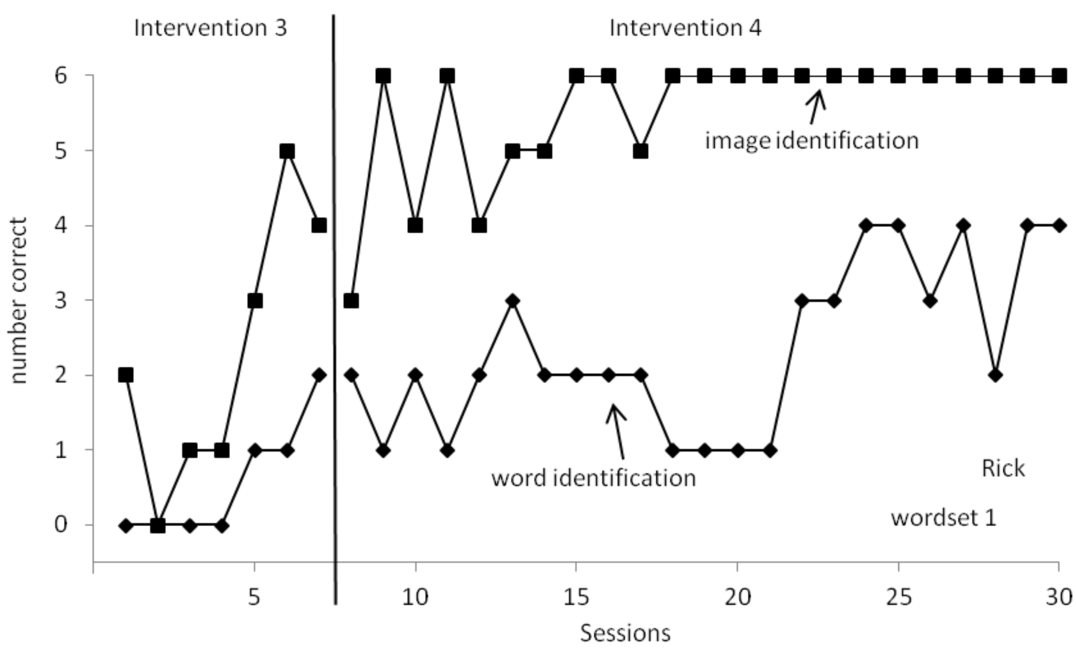

Figure 2: Rick's data from 3-s round of CTD for word identification and word comprehension

Research Question 2. What are the effects of Direct Instruction on the maintenance of acquired mathematical vocabulary on early elementary students with autism?

Maintenance Probes. Maintenance data were collected on two separate sessions, (i.e., 48, 51). Roger retained reading for the all five words from intervention. He was also able to verbally identify the word *little* but unable to select the image. No maintenance data were collected on Tom because he was removed from the study before he met criteria on wordset one. No maintenance data were collected on Rick because he did not meet criteria, five out of six words read correctly for three consecutive sessions, before the study ended.

Research Question 3. What are the effects of Direct Instruction on the generalization of acquired mathematical vocabulary on early elementary students with autism?

Generalization Probes. Two sets of generalization data were collected, print generalization and book generalization. The first generalization probe was collected on session 46; this was the session immediately following the session criteria was met for wordset one. The second print generalization probe was collected on session 53. Roger continued to correctly read five of six words with different materials. Book generalization probe was collected on session 50. Roger correctly read four of six words in wordset one; again, he verbally identified the word little but was unable to identify the image. Generalization probes occurred every four sessions and were embedded with maintenance probes. No generalization data were collected on Tom because he was removed from the study before he met criteria on wordset one. No generalization data were collected on Rick because he did not meet criteria on wordset one before the study ended.

Research Question 4. To what extent do teachers and parents feel instruction in mathematical vocabulary has benefitted student learning?

Social Validity. This study also assessed the social validity of the intervention based on the perceptions of parents, teachers and students through a questionnaire. Questionnaires were completed by all stakeholders, including two parents, two teachers, and two students.

Overall, most of the responses from the questionnaire indicated that stakeholders felt the early mathematical vocabulary instruction using DI was beneficial for the students with autism. Question one asked if the math vocabulary instruction was helpful. All of the respondents felt it was either helpful (i.e., one parent, one student) and the remaining respondents felt it was very helpful (i.e., one parent, two teachers, one student). Question two asked if student responses would have increased without instruction. The responses for this question ranged from not at all to helpful. More specifically, one teacher responded 'not at all', one teacher responded 'a little', two parents responded 'somewhat', and the two students responded, 'helpful'. Question three asked if DI was enjoyable for the students. Responses ranged from 'helpful' to 'very helpful'. One student responded that it was 'helpful' and two parents, two teachers, and one student responded that it was 'very helpful'. Question four asked if the students had a comprehensive understanding of the words taught. For this question, there were only five responses using the rating scale. Responses ranged from 'helpful to very helpful'. One student responded 'helpful' and one parent, two teachers and one student responded 'very helpful'. One parent did not respond but instead wrote a comment, "I don't know. I have not worked with him using the math vocabulary words yet".

Question five on the questionnaire was an open ended question gave, which gave parents, teachers, and students an opportunity to make specific comments regarding the use of Direct Instruction to teach early mathematical vocabulary to students with autism. One teacher commented, "The mathematical vocabulary instruction seemed beneficial to the students." The other teacher commented, "I saw a lot of improvement in the student using the Direct Instruction approach! Show me how and I will continue to teach the two students." One parent commented, "As we did not observe the sessions, and we are not familiar with the manner of instruction, I do not feel equipped to answer this. However, it was done, I know my son benefitted, and he learned many new words. I am glad he had this opportunity and definitely think it was worthwhile."

Question six was only available to teachers on the Teacher Questionnaire. It asked the teachers if they thought they would use DI to teach students mathematical vocabulary. One teacher responded, 'helpful' and the other responded 'very helpful'. Results from social validity questionnaires are in Table 1.

Table 4.1

Social Validity Data

Statement	NAA	AL	SW	H	VH
Teacher/Parent/Student					
1. Math vocabulary instruction was helpful?				1P, 1S	1P, 2T, 1S
2. Without instruction student responses would have increased?	1T	1T	2P	2S	
3. Direct Instruction was enjoyable for students?				1S	2P, 2T, 1S
4. Students have comprehensive understanding of words taught?				1S	1P, 2T, 1S
Teachers					
6. Use of DI to teach mathematical vocabulary				1T	1T

Note. NAA =Not At All. AL =A Little. SW =Somewhat. H =Helpful. VH =Very Helpful

CHAPTER 5: DISCUSSION

The primary purpose of this research was to determine if DI, a group instructional method, was effective for teaching early mathematical vocabulary to students with autism. The following research questions guided the investigation:

1. What are the effects of Direct Instruction on the reading of core content mathematical vocabulary on early elementary students with autism?
2. What are the effects of Direct Instruction on the maintenance of acquired mathematical vocabulary on early elementary students with autism?
3. What are the effects of Direct Instruction on the generalization of acquired mathematical vocabulary on early elementary students with autism?
4. To what extent do teachers and parents feel instruction in mathematical vocabulary has benefitted student learning?

A single-case, multiple-case across word sets design with replication across students was employed to determine the effects of the independent variable (i.e., DI) on the dependent variable (i.e., student ability to read early mathematical vocabulary). Results will be discussed and analyzed according to their relationship to instructional methods, students with autism, and learning vocabulary. In addition, limitations, recommendations for future research, and implications for practice will be discussed in this chapter.

Effects of Intervention on Dependent Variable

1. What are the effects of Direct Instruction on the acquisition of core content mathematical vocabulary on early elementary students with autism?

The DI procedure was implemented on three students, two kindergarteners and one first grader with autism. Findings from this study provided limited results and are discussed for each student separately.

For Roger, two revisions to the initial intervention (i.e., Intervention 2, Intervention 4) were required for a functional relationship between DI and mathematical vocabulary word reading to occur; however, because the investigation was halted prior to year end accountability testing, the functional relationship was only observable with word set one and with preliminary replication to word set two. Figure 1 represents the slope of the data was increasingly steeper from baseline to Intervention 4. Immediate visual analysis of graphed data in Intervention 1 indicated no change in slope or trend; therefore, Intervention 2 was introduced after session five. By making the following changes to Intervention 1: (a) adding edible reinforcers for correct responding and remaining seated, (b) reducing the number of targets from two to one, and (c) ensuring extended viewing of the word card, a change in slope on the graph occurred for Roger. A gradual increase in slope was stalled with the introduction of two definition words (i.e., *week*, *little*), resulting in a hold on each of these words. After session 22 of Intervention 2, Intervention 4 was introduced. Once all the words were changed to image comprehension, Roger's rate of acquisition per word averaged four sessions.

Direct Instruction was not an effective method for learning early mathematical vocabulary for Rick. Similar to Roger, two intervention changes were required before a change from baseline was detected. After 16 sessions of DI intervention without any observable changes in the data, Intervention 3 was introduced. Unlike, Roger where the revisions to group instruction using DI facilitated learning, Rick required more individualized instruction, so CTD was employed. This method paired with continued instruction with DI established intermittent progress for Rick. After 10 sessions of CTD instruction, Rick successfully read the word *two* (i.e., three consecutive days). Rick had intermittent progress with the word *Saturday* for 12 sessions, until session 49, when he was successful. Interestingly, in session 36, Rick read the word *rectangle*, which did not occur again until session 48, at which time he successfully read the word in three sessions. By the end of the intervention, Rick successfully read four words from wordset one and was demonstrating emerging success with the fifth word.

Careful examination of the CTD graph (Figure 4) suggests the use of images facilitated identification of the printed vocabulary words followed by reading the words in probe sessions. After Rick consistently demonstrated comprehension of the words, graphed probe data indicated a steady change in slope. This supports information from the NRC (2001b) describing the individualized learning needs of students with autism and Vacca's (2007) acknowledgement that images give words meaning.

Neither DI nor CTD were effective methods for Tom. After 23 sessions and three revisions to the intervention, Tom was unable to make progress in learning mathematical vocabulary. Although his situation was unique, it is a clear indication of the level of intensity and individualized instruction required for students with autism. Initially, Tom presented himself as the most engaged and receptive student with his immediate verbal responses and responsiveness to the researcher and peers. Unfortunately, the frequency, intensity, and duration of his inappropriate behaviors resulted in his withdrawal from the investigation.

Despite the revisions made to the intervention to fit the learning needs of the students, the functional relationship established with one student could not be replicated across word sets or students. The results from this investigation indicate that young children with autism have individualized learning and behavioral profiles and small group DI for an extremely novel skill (i.e., mathematics vocabulary) may not be the best method. Novel skills may be better taught in a one-to-one format (Thompson, et al., 2012); however, this is not to discount the importance of explicit instruction in mathematical vocabulary embedded into math lessons (Carter & Dean, 2006; Kostos & Shin, 2010; Lim & Pugalee, 2004; Morrison, 2011; Shamir & Baruch, 2012). Many of the studies reviewed, targeted middle-school-aged students without disabilities (Capraro & Capraro, 2006; Carter & Dean, 2006; Friedman, Kazerouni, Lax, & Weisdorf, 2011; Lim & Pugalee, 2004). Only one study (Morrison, 2011) involved middle-school aged students with disabilities. This investigation showed mixed results with the group of nonverbal students unable to meet mastery criteria. In the Kostos and Shin (2010) study, second grade students gained a better understanding of mathematical concepts after instruction on how to use vocabulary in journal entries. Shamir and Baruch (2012) taught similarly aged student mathematics vocabulary through the use of e-books. Additionally, two studies (Chard et al., 2009; Clarke et al., 2011) used a curriculum that embedded vocabulary into lessons for kindergarten students. Incorporating mathematical vocabulary into regularly scheduled mathematics instruction is the common thread throughout all of these studies, despite the specific instructional methods. The results from the current study indicate (a) the critical need for additional research and (b) that young students with autism may require explicit, instruction to meet their individual needs.

This research also suggests that students with autism must have very similar profiles before a group for intensive learning is established. Furthermore, young students with autism may need familiarization with intensive group-learning skills before instruction on new content is delivered. This can be accomplished by teaching new information on a one-to-three ratio, meaning for each new skill (i.e., mathematical vocabulary word), three known skills should be embedded. Another consideration includes choice of materials more appropriate to the student's current level of understanding (Ganz & Flores, 2009; Knight, Smith, Spooner, & Browder, 2012; Mims, Lee, Zakas, Flynn, 2012). In each of the studies, the researchers used objects or other materials (i.e., pictures, words; Mims, et al., 2012) during group instruction dependent on the students' current level of communication. By building student success within the group, they may feel more adapt with expectations for group learning. The current study may have been more effective if the images were introduced before the word identification was taught, therefore, better targeting students' individualized learning needs and level of communication while developing an understanding of the words. Interestingly, there was no negative impact from DI on Rick after CTD was added to his instructional sessions. In fact, the small group DI instruction may have expedited math vocabulary reading during CTD intervention through observational and incidental learning (Ledford, Gast, Luscre, & Ayers, 2008; Taylor, DeQuizno, & Stine, 2012).

This may be the first study to use DI in a small group setting to teach early mathematical vocabulary to students with autism. Previous research has determined that components of DI are effective in one-to-one instructional formats when teaching single word reading (Fallon, Light, McNaughton, Drager, & Hammer, 2004) for students requiring augmentative and alternative communication and specific math skills for elementary-aged students with ASD (Thompson, et al., 2012). The limited results in the Thompson, et al., (2012) study suggest that DI may be appropriate for some students with autism; however, the uniqueness of the disability may reduce its effectiveness as an exclusive method for students with autism; suggesting supplemental instruction may at times be necessary for skill acquisition. Recent research has suggested that DI integrated into an instructional package is an effective instructional method in a small group of middle-school-aged students with autism to learn science concepts (Knight, Spooner, & Browder, 2013), reading comprehension in older students with ASD (Flores & Ganz, 2009), and identification of vocabulary using objects (Ganz & Flores, 2009). Only one study investigated the use of DI to teach content specific vocabulary with early elementary students with autism (Knight, Smith, Spooner, & Browder, 2011). Unlike the current investigation, Knight et al., (2011) used objects to teach science concepts but generalization to pictures was limited.

2. What are the effects of DI on the maintenance of acquired mathematical vocabulary on early elementary students with autism?

With the limited results, two maintenance data points were collected over 10 calendar days establishing Roger's ability to retain mathematical vocabulary (Flores & Ganz, 2009; Ganz & Flores, 2009; Knight, Spooner, & Browder, 2013; Thompson, et al. 2012). During maintenance probes, Roger executed word reading exactly as he did in probe sessions; he read five words and verbally identified *little* without comprehension.

More importantly, because intervention sessions followed the school year calendar, a ten-day vacation occurred during Intervention 4. Upon returning from vacation, both Roger and Rick retained 100% of the words learned, providing some evidence that once attained young students with autism maintain taught mathematical vocabulary.

3. What are the effects of DI on the generalization of acquired mathematical vocabulary on early elementary students with autism?

Generalization probes were conducted in two separate formats: word reading and story reading. Similar to DI intervention, the word-reading format employed word cards and image cards. The original set of intervention cards was in black, Comic Sans MS, 36-point font and print generalization cards were in green, Arial narrow 44-point font. The image cards were altered by using similar images from an Internet image website (e.g., Google™ images). Data from this format were collected in sessions 48 and 51, with the first generalization session occurring during the session in which criteria were met for wordset one. Graphed data illustrate that Roger generalized five of the six vocabulary words in the first generalization session and six words in the third generalization session. The second format, story reading, employed a digital story developed by the researcher with each word placed in a separate sentence throughout the story. Story reading was delivered on an interspersed schedule with word reading format. Graphed data from the story reading generalization session demonstrate generalization for four of the six words. Given the challenges individuals with autism have with executive functioning (Hedvall, Fernell, Holm, Johnels, Gillberg, & Billstedt, 2013; Verte, Geurts, Roeyers, Oosterlaan, & Sergeant, 2006) and their focus on the detail or specifics of items, generalization has been known to hinder real-world application of attained skills; however, the results from generalization probes contradict this notion. The use of examples and nonexamples training in the intervention may be the reason for Roger's performance on the generalization measures. The intervention in this study used nonexamples during instruction, which helped Roger develop an understanding of the concept through demonstrations of what the concept did not include. This may have assisted him with learning discrimination, that not all items on the topic are always the target item (Engelmann & Carnine, 1991). Another reason for the high rate of generalization may be attributed to the materials used. Through the use of gradual changes to the instructional examples (e.g., different color and font of word cards, similar image cards), Roger was able to overlook the specific details, such as letter size and color and identify the salient features (e.g., beginning letters, formations of images).

4. To what extent do stakeholders (parents, teachers, students) feel instruction in mathematical vocabulary has benefitted student learning?

Stakeholders (parents, teachers, and students) believed the instruction was helpful and that students developed a comprehensive understanding of the targeted words. It is important to note that during the course of the investigation, parents and teachers were unaware of the specific vocabulary words taught. This was a deliberate action taken by the researcher to ensure that specific tutoring on the designated words did not occur; however, this did not take into account the regular, classroom instruction of concepts for target vocabulary such as daily calendar activities or regular math instruction. Interestingly, the lowest scores on the social validity questionnaire were derived from question two, indicating that all adult responders felt students would not have learned the vocabulary without the DI sessions. Limited research has been conducted on group instruction for young students with autism and this research includes acquisition of science concepts (Knight, Smith, Spooner, Browder, 2011) word identification (Taylor, DeQuinzo, & Stine, 2012) and group literacy (Carnahan, Musti-Rao, & Bailey, 2009); however, it is becoming evident that explicit instruction in mathematical vocabulary may be a critical need for young students with autism. Teaching vocabulary across content areas has become a priority to ensure students have the communication skills necessary to build a deep understanding of content in preparation for post-school outcomes (NGAC, CCSSO, 2010). To date, this is the first study to investigate the methods necessary to assist young students with autism to extend mathematical learning beyond execution of skills to developing understanding of terminology.

This research was conducted in the 18th largest school system in the U.S., in a school with one of the largest enrollments of students with autism receiving their education in separate classroom settings (i.e., 28). Even with these numbers, there were only three students who met the eligibility criteria for inclusion into this study; however, those three students were not similar enough to compose a cohesive group for instruction. Although the three students met the eligibility criteria to participate in the study, their individual differences had a remarkable impact on overall acquisition. For example, Roger exhibited emerging literacy skills through early phonemic awareness. This was evident during baseline probes for word sets two and three, at which time he stated a word from wordset one that began with the same letter (i.e., *week* for *Wednesday*, *Saturday* for *set*). By the same token, Rick demonstrated preemergent literacy skills with his ability to identify images that represented spoken words. This was evident early in DI intervention when Rick resorted to labeling familiar distractor images instead of identifying them as “not the target” (e.g., *triangle* instead of *not Saturday*, *flower* instead of *not two*). Rick also over-generalized a word (e. g., *two*) to all words presented in wordset one for several sessions, suggesting his inability to discriminate letters and phonemes. Furthermore, Tom was unable to identify letters, numbers, or images, despite his more advanced social and interaction skills. Tom's limited academic ability may have been the source of his lack of progress and increased problematic behavior. Consequently, using small group instruction may help meet the demands of teachers throughout the school day and may prepare students for lessons more aligned to group instruction consistent with general education settings. Because the needs and abilities of students with autism are extremely individualized, learning for this group, especially those in early elementary grades, may reap the best results when using a one-to-one instructional format. This would align with the research conducted by Carnahan, Musti-Rao, and Bailey (2009) where the researchers attempted to teach components of literacy during a regularly scheduled group lesson; however, the two early elementary students with autism were unable to meet criteria on identified targets despite the modifications made to the instructional sessions. Information from the current study with support from Carnahan et al., (2009) suggests that young students with autism may require a one-to-one format when learning new skills, which is supported by the NRC (2001b). The NRC (2001b) indicates that young children with autism "lack social and communication skills necessary for attending to an adult and learning from distal instruction" (p. 137). With this and the results from the current study in mind, group instruction may be warranted when young students with autism are engaged in maintenance and generalization skills.

Limitations and Recommendations for Future Research

This study has many limitations and recommendations for future research. First, the extended time required to develop an intervention suitable to the individual learning needs of the students resulted in inadequate outcomes. As the initial study on this topic, future research needs to begin where this research ended, using images to teach one early mathematical vocabulary word at a time with small groups that have more similar foundations (i.e., labeling of alphabet letters, preemergent literacy skills, engagement). A second limitation to this research was the eligibility criteria of the students. Using small group DI may be more appropriate for older students (e.g., grades three to five) who have more developed social and communication skills and are more familiar with the rigors of classroom instruction.

Future research needs to be conducted on either much more similarly skilled young students with autism or within older age bands (e.g., third to fifth grade, middle school) employing small group instruction such as DI (Knight, Smith, Spooner, & Browder, 2012; Ganz & Flores, 2009) or CTD (Ledford, Gast, Luscre, & Ayres, 2008). Group instruction can be more effective when all members of the group have a common foundation. For example, in the Knight et al., (2012) study early elementary students with autism learned science concepts with objects. All the participants in this investigation were at the picture discrimination stage of development, therefore, using objects during instruction was a common foundation. By conducting research using more common foundational materials, researchers can identify the effectiveness of the method. Additionally, by conducting research on small group learning with older students (Mims, Lee, Browder, Zakas, & Flynn, 2012), the students are more accustomed to the school learning skills and learning to learn is no longer the focus.

A third limitation to this research is the lack of connection between content and its application. Future research needs to investigate the effects of teaching mathematical vocabulary during math lessons, therefore, providing students with mapping (Comely & Azevedo, 2007; Friedman, et al., 2011) necessary to facilitate learning and apply relevance. Mapping suggests that when students can connect new information to previously acquired knowledge, they formulate clearer understanding of the new material. Comely and Azevedo (2007) determined that background knowledge was one of most important factors that contributed to reading comprehension for high school students. In the current study, because the instruction occurred in isolation, (i.e., outside of the classroom and outside of regular mathematical instruction), the students had no point of reference. By conducting research on mathematical vocabulary embedded into math lessons, students can associate the words with the skills.

Finally, a fourth limitation to this study is the lack of replication across word sets and students. The goal of this research was to determine if small group instruction was an effective format for teaching. This research extended information previously established on teaching vocabulary from an otherwise overlooked content area (i.e., mathematics), using a different instructional method (i.e., DI), with a specific group of students (i.e., students with autism receiving education at the separate classroom level of support). Future research needs to collapse this research endeavor into smaller components such as (a) employing DI to teach Tier one (McKeown, Beck, & Kucan, 2002; 2008) words such as functional vocabulary or nouns, (b) employing CTD to teach mathematical vocabulary in either a one-to-one format or in a small group, (c) employing DI to teach mathematical vocabulary to older students with autism or those receiving educational services at a less restrictive level of support (i.e., 40% or less special education services), or (d) employing small group format during maintenance and generalization of skills.

Investigating the listed recommendations will make significant contributions to the field and provide essential feedback to the advancement of teacher education and research-based classroom practices.

Implications for Practice

This research made a valuable contribution to stakeholders. Chiefly, students with autism can learn to read, maintain, and generalize age appropriate mathematical vocabulary when individualized instruction is provided. This is critical information for educators, especially when legislation calls for rigorous education for all students (NCLB, 2001) to be aligned with grade level content (IDEA, 2004). Learning mathematical skills, such as computation and money values, are essential for daily living; however, reading (i.e., identifying, comprehending) the terminology develops depth of understanding (NCTM, 2000) and inadvertently further develops vocabulary and communication skills, a critical skill for individuals with autism. This research signifies an area of instruction that has been overlooked. Teachers need to incorporate mathematical vocabulary instruction into math lessons. In doing this, teachers must be cognizant of each student's level of communication when planning for instruction. For students with severe disabilities this would include the use of objects, pictures, or words. Each of these symbols is considered an aided system of communication (Westling & Fox, 2009). Students using objects are at a foundational level of communication; at this level students are using actual objects as a method of communication. For example, a spoon may represent the actual word spoon or an activity requiring a spoon, such as eating or breakfast. Students using pictures have advanced to a more abstract level of communication; at this level students are using either photographs of line drawings to represent the actual word or an activity. For example, a photograph of a book may represent the word book or an activity requiring a book, such as story time. Students using words are at a sophisticated level of communication; at this level students are using words as a method of communication. For example words begin to have an exclusive meaning for an item or an activity; rectangle is the same as the shape of a rectangle and math means that it is time for math instruction.

As budget cuts continue to impact school systems across the nation, it is vital that classrooms for students with autism continue to receive the financial support necessary to maintain appropriate student and teacher ratios, especially for young students. Providing individualized instruction is critical to meet the educational needs of early elementary students with autism and may best be delivered in a one-to-one instructional format. Despite the economical advantages to group instruction, this research suggests that small group DI may not be appropriate for learning novel material but may be more suitable for maintenance and generalization of concepts.

Additionally, teaching core content vocabulary may be most effective when it is embedded into content area lessons. In doing this students have opportunities to make connections to previous information (Comey & Azevedo, 2007) while building association and capacity; therefore, generating more relevance for the students.

Furthermore, when forming groups of early elementary students with autism for instruction it is necessary for the students to be more homogenous. This can be executed by conducting quick formative or summative assessments on students. For example, when teaching reading, grouped students should have letter recognition and phonemic awareness skills. Above all, small group DI may be most effective with those students that are more familiar with group learning; this often involves older students, those that are not learning to learn. Older students (e.g., grades 3-5, 6-8) are typically more accustomed to school and classroom routines and have a better understanding of learning behaviors.

Lastly, teachers require ongoing professional development to ensure they are informed of the most current research-based practices. This knowledge could not only advance teachers' own repertoire of effective methods but also enhance student learning.

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APPENDIX A: WORD LIST

Counting/cardinality/numbers and Operations	Geometry	Measurement and Data	Operations and Algebraic Thinking
Written number 0-30 (e.g., one, two, three)	Circle	Length	Take away
More	Square	Compare	Subtract
Less	Triangle	Longer	Odd
How many?	Rectangle	Shorter	Even
Equal	Whole	Before	
Set	Big	After	
Whole	Little	Now	
Part	Small	Later	
Number line	Medium	Soon	
Before	Large	Never	
After one more	Equal	Day	
One less	Match	Week	
	Larger	Different	
	Smaller	Today	
	Half	Tomorrow	
		Yesterday	

		Schedule	
		Addition	
		Dollar	
		Penny	
		Graph	
		Sunday	
		Monday	
		Tuesday	
		Wednesday	
		Thursday	
		Friday	
		Saturday	
		Same	

APPENDIX B: DEFINITION/IMAGE SOURCES

Sources Definitions/Images

words	*Writing with Symbols* (2000)	Internet Images	Dictionary.com	http://www.amathsdictionaryforkids.com/dictionary.html
Mathematical vocabulary targets	two, Saturday, three, penny, five, Monday	rectangle, circle, square	little*, Wednesday	week*, equal, set, half, whole, day*, large
Nonexample targets	kite, forty, gate, peanuts, star, moon, add, oval, crayons, bicycle, coconut, girl, pull, tree, dog, flower, dollar, ten, taste, graph, mountains, wet, wood, take, teacher, parents, construction worker, mechanic, chair, closet, who, draw	triangle		

*adapted to participants ability

APPENDIX C: SCRIPTS

Script/Procedural Fidelity Checklist Intervention 1

Read words	Comprehend image words	Read words	Comprehend definition words
Model Component ___“Get ready” ___“This word is (_____).” **Test Component** ___“Together” ___“Read this word.” ___ 3-s wait *correct response*: ___“Yes, (_______)” *incorrect/no response from 2 or more participants*:	**Model Component** ___“Get ready” ___“This is (_), this is not (_), this is not (_), this is (_), this is (_)” stated according to card placement **Lead Component** ___“With me” ___“This is (_), this is not (_), this is not (_), this is (_), this is (_)” **Independent Test** ___ Shuffle cards ___“Your turn” ___“This is (____)?”	**Model Component** ___“Get ready” ___“This word is (_____).” **Test Component** ___“Together” ___“Read this word.” ___ 3-s wait *correct response*: ___“Yes, (____)” *incorrect/no response from 2 or more participants*: ___ This word is	**Model Component** ___“Get ready” ___“(___) means a (______).” **Test Component** ___”Together” ___“What does (___) mean?” ___ 3-s wait *correct response*: ___“Yes, (___) means (____).” *incorrect/no response from 2 or more participants*:

___ “This word is (______).” ___ “Together” ___ “Read this word.” ___ 3-s wait ___ “Yes (___)” *For those students with no/incorrect response-**1:1*** ___”This word is (_____).” ___ “Read this word.” ___ 3-s wait ___ “Yes (___)” ___ followed procedure until participant responded correctly ___ followed designated	___ 3-s wait correct response: ___“Yes, (____)” ___ move onto adjacent card incorrect response: ___“This is (___).” ___ “This is (____)?” ___ “Yes, (____)” ___ move onto adjacent card ___ completed the designated steps for each of the remaining 4 cards Next participant ___ Shuffle cards ___“Your turn” ___“This is (____).?”	(____).” ___ “Together” ___ “Read this word.” ___ 3-s wait ___ “Yes (___)” *For those students with no/incorrect response-**1:1*** ___”This word is (_____).” ___ “Read this word.” ___ 3-s-wait ___ “Yes (___)” ___ followed procedure until participant responded correctly ___ followed designated procedure for each	___“(___) means (________)” ___ “Together” ___“What does (__) mean?” ___3-s wait ___ “Yes (___) means (______)” *For those students with no/incorrect response-**1:1*** ___ “(__) means (______).” _____ “What does (__) mean?” ___“Yes (___) means (____).” ___ followed procedure until participant responded correctly ___ followed

procedure for each participant as needed **Independent test** ___"Your turn" ___"Read this word." ___ 3-s wait ___ "Yes (___)" Next participant ___"Your turn" ___"Read this word." ___ 3-s wait ___ "Yes (___)" Next participant ___"Your turn" ___"Read this word." ___ 3-s wait ___ "Yes (___)"	___ 3-s wait correct response: ___"Yes, (____)" ___ move onto adjacent card incorrect response: ___"This is (___)." ___ "This is (____)?" ___ "Yes, (____)" ___ move onto adjacent card ___ completed the designated steps for each of the remaining 4 cards Next participant ___ Shuffle cards ___"Your turn" ___"This is (____)?" ___ 3-s wait	participant as needed **Independent test** ___"Your turn" ___"Read this word." ___ 3-s wait ___ "Yes (___)" Next participant ___"Your turn" ___"Read this word." ___ 3-s wait ___ "Yes (___)" Next participant ___"Your turn" ___"Read this word." ___ 3-s wait ___ "Yes (___)"	designated procedure for each participant as needed **Independent test** ___"Your turn" ___"What does (___) mean?" ___ 3-s wait ___ "Yes (___)" Next participant ___"Your turn" ___"What does (___) mean?" ___ 3-s wait ___ "Yes (___)" Next participant ___"Your turn" ___"What does (___) mean?" ___ 3-s wait

If any participant responds incorrectly during testing, 1:1 reteaching will occur with testing immediately following.	correct response: ___“Yes, (____)” ___ move onto adjacent card incorrect response: ___“This is (___).” ___ “This is (___)?” ___ “Yes, (____)” ___ move onto adjacent card ___ completed the designated steps for each of the remaining 4 cards If any participant responds incorrectly during testing, 1:1 reteaching will occur with testing immediately following.	If any participant responds incorrectly during testing, 1:1 reteaching will occur with testing immediately following.	___ “Yes (___)” If any participant responds incorrectly during testing, 1:1 reteaching will occur with testing immediately following.

Script/Procedural Fidelity Checklist Intervention 2

Read words	Comprehend image words
Model Component ___"Get ready" ___"This word is (_____)." **Test Component** ___"Together" ___"Read this word." ___ 3-s wait *correct response*: ___"Yes, (________)" *incorrect/no response from 2 or more participants*: ___ "This word is (_______)." ___ "Together" ___ "Read this word." ___ 3-s wait ___ "Yes (___)" *For those students with no/incorrect response-**1:1*** ___"This word is (______)."	**Model Component** ___"Get ready" ___"This is (_), this is not (_), this is not (_), this is (_), this is (_)" stated according to card placement ___ target word is placed on the table above the target /image **Lead Component** ___"With me" ___"This is (_), this is not (_), this is not (_), this is (_), this is (_)" ___ target word is placed on the table above the example/image ___repeat procedure **Independent Test** ___ Shuffle cards ___"Your turn" ___"This is (____)?"

___ "Read this word." ___ 3-s wait ___ "Yes (___)" ___ followed procedure until participant responded correctly ___ followed designated procedure for each participant as needed ___ "This word is (_______)." ___ "Together" ___ "Read this word." ___ 3-s wait ___ "Yes (___)" **Independent test** ___"Your turn" ___"Read this word." ___ 3-s wait ___ "Yes (___)" Next participant ___"Your turn" ___"Read this word." ___ 3-s wait	___ 3-s wait correct response: ___"Yes, (____)" while placing target word above the target image ___ move onto adjacent card incorrect response: ___"This is (___)." ___ "This is (____)?" ___ "Yes, (____)" ___ displays target word above target symbol ___ "right" if non example ___ move onto adjacent card ___ completed the designated steps for each of the remaining 4 cards Next participant ___ Shuffle cards ___"Your turn" ___"This is (____).?" ___ 3-s wait correct response: ___"Yes, (____)"while placing target word above the image

___ "Yes (___)" Next participant ___"Your turn" ___"Read this word." ___ 3-s wait ___ "Yes (___)" If any participant responds incorrectly during testing, 1:1 reteaching will occur with testing immediately following.	___ move onto adjacent card incorrect response: ___"This is (___)." ___ "This is (____)?" ___ "Yes, (____)" ___ displays target word above target symbol ___ "right" if non example ___ move onto adjacent card ___ completed the designated steps for each of the remaining 4 cards Next participant ___ Shuffle cards ___"Your turn" ___"This is (____)?" ___ 3-s wait correct response: ___"Yes, (____)"while placing target word above the image ___ move onto adjacent card incorrect response: ___"This is (___)." ___ "This is (____)?"

	___ "Yes, (____)" ___ displays target word above target symbol ___ "right" if non example ___ move onto adjacent card ___ completed the designated steps for each of the remaining 4 cards If any participant responds incorrectly during testing, 1:1 reteaching will occur with testing immediately following.

Script/Procedural Fidelity Checklist Intervention 3

0 second	*0 second*
Reading	Comprehension
___ Teacher- "Get ready." ___ Teacher- "Read this word." "word" ___ Student- "word" ___ Teacher- "yes, word" ___ complete process for each of word in wordset	___ Teacher- "What does word mean?" touch image from array of three or give definition ___ Student- touches correct image or state definition ___ Teacher- "yes word or definition" ___complete process for each of word in wordset
3 second delay	*3 second delay*
___ Teacher- "Get ready." ___ Teacher- "Read this word." ___ Student- "word" ___ Teacher- "Yes, word."	___ Teacher- "What does word mean?" ___ Student- points to image from array of 3 or states definition ___ Teacher- "Yes, word or definition"
or waits (prompted correct) ___ Student- wait 3s ___ Teacher- "Good waiting, this word is _______." ___ Teacher- "Read this word." ___ Student- "word"	*or waits (prompted correct)* ___ Student-wait 3 seconds ___ Teacher- "Good waiting, word means _______." either touch image from array of 3 or state definition ___ Teacher- "What does word mean?"

___ Teacher- "yes, word"	___ Student- touches image or states definition ___ Teacher- "Yes, ______."
or nonwaiting errors (incorrect response) ___ Student-incorrect response ___ Teacher- "No, this word is _____." ___ "Read this word." ___ "word" ___ Teacher- "yes, word."	*or nonwaiting errors (incorrect response)* ___ Student- incorrect response ___ Teacher- "No, word means ______." either touch image from array of 3 or state definition
If for any single word, participant has 2 or more errors (waits or nonwaiting errors) that word will be placed in the back of the pile and 0s delay will be used for 3 consecutive rounds. This can be for either reading or comprehension component. ___ # of words @ 0s round	If for any single word, participant has 2 or more errors (waits or nonwaiting errors) that word will be placed in the back of the pile and 0s delay will be used for 3 consecutive rounds. This can be for either reading or comprehension component. ___ # of words @ 0s round
If participant responds with errors 3 or more words per session, the entire wordset will return to 0s delay round the following session. The participant will	If participant responds with errors 3 or more words per session, the entire wordset will return to 0s delay round the following session. The participant will have a short

have a short break (less than five minutes) then return for 3s round. ___ # of words with errors	break (less than five minutes) then return for 3s round. ___ # of words with errors

APPENDIX D: DATA COLLECTION SHEET

Word Selection Data Sheet

Participant ________________

Data Collection:

U- unknown: cannot read sword

RO- read only: incorrect or no response for definition

K- known: part or full definition and also read correctly

Date	word	U, RO, K	Date	word	U, RO, K
	One			More	
	Two			less	
	Three			How many	
	Four			Equal	
	Five			Set	
	Six			Whole	
	Seven			Part	
	Eight			Number line	
	Nine			Before	
	Ten			After	
	Eleven			One more	
	Twelve			One less	
	Thirteen			Circle	
	Fourteen			Square	
	Fifteen			Rectangle	
	Sixteen			Triangle	
	Seventeen			Big	
	Eighteen			Little	
	Nineteen			Small	
	Twenty			Medium	
	Twenty one			Large	
	Twenty two			Equal	
	Twenty three			Match	
	Twenty four			Larger	
	Twenty five			Smaller	
	Twenty six			Half	
	Twenty seven			Length	
	Twenty eight			Compare	
	Twenty nine			Longer	

	Thirty			Shorter	
	Before			After	
	Now			Later	
	Soon			Never	
	Day			Week	
	Different			Today	
	Tomorrow			Yesterday	
	Take away			Subtract	
	Odd			Even	
	Schedule			Addition	
	Dollar			Penny	
	Graph			Same	
	Sunday			Monday	
	Tuesday			Wednesday	
	Thursday			Friday	
	Saturday				

Probe Data Sheet

Participant 1 2 3

Data Collection:
+ read word correctly
- read word incorrectly or no response

Session	Wordset 1	+/-	Session	Wordset 1	+/-
	two			two	
	rectangle			rectangle	
	Saturday			Saturday	
	little			little	
	equal			equal	
	week			week	
	Wordset 2			Wordset 2	
	three			three	
	circle			circle	
	penny			penny	
	half			half	
	Wednesday			Wednesday	
	set			set	
	Wordset 3			Wordset 3	
	five			five	
	Monday			Monday	
	square			square	
	day			day	
	large			large	
	whole			whole	

Constant Time Delay Data Sheet

Participant 1 2 3

Data Collection:

+ correct answer, read word correctly

+P prompted correct, answered correctly with prompt after 3s delay

- incorrect answer, read word incorrectly

Session	Wordset 1 (read)	+/+P/-	0s req'd	Wordset 1 (comprehend)	+/+P/-	0s req'd
	two			two		
	rectangle			rectangle		
	Saturday			Saturday		
	little			little		
	equal			equal		
	week			week		
	Wordset 2			Wordset 2		
	three			three		
	circle			circle		
	penny			penny		
	half			half		
	Wednesday			Wednesday		
	set			set		
	Wordset 3			Wordset 3		
	five			five		
	Monday			Monday		
	square			square		
	day			day		
	large			large		
	whole			whole		

APPENDIX E: SOCIAL VALIDITY QUESTIONAIRE

Teacher Social Validity Questionnaire

Date: ______________________

Please complete the following questions regarding your opinion of the instructional format

1. Do you believe that the teaching session was helpful in assisting the students with mathematics vocabulary skills?

1	2	3	4	5
Not at all	a little	somewhat	helpful	very

2. Do you believe that the students' responses may have increased without the help of the intensive instruction provided?

1	2	3	4	5
Not at all	a little	somewhat	helpful	very

3. Do you feel like the students enjoyed the direct instruction approach used for mathematics instruction?

1	2	3	4	5
Not at all	a little	somewhat	helpful	very

4. Do you feel like the students have developed a comprehension base of words taught?

1	2	3	4	5
Not at all	a little	somewhat	helpful	very

5. Please provide additional comments regarding your perceptions of mathematics vocabulary instruction.

6. Do you feel that you would use direct instruction to teach your students mathematical vocabulary?

1	2	3	4	5
Not at all	a little	somewhat	helpful	very

Parent Social Validity Questionnaire

Date: ______________________

Please complete the following questions regarding your opinion of the instructional format

1. Do you believe that the teaching session was helpful in assisting your child with mathematics vocabulary skills?

1	2	3	4	5
Not at all	a little	somewhat	helpful	very

2. Do you believe that your child would have learned the mathematics vocabulary without the help of the intensive instruction provided?

1	2	3	4	5
Not at all	a little	somewhat	helpful	very

3. Based on communication from your child's teacher, do you feel like your child enjoyed the intensive (direct) instruction approach used for mathematics instruction?

1	2	3	4	5
Not at all	a little	somewhat	helpful	very

4. Do you feel like your child has better developed an understanding of words taught?

1	2	3	4	5
Not at all	a little	somewhat	helpful	very

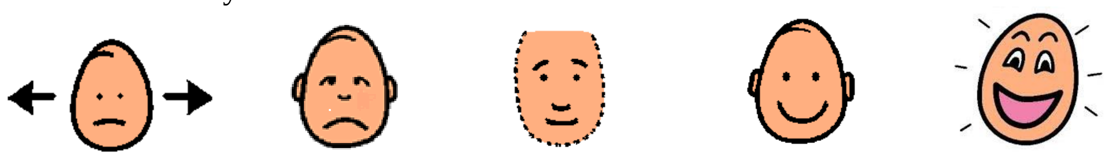
5. Please provide additional comments regarding your perceptions of mathematics vocabulary instruction.

Student Social Validity Questionnaire

Date: ______________________

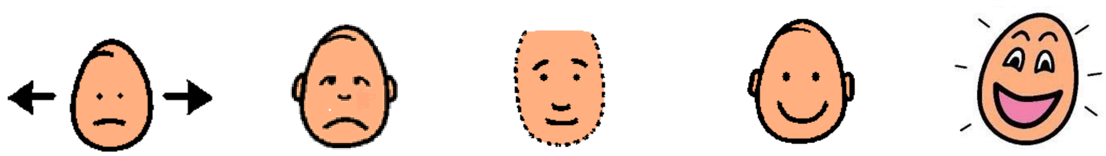
Please complete the following questions regarding your opinion of the instructional format

1. Do you believe that the teaching session was helpful for you with mathematics vocabulary skills?



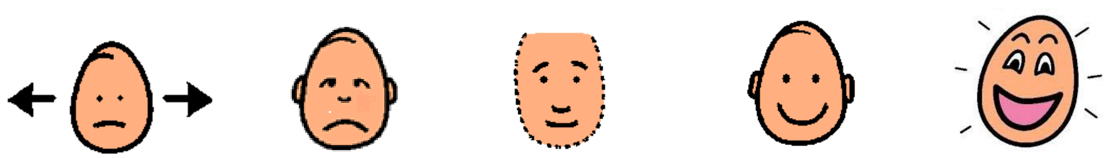
1	2	3	4	5
Not at all	a little	somewhat	helpful	very

2. Do you believe that you would have learned the math vocabulary without the help of the intensive instruction provided?



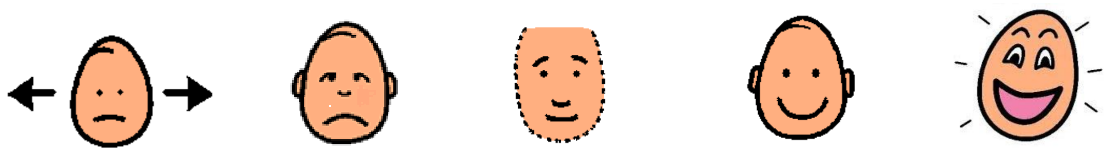
1	2	3	4	5
Not at all	a little	somewhat	helpful	very

3. Do you feel like you enjoyed the intensive teaching approach used to learn mathematics?



1	2	3	4	5
Not at all	a little	somewhat	helpful	very

4. Do you feel like you have a better understanding of words taught?



1	2	3	4	5
Not at all	a little	somewhat	helpful	very

5. Please provide additional comments regarding your perceptions of mathematics vocabulary instruction.