EFFECTS OF SUPPORTED ELECTRONIC TEXT AND EXPLICIT INSTRUCTION ON SCIENCE COMPREHENSION BY STUDENTS WITH AUTISM SPECTRUM DISORDER

by

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ABSTRACT

VICTORIA FLOYD KNIGHT. Effects of supported electronic text on science comprehension by students with autism spectrum disorder. (Under the direction of DR. FRED SPOONER)

Supported electronic text (eText), or text that has been altered to increase access and provide support to learners, may promote comprehension of science content for students with disabilities. According to CAST, *Book Builder*™ uses supported eText to promote reading for meaning for all students. Although little research has been conducted in the area of supported eText for students with autism spectrum disorders (ASD), technology (e.g., computer assisted instruction) has been used for over 35 years to instruct students with ASD in academic areas. The purpose of this study was to evaluate the effects of a supported eText and explicit instruction on the science vocabulary and comprehension of four middle school students with ASD. Researchers used a multiple probe across participants design to evaluate the *Book Builder*™ program on measures of vocabulary, literal comprehension, and application questions. Results indicated a functional relation between the Book Builder™ and explicit instruction (i.e., model-lead-test, examples and non-examples, and referral to the definition) and the number of correct responses on the probe. In addition, students were able to generalize concepts to untrained exemplars. Finally, teachers and students validate the program as practical and useful.

DEDICATIONS

I would like to dedicate this dissertation to my mothers; all three of them. First, I would like to dedicate this to the memory of my "other" mama, BJ Vanpelt. I hope you are finally at peace. Thank you for always believing in me, for making me feel like your daughter, rather than a daughter-in-law, for your strength, your grace, and your laughter.

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CHAPTER 1: INTRODUCTION

A basic understanding of science is important for all students, yet many of them lack the knowledge and skills needed to be scientifically literate. Despite continuing reform efforts underscoring the importance of a scientifically literate community, Roseman and Koppal (2008) suggest that the majority of students in the United States will graduate from high school without a fundamental "understanding of core concepts and skills in science" (p. 104). Findings from the Trends in International Mathematics and Science Study (TIMSS, 2008) indicate that although scores for the U.S. in math have increased in the past 13 years, U.S. science scores have been stagnant since 1995.

If science scores for typically developing students have not increased, science outcomes for students with disabilities are likely to be even more disappointing. For example, students with disabilities receive lower grades and do not perform as well as their typically developing peers in science (Cawley, Kahn, & Tedesco, 1989; Lynch et al., 2007). Past national reform efforts have attempted to address these deficits by recommending "science for all" (American Association for the Advancement of Science; AAAS, 1993; National Committee on Science Education Standards and Assessments of the National Research Council; NRC, 1995; 2007). Further, as of the 2007-08 school year, the IDEA and NCLB have mandated state-level assessments in science as part of adequate yearly progress (AYP; NRC, 2007). As a result, teachers must teach students with severe disabilities in ELA, math, and science. These new mandates may increase expectations for students with disabilities. NCLB permits states to include up to 1% of students with significant cognitive disabilities, including students with ASD, in alternate assessments based on alternate achievement standards (AA-AAS). Requirements of the alternate achievement standards include (a) alignment with the state's academic content standards, (b) promotion of access to the general curriculum, and (c) reflect professional judgment of the highest achievement standards possible (Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006). The call for science for all children combined with a new level of accountability challenges educators to meet the scientific literacy needs of an increasingly diverse student body, including students with autism spectrum disorders (ASD).

Unfortunately, students with significant cognitive disabilities and ASD have historically been excluded from academic content instruction due to students' deficits in communication, learning, socialization, and behavior (e.g., Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006; Courtade, Spooner, & Browder, 2007). Further compounding this issue is the lack of research-based strategies for teachers on how best to teach this population (Hess, Morrier, Heflin, & Ivey, 2008; Lerman, Vorndran, Addison, & Kuhn, 2004). Specifically, there is a scarcity in the literature for how to teach students with significant cognitive disabilities and ASD science skills and concepts. For example, a literature review conducted by Courtade, Spooner, and Browder (2007) found only 11 studies with links to science concepts. Nine of the 11 studies were studies on teaching daily living skills that were considered to have links to science (e.g., first aid skills, Spooner, Stem & Test, 1989).

Although the reasons for teaching science to students with ASD, especially students with ASD who also may experience significant cognitive disabilities, may not be readily apparent, a solid educational foundation in science can build many crucial, everyday skills, such as reasoning, problem-solving, working in teams, planning, using technology, and comparing information. According to the AAAS (1993), scientific literacy includes: (a) experience and excitement about the natural world; (b) ability to use and apply scientific processes and principles; (c) engage intelligently in scientific debate; and (d) an increase economic productivity using scientific knowledge, understanding, and skills. In addition, science is considered an important academic area since it teaches functional skills (e.g., observing, manipulating, and classifying information), as well as knowledge about the natural world (Mastropieri & Scruggs, 1992). Since the literature review in science for students with significant cognitive disabilities and ASD conducted by Courtade et al. (2007), recent evidence suggests that this population can learn grade-appropriate science material including science terms (Collins, Evans, Creech-Galloway, Karl, & Miller, 2007; Spooner, Knight, Browder, Courtade, & Jimenez, 2009), science concepts using graphic organizers to learn science vocabulary and concepts (Knight, Spooner, Browder, & Wood, 2009), steps in an inquiry-based science lesson (Courtade, 2006; Courtade, Browder, Spooner, & DiBiase, 2009), and standards-based academic science skills in physical and life science using the SDLMI strategy (Agran, Cavin, Wehmeyer, & Palmer, 2006).

Using these studies as preliminary evidence of teaching grade-level science to students with intellectual disabilities as a guide to develop science curricula, teachers can meet the needs of diverse learners by universally designing classroom goals, methods, technologies, and materials in the science classroom so that all students have opportunities for meaningful participation in grade- specific content (Rose, Meyer, &

Hitchcock, 2005; Spooner, Baker, Harris, Ahlgrim-Delzell, & Browder, 2007). CAST (2009) defines Universal Design for Learning (UDL) as "a framework for designing curricula that enable all individuals to gain knowledge, skills, and enthusiasm for learning. UDL provides rich supports for learning and reduces barriers to the curriculum while maintaining high achievement standards for all." Due to UDL's current presence in the Higher Education Opportunity Act (HEOA, 2008), it will likely be used as a model supporting the reform movement in education (e.g., National Universal Design for Learning Task Force, 2008). In fact, researchers and authors recommend UDL's use for students with ASD (Hart & Whalon, 2008) and specifically in science to address a wide range of learner interests and needs (Curry, et al., 2006; Dymond et al., 2006).

The inherent flexibility of computers can transform traditional media, such as print and speech, making it a powerful teaching tool and a critical component of UDL. Customized, adaptable, and responsive media has the potential to reduce barriers for many students (Rose, Meyer, & Hitchcock, 2005). Although UDL is a contemporary concept, technology (e.g., computer assisted instruction, assistive technology) has been used to teach various skills to students with ASD for over 35 years (Colby, 1973; Panyan, 1984). For example, Panyan (1984) conducted a review of technology use by individuals with autism and found computers to be motivating in that they increased learning rate, increased independence (reducing the amount of one to one teacher), and an increase in curiosity, attention, and socialization. More recently, Wehmeyer, Smith, Palmer, and Davies (2004) conducted a review on the use of technologies by individuals with intellectual disabilities, including students with ASD, and found evidence for technology use in both life skill (e.g., communication, mobility, activities of daily living and inclusion, employment, and leisure) and academic areas (e.g., basic skills in mathematics and word recognition). Wehmeyer et al. recommended additional research on the impact of universally designed, cognitively accessible technologies for individuals with intellectual disabilities, including students with ASD, to determine which design features of the technology can improve student outcomes. Further, Stock, Davies, Wehmeyer, and Palmer (2008) advocated further research in the area of cognitively accessible technologies for individuals with intellectual disabilities, as most examples from the literature did consider computer accessibility as a design feature.

Principles of UDL, including the design of accessible technology, can be considered when creating computer based instruction. Computer based instruction, also called computer assisted instruction (CAI), or computer-mediated instruction refers to the "application of computer software to address student needs" (The Access Center: Improving Outcomes for All Students K-8, 2009). One aspect of computer assisted instruction may be the use of hypermedia to support literacy development (Anderson-Inman & Horney, 2007; Proctor, Dalton, & Grisham, 2007). Common supports for computer assisted instruction include facilitation of content access (e.g., text to speech, TTS) or embedded supports to answer comprehension questions. Little research has been conducted in the area of particular CAI supports needed to benefit various populations of students (e.g., students with ASD or significant cognitive disabilities; Anderson-Inman & Horney).

Although additional research is needed to determine the effects of certain aspects of CAI for students with ASD, emerging research indicates CAI is beneficial for both students with ASD and cognitive disabilities (e.g., Mazzotti, Test, Wood, & Richter, 2009). CAI has been used to teach academic content and daily living skills to students with ASD and significant cognitive disabilities (e.g., Coleman-Martin, Heller, Cihak, & Irvine, 2005; Hetzroni & Tannous, 2004). For example, CAI has been used to teach academic skills to students with ASD, such as orthographic symbols of food items (i.e., participants included non-verbal children with autism; Hetzroni & Shalem, 2005), decoding and word identification (Coleman-Martin, et al.), sentence construction (Yamamoto & Miya, 1999), and basic reading and communication skills (Heimann et al., 1995). In addition, effects of CAI on communication about daily living skills (i.e., play, food, and hygiene; Hetzroni & Tannous) and problem solving (Bernard-Opitz, Sriram, & Nakoda-Saphan, 2001) also has been investigated.

For example, Heimann et al. (1995) evaluated the effects of a computer program on the reading and communication skills of three groups of students; students with ASD, students with multiple disabilities, and typical students. Evaluations of reading, phonics, and verbal and nonverbal behaviors were conducted for all students. Results indicated significant gains in pre to post scores for students with ASD; however, results for maintenance data were not significant. Authors recommended the computer program as a motivating program to foster reading and communication for students with ASD and multiple disabilities, and suggested that teachers, parents, and other stakeholders must prepare and monitor technologically based interventions.

Employing the idea of accessible technology as part of the framework of UDL, Stock et al. (2008) used a multimedia cell phone interface system and other software methods to teach 22 individuals with intellectual disabilities to use a cell phone resulting in individuals requesting less help and making fewer errors on the phone calls; however, the utility of a universally designed technology has not been yet been studied in content specific areas, such as science for students with ASD.

Supported electronic text as a component of CAI holds promise for promoting access to science for all students. According to Anderson-Inman and Horney (2007), electronic text (eText) refers to "…textual material read using a computer or some other electronic device such as a Palm, iPod, or even a LeapPad (p. 153)." Specifically, supported eText is text that been changed to promote access to content areas. Supported eText is advantageous for all readers due to the inherent flexibility of the medium. For example, eText can be manipulated to increase the font face, size, and contrast; text can be read aloud via text to speech; concepts can be clarified and explained via hyperlinks to other digital pages; and enhancements such as graphics and vocabulary definitions can be provided (Anderson-Inman & Horney). For example, one can modify text to support or scaffold comprehension and extend meaning from the text using: (a) embedded supports (e.g., in the form of coaches, who may support students on text comprehension using increasing levels of prompts); (b) hyperlinks to additional information (e.g., vocabulary definitions, background information, concept maps); and (c) multiple modes of communication (e.g., text to speech; Proctor et al., 2007). These text transformations have the potential to enhance learning in content areas for students with diverse learning needs (Anderson-Inman & Horney, 2007), including students with ASD. According to a review conducted by MacArthur, Ferretti, Okolo, and Cavalier (2001), research related to the efficacy of electronic text on literacy is mixed. Authors recommended future research should determine the effect of specific types of electronic supports with different types of learners. Further maintaining this need, Anderson-Inman and Horney suggest "…a dire need for rigorous experimental research on all types of supportive resources in eText documents, with special attention to determining the individual and combined impact of these resources on the reading comprehension of students who are struggling in school" (p. 156).

If there is a need for additional research in the broad area of supported electronic text, there is an even greater need for investigations of supported electronic text in the content areas, such as math and science, as only a few studies have examined the effects of eText on acquisition of content specific information in history and biology (e.g., Chang, Sung, & Chen, 2001; Twyman & Tindal, 2006). Further, although there is a need for evaluations related to the effects of supported eText on students' reading comprehension (Anderson-Inman, 2007), one study to date has examined the effects of electronic text on word recognition by students with ASD. A preliminary investigation conducted by Williams, Wright, Callaghan, and Coughlan (2002) evaluated the effects of traditional versus electronic books on independence, motivation, and in-context word recognition for students with ASD aged 3 to5. Results indicated that electronic books were more motivating (i.e., students spent more time on task in the computer assisted condition) and increased in-context word recognition during reading for students with ASD.

Williams et al. (2002) highlights the most common electronic reading environment, the "electronic book." To be considered an electronic book, the software in question: (a) must have electronic text presented visually; (b) must adopt similarities of a book, such as having "pages" or a table of contents; (c) must have an organizing theme (e.g., the world wide web does not have an organizing theme or a printed equivalent); and

(d) must have supportive media which makes the document easier to understand or improves it in some way (i.e., the media is related to the content; Anderson-Inman & Horney, 1997).

One example of a program which has met these standards for an electronic book is the *Book Builder*™ program, one of the universally designed accessible formats available for the public domain through CAST's website. *Book Builder*™ has a digital book-building authoring tool which allows teachers to create accessible digital storybooks for readers with disabilities. Further, *Book Builder*™ promotes "reading for meaning" in which students engage with age-appropriate texts. There are three components to the UDL frameworks. First, the recognition network (i.e., the "what of learning") is represented by *multiple means of representation* in the feature of having the text read aloud. The strategic network (i.e., the "how of learning") is the second area, and is encouraged through *multiple means of expression*. *Book Builder*™ offers built in enhancements in the form of coaches, designed to encourage connections to the text through a variety of means, such as reminding students to relate the text to their own experience and/or to visualize the images from the text. Finally, affective networks (i.e., the "why" of learning) determine the interest and motivation in reading, referred to as *multiple means of engagement* (CAST, 2009).

Significance of the Study

First, according to the recent Report from the National Autism Center's National Standards Project (2009), which examined over 775 research studies supporting interventions for individuals with ASD, academic instruction was considered an "unestablished treatment" (i.e., studies which had little to no evidence; methods are neither considered effective, nor ineffective). Only 10 of the 775 studies were considered academic interventions. This study will add to the lack of research on academic instruction for individuals with ASD. Emerging research suggests that students with ASD can learn science (e.g., Collins et al., 2007; Knight et al., 2009, Spooner et al., 2009); however, these investigations are limited because they did not examine the effects of the independent variable on comprehension of expository, science text. Further, research indicates students with ASD can learn skills in reading, such as sight words and sentence construction when technology is accessible, interesting, and motivating (Coleman-Martin, et al., 2005; Heimann et al., 1995; Yamamoto & Miya, 1999). For example, according to the National Standards Project Report, Technology-based treatments (e.g., using the medium of computers, Alpha Program, robot, PDA) are considered "emerging treatments" (i.e., one or more studies suggest favorable outcomes, but additional high quality studies are needed to confirm the treatments as effective). Further, the report recommends emerging treatments as "…fertile ground for further research…" (p. 20).

Teachers and researchers might consider appropriate science interventions which require little teacher supervision and promote student independence for students with disabilities, such as those offered through technology-based media (Mechling, 2008). Creating an inclusive and challenging learning environment for all students may be achieved as a result of implementing UDL principles. The Book Builder™ program will be used in this study as a supplemental tutoring program, which can be used in the classroom in a number of ways. For example, practical applications of this program include: (a) a pre-teaching tool, to assist in the comprehension and understanding of inquiry-based science lessons; (b) a strategy to augment existing science instruction, or

(c) a procedure to remediate instruction for students who need additional support in comprehending science material.

Purpose of the Study

The purpose of this study will be to contribute to the sparse literature on teaching science to students with ASD eligible for the alternate achievement assessment by examining the effects of supported eText, using a universally designed program on the science vocabulary and comprehension skills for students with ASD. The following research questions will be addressed:

1. What is the effect of supported electronic text using the *Book Builder*™ program on comprehension and vocabulary of middle school science content for students with ASD?
2. What is the effect of a modified version of Book Builder to include the use of explicit instruction on the science comprehension and vocabulary of middle school students with ASD?
3. How do students evaluate the supported electronic text used in this study?
4. How do general education teachers evaluate the supported electronic text used in this study?
5. How do special education teachers evaluate the supported electronic text used in this study?
6. Do general education teachers validate the strategy as useful for students in their classes?

Delimitations

The study will evaluate the efficacy of a universally designed, supported electronic text on the comprehension of expository science text and science vocabulary for students with ASD eligible for alternate assessments by employing a single subject research design. Possible delimitations of this investigation will be discussed in this section. First, this investigation will be conducted with five students with ASD and one researcher; therefore generalizations can only be made to students with ASD and researcher-implemented strategies. Second, the students in this study will be students at the middle-school level. Generalizations to other grade levels, such as high school will not be assessed. Third, the study will evaluate an intervention using specific science information, which may not generalize to other content areas.

Definitions

Alternate achievement standards- Alternate achievement standards are used for reporting adequate yearly progress for students with significant cognitive disabilities (up to 1% of the student population; Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006).

Book builder™ - “Book Builder™ is a free on-line authoring tool for educators that can be used to create supported digital books designed to improve the emerging reading skills of students with cognitive disabilities and other struggling readers. Book builder promotes ‘reading for meaning’ in which students engage with age appropriate narrative texts (CAST, 2009).”

CAST- The Center for Applied Special Education Technologies in an internationally known, nonprofit “research and development organization that works to expand learning opportunities for all individuals, especially those with disabilities, through Universal Design for Learning (CAST, 2009)."

Comprehension- The reason for reading, comprehension is the "process of simultaneously extracting and constructing meaning through interaction and involvement with written language. We use the words *extracting* and *constructing* to emphasize both the importance and the insufficiency of the text as a determinant of reading comprehension" (RAND Reading Study Group, 2002, p. 11). Comprehension includes the following components: the "person reading, the text being read, the task the reader is trying to accomplish, and the context in which the reading is being done" (Bursuck & Damer, 2007, p. 321). Text may include any printed or electronic text (RAND Reading Study Group, 2002).

Computer assisted instruction- refers to the application of computer software to address student needs (The Access Center: Improving Outcomes for All Students K-8, 2009).

Electronic text- "textual material read using a computer or some other electronic device such as a Palm, iPod or even a LeapPad (Anderson-Inman & Horney, 2007, p. 153).

Embedded support- Allows students to take full advantage of electronic text to support comprehension and extends meaningful learning (e.g., definitions of unfamiliar terms; Anderson-Inman & Horney, 2007).

Explicit Instruction- "The unambiguous, clear, and direct teaching of skills and strategies. Explicit instruction clear instructional objectives, a clear purpose for learning clear and understandable directions and explanations, adequate modeling, demonstration, guided and independent practice with corrective feedback, and valid assessments for instructional decision making" (Bursuck & Damer, 2007).

Expository text- Non-fiction text, which is "written to inform, persuade, or explain" (Bursuck & Damer, 2007, p. 322). Expository text is different from narrative text, which tells a story. Examples of expository text include content area textbooks, such as science or history texts, newspapers, reference books, encyclopedias, and most of writing online (Bursuck & Damer, 2007).

Students with ASD- Students with ASD often have difficulty with communication, socialization, and behavior (A. Simpson, Langone, & Ayres, 2004; R. L. Simpson, 2004, 20005a, 2005b; R. L. Simpson, McKee, Teeter, & Beytien, 2007; Stichter, Randolf, Gage, & Schmidt, 2007). As the fastest growing category of disability, the prevalence of ASD has increased to 1 in every 150 children in 2008 (Autism Society of America, 2007). ASD considered a "spectrum" due to the extreme variability in symptoms, age of onset and associations with other disorders/disabilities (e.g., cognitive disabilities, language delays, epilepsy; National Research Council (U.S.) Committee in Educational Interventions for Children with Autism, 2001).

Students with severe disabilities – generally encompasses students with significant disabilities in intellectual, physical, and/or social functioning, including autism (Heward, 2003).

Supported electronic text- Referred to as text that has been altered to increase access and provide support to learners (Anderson-Inman & Horney, 2007).

Universal Design for Learning (UDL)- "Universal Design for Learning (UDL) is a framework for designing curricula that enables all individuals to gain knowledge, skills, and enthusiasm, for learning. UDL provides rich supports for learning and reduces barriers to the curriculum while maintaining high achievement standards for all." (CAST, 2009).

CHAPTER 2: REVIEW OF THE LITERATURE

Despite national reform efforts in science education, average U.S. science scores have remained unchanged since 1995 (TIMMS, 2008). Students with disabilities have challenges in science resulting in lower performance outcomes than their typically developing peers (Carnine & Carnine, 2004; Cawley, Kahn, & Tedesco, 1989; Lynch et al., 2007). Out of concern for our nation to compete in a globally competitive market, science literacy for all students has been emphasized in both legislation and the National Science Education Standards; however, research-based instructional practices in science for students with severe disabilities are lacking in the literature (Rosman & Koppal, 2008; Courtade et al., 2007).

The framework of Universal Design for Learning (UDL) may be a promising approach for the inclusion of all students in grade aligned science content, as UDL promotes the idea of flexible goals, methods, materials and assessments (Rose & Mayer, 2002; Rose, Meyer, & Hitchcock, 2005). Preliminary investigations have demonstrated that teachers can learn how to align lesson plans with the concept of UDL and to implement universally designed science classes (Dymond et al., 2006; Spooner, Baker, Harris, Ahlgrim-Delzell & Browder, 2007). Technology is an essential feature of UDL due to the inherent flexibility of digital materials.

Although the concept of UDL is current, technology (e.g., computer assisted instruction) has been used to instruct individuals with ASDs for over 35 years in academics, behavior, and life skill areas (e.g., Colby, 1973; Panyan, 1984). In addition, CAI and digital materials have been used to promote comprehension for typically developing students, students with learning disabilities, and students with ASD (e.g., Heimann, Nelson, Tjus, & Gillberg; 1995; Tjus, Heimann, & Nelson, 2001).

Comprehension is a challenging skill for many students in content areas, and can be especially challenging for students with ASD (e.g., Chiang & Lin, 2007; Whalon, Otaiba, & Delano, 2009). As students enter middle and high school, students shift from reading primarily narrative text to expository text. Reading in content areas can exacerbate the reading challenges some students face (Gajria, Jitendra, Sood, & Sacks, 2007; Gersten, Fuchs, Williams, & Baker, 2001). Emerging research suggests that supported electronic text (eText) may benefit students by reducing the barriers typical of print-based instruction (Anderson-Inman & Horney, 2007). Specifically, supported electronic text (eText) may promote access to content areas, such as science, for students with disabilities; however, little research in this area has been conducted. *Book Builder*™ is a digital authoring tool in which teachers can create individualized, supported eText to promote reading for meaning in a universally designed format. If challenging, grade-aligned expository science text is presented in this supported format, students with disabilities may increase comprehension and vocabulary knowledge. The purpose of this study will be to investigate the effects of supported eText, using a universally designed program, on the science vocabulary and comprehension skills for students with ASD.

The following sections will use both conceptually and empirically-based literature to evaluate the basis of using supported eText in science for students with ASD. In the first section of the chapter, a rationale for teaching science to all students, including students with ASD will be provided. This section will examine the literature on teaching science to students with severe disabilities. In the second section of the chapter, the framework of UDL and specific research-based applications for students with severe disabilities will be discussed. The third section will review the literature on technology applications for students with disabilities, with a specific focus on technology to support learners with ASD in academic areas. This section will also reference the extant literature for supported eText and provide a rationale for its use with students with disabilities in content areas. Finally, instructional strategies to promote comprehension and vocabulary will be discussed. Since the available literature in the area of comprehension strategies for students with ASD is limited, additional research on students with high incidence disabilities will be reviewed to offer support for the current investigation. This section will focus on strategies to promote comprehension and vocabulary in content areas for individuals with disabilities.

2.1 Science for All

The disappointing reality for most students is that they will graduate from high school with little understanding of the processes, skills, and content needed to be scientifically literate (Roseman & Koppal, 2008). According to the National Science Education Standards (NSES; National Academy of Sciences, 1996), scientific literacy includes an understanding of scientific concepts, processes, and abilities which are essential for personal decision making, participation in civic responsibilities, and economic productivity. “Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena” (National Academy of Sciences, p. 22). Further, Scientific literacy involves the ability to engage in discourse about current scientific events in science, including the ability to pose and assess varying points of view based on facts and support from data (National Academy of Sciences).

Although not all students may want to pursue a career in science, science literacy for all students is essential because it teaches an understanding of the world around us and how we fit into that world (Jimenez, Spooner, Browder, DiBiase, & Knight, 2008). While all students should have access to authentic science learning, the NSES recognizes that students may acquire an understanding of science vocabulary, concepts, principles, and processes in different ways, and with varying degrees of understanding (National Academy of Sciences, 1996).

Even with this recognition of diverse learning needs from NSES, students with severe disabilities have traditionally been left out of these authentic learning experiences due to the low expectations set for the population (Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozinne, 2006; Courtade, Browder, Spooner, & DiBiase, in press). Recently, a conceptual framework has been developed to determine why the content area of science is essential for students with severe disabilities, and the expected gains as a result of science instruction. (Jimenez et al., 2008) believe the quality of life for students with severe disabilities, including students with ASD, can be enhanced through instruction in science. Involvement in the inquiry process and in authentic learning experiences in science can promote wonder and awe of the natural world, leading students to ask questions of the world around them and their place in the world. Facilitating students' natural curiosity, scientific inquiry can foster communication skills as students begin posing and investigating scientific questions. In fact, one of the earliest references to teaching science to students with “mental retardation” suggests that “…while science instruction may be desirable for normal children, it seems almost imperative for the development of language and logic in handicapped children” (Rowe, 1973). Further, learning of science processes and content can teach personally relevant skills, such as observing, manipulating, and classifying, and problem solving (Mastropieri & Scruggs, 1992). Science content and the inquiry method can be viewed as a cyclic development, in which inquiry can guide conceptual progress, and in turn, increased conceptual knowledge can advance inquiry (Metz, 2008).

Research on science instruction for students with severe disabilities is limited despite federal calls for science for all students (*A Nation at Risk*, 1983 and *Project 2061: Science for all Americans*), as well as mandates requiring accountability of students in core academic subjects (i.e., Individuals with Disabilities Education Act, IDEA, 1997; No Child Left Behind, NCLB, 2001). Although limited, there is now emerging evidence supporting the use of systematic instruction to teach science to students with moderate and severe intellectual disabilities. For example, (Courtade et al., in press; Courtade, Spooner, & Browder, 2007) conducted a literature review and found only 11 studies with links to science concepts. Nine of the 11 studies were studies on teaching “functional” skills that were considered to have links to science (e.g., first aid skills, Spooner, Stem & Test, 1989); the extent to which these skills were aligned to grade level content is unknown. Since this literature was conducted, there have been at least five studies which have targeted various systematic instructional practices (e.g., embedded instruction, constant time delay) on acquisition, maintenance, and generalization of grade aligned science content for students with moderate and severe disabilities, including ASD.

First, Agran, Cavin, Wehmeyer, and Palmer, (2006) used a multiple baseline across participants design to evaluate the Self-Determined Learning Model of Instruction (SDLMI; Agran, Blanchard, & Wehmeyer, 2000) on learning of general education content by students with moderate to severe disabilities, including ASD. The SDLMI teaches students both self-determination and self-regulation by setting goals, planning actions, evaluating progress, and adjusting goals based on progress. The intention of the intervention is to be used in combination with explicit instruction, and is meant to augment the typical instruction. Two of the three participants wanted to gain academic skills in science; specifically in the domains of physical and life science. For example, one student wanted to improve her skills in an inquiry lesson by increasing activities related to the science lab, such as gathering materials or writing answers in a log book. Another student, who was classified as having ASD and was nonverbal, wanted to learn functions of the body, and was asked to match an image of a body system to an image of the function of the body. Findings of this study demonstrate a functional relationship between the SDLMI strategy and an increase in performance of students' grade aligned targeted skills. Agran et al. suggest the need to promote active student participation and learning in the general education curriculum to actualize the vision set forth by NCLB and IDEA. In addition, the authors recommend that instruction should be carefully planned to account for individual needs to facilitate progress in academics. Finally, the authors propose additional research on academic skills for students with varying levels of support needs and the need for students with disabilities to be active agents in their own lives.

In a second study, Collins, Evans, Creech-Galloway, Karl, and Miller (2007) compared the effects of three instructional formats: (a) massed trial instruction in a special education classroom, (b) distributed trial instruction in a general education classroom, and (c) embedded instruction in a general education classroom. Using an adapted alternating treatment across conditions and participants design, researchers collected data on the acquisition and maintenance of core and functional sight words from students with moderate and severe disabilities. One of the 4 students was taught functional and core content words based on the general education science curriculum; this student was a male, aged 9, who was classified as having moderate to severe disabilities. The functional sight words were based on the students' IEP and included the words combine, refrigerate, measure, and the core content words were chosen with the assistance of a general education teacher and included the words vibration, electricity and precipitation. In the massed and distributed trial formats, students were taught using the systematic instructional procedure of simultaneous prompting, while in the embedded trial format, students were not provided with any systematic instructional procedures. In the embedded trial format, students received the same instruction as their typical peers, including teacher lecture, worksheets, and activities. There were minimal differences on the acquisition and maintenance of the core and functional words across formats; however, authors recommend caution in concluding that embedded instruction without systematic instruction is more effective than decades of research supporting the use of systematic instruction. Authors stated that results may have been different if teachers had used a strategy such as constant time delay, as students in this study had become dependent on prompts from the simultaneous prompting procedure. Finally, authors offer recommendations to teach both core content and functional words. Researchers state core content words are often more abstract than functional words, and that instruction may need to be individualized for students, letting the data guide the instructional decisions.

In another study which used an adapted alternating treatment design, McDonnell, Johnson, Polychronis, Riesen, Jameson, and Kercher (2006) compared embedded instruction in a general education context to small group instruction in a special education class with four middle school students with moderate disabilities. In both formats, teachers used constant time delay, differential reinforcement, and error correction to teach students to five definitions of vocabulary words from the general education curriculum. Target skills for 2 (i.e., both male, aged 13-15) of the 4 students were aligned with general education science curriculum, and included words such as atom, molecule, cell, and mitosis. Results of this study indicate the embedded and small group formats were both effective for developing and generalizing grade appropriate vocabulary definitions.

In a subsequent study conducted by Jameson, McDonnell, Johnson, Riesen, and Polychronis (2007), researchers compared one-to-one embedded instruction in a general education class to one-to-one massed practice instruction in a special education classroom using an alternating treatment design. Probes were conducted weekly on the students with moderate to severe disabilities to assess the acquisition of the target vocabulary during each condition. In each setting, students were taught vocabulary definitions from the general curriculum using constant time delay, differential reinforcement, and error correction. One of the 4 students was taught definitions from the general education science curriculum related to states of matter (i.e., solid, liquid, gas;

boil, melt, freeze). In contrast to the Collins et al. (2007) study, results of this study were mixed in that 2 the 4 students with moderate developmental disabilities acquired the skills more quickly in the one-to-one massed trial format in the special education context, 1 of the 4 students gained skills more quickly in the embedded trial format in the general education context, and for one of the students, there was no difference between the interventions. These results suggest that although embedded instruction may be a promising strategy for use in the general education setting, the massed trial format may be more effective for some discrete discrimination tasks (e.g., highly similar stimuli). A limitation to the study is the evaluation of the effects of the intervention on discrete responses, rather than more complex behaviors.

Finally, in a follow up investigation to the McDonnell et al. (2006) and Jameson et al. (2007) studies, Jameson, McDonnell, Polychronis, and Riesen (2008) used a multiple probe across participants design to evaluate the effects of a peer-delivered constant time delay procedure in an embedded format on targeted skills from the general education curriculum. One student, who was classified as having a severe intellectual disability (IQ= 46), was taught to describe the effects of smoking tobacco on specific body parts/organs. Peers used a constant time delay procedure to deliver the stimulus set (e.g., flashcards with words such as lungs, teeth, arms, legs) to the students with moderate disabilities. Researchers measured correct response to the stimulus sets (e.g., when presented with a flashcard that says ‘lungs,’ the correct response would be ‘Gets less air. Can get cancer’). Results indicate that the peer delivered constant time delay procedure in an embedded instructional format was effective for all students in the acquisition of grade level content. Researchers suggest that a limitation to this study was the focus on one set of discrete skills which may not be consistent with typical instruction, in which students are working on multiple goals in a school year. Similar to the Jameson et al. (2007) study, researchers recommend additional research on more complex student outcomes, such as behavior chains.

In addition to these studies specifically for students with moderate and severe disabilities, research in the area of high incidence disabilities may provide a basis for additional instructional strategies for students with developmental disabilities. For example, empirical studies on teaching methods to support conceptual and procedural understanding in science instruction for students with mild disabilities suggests using hands-on materials, graphic organizers, teaching vocabulary words in context, organizing information around the big ideas in science, and personalizing the lesson for the learner (e.g., Mastropieri & Scruggs, 1992; Scruggs, Mastropieri, & Okolo, 2008). Emerging research supports the use of some of these strategies to teach science to students with developmental disabilities (e.g., hands-on science in Courtade et al., 2009; graphic organizers and organizing information around the big ideas in Knight et al., 2009).

Research from each of these contemporary examples, taken together with the results from the Courtade et al. (2007) review, suggests that systematic instruction is an effective method for teaching science processes (i.e., inquiry) and content (i.e., vocabulary) to students with severe disabilities, including students with ASD. In addition, researchers mention the benefit of individualized instruction for this population, and discourage a “one size fits all” approach. Self-directed learning strategies (e.g., SDLMI) may be used to supplement existing academic instruction (Agran et al., 2000; Agran et al., 2006). Studies on science for this population have recommended additional research on various instructional formats needed to teach skills aligned with the general education curriculum. Further, most of the studies concentrated on teaching students to recognize vocabulary words (i.e., weather words, safety words), or to correctly perform the steps in a task analysis (e.g., of first aid skills, of safe handling and disposing of materials). Based on these research concentrations, there is a clear need for additional experimental studies which evaluate more complex skills, such as comprehension. Finally, experimental research in the area of science for mild disabilities shows that explicit instructional strategies can be used to teach concepts in content areas, such as science (Bursuck & Damer, 2007). Researchers in the area of high incidence disabilities students and students who are at risk also suggest that vocabulary can be developed to support conceptual development through the use of an explicit instruction, such as direct instruction (e.g., model-lead-test; Bursuck & Damer, 2007).

2.2 Universal Design for Learning

There is a national need to improve academic performance in our schools. Sobering reports, such as *A Nation at Risk* (1983) documenting the need for more adequate preparation of diverse students for a global economy, led to the current standards-based movement. To address current national reform efforts, and as evident from recent federal mandates such as Individuals with Disabilities Education Act (IDEA, 1997, 2004) and No Child Left Behind (NCLB, 2001), there is a need to provide effective learning opportunities for all students in the general education curriculum. Goals of these authorizations include alignment with standards, preparation of highly qualified teachers, increasing accountability for student performance (CAST, 2009). A central goal of federal policy is the promotion of access to, and progress within in the general education curriculum for students with disabilities (Wehmeyer, 2006).

Access to general education content at the secondary level can increase options for students after they graduate high school (Johnson, Stodden, Emanuel, Luecking, & Mack, 2002).What does access to the general curriculum mean? First, the general curriculum is defined by IDEA as “the same curriculum for nondisabled children” (Federal Register, 1909, p. 1259). Further, the general education curriculum includes both state academic content and standards required by the No Child Behind Act (2001; Wehmeyer, 2006). According to (Rose & Meyer, 2002), there are four components of the general curriculum: (a) goals of instruction in the form of a scope and sequence; (b) materials (including media) used by students; (c) instructional teaching methods; and (d) means of assessment to measure student progress. Traditional curricula may be one of the greatest barriers to student progress. To fully actualize the goal in which no student is to be left behind, the traditional curriculum itself must be evaluated (Rose & Meyer, 2002; Rose, Meyer, & Hitchcock, 2005).

Traditional curricula are inflexible, preventing many students from accessing general curriculum content (Meo, 2008; Rose, 2001; Rose & Meyer, 2002; Rose, Meyer, et al., 2005). The challenge for many teachers is to provide effective instruction in a classroom where students have differing abilities, needs, motivations, and preferences. To meet this challenge, Rose and colleagues from CAST have developed a “scientifically valid framework for guiding educational practice” called Universal Design for Learning (The Higher Education Opportunity Act of 2008; HEOA, Sec. 103, (24)). The promise of UDL is to address students’ diversity by offering students flexibility in the way that information is presented, flexibility of responses for participation, and flexibility for engaging in the learning process. UDL reduces the barriers to the curriculum by designing curriculum goals, methods, materials, and assessments from the onset of development with consideration of the needs of the widest range of learners. UDL abandons the historical notion in our schools that the curriculum is unattainable by some students due to *student* deficits, and shifts the focus of deficits to the *curriculum* (Meo, 2008; Rose, 2001; Rose & Meyer, 2002; Rose, Meyer, et al., 2005).

A definition of UDL is offered as part of the most recent provisions to the Higher Education Opportunity Act (HEOA, 2008) which infuses UDL into teacher preparation programs. HEOA defines UDL as a:

> scientifically valid framework for guiding educational practice (24) that: provides flexibility in the ways information is presented, in the ways students respond or demonstrate knowledge and skills, and in the ways students are engaged (24A); and reduces barriers in instruction, provides appropriate accommodations, supports, and challenges, and maintains high achievement expectations for all students, including students with disabilities and students who are limited English proficient (24B).

Consistent with this definition, UDL is characterized by three key principals of curricula: flexible means of representation (e.g., how information is presented); (b) flexible means of expression (e.g., how students respond or demonstrate knowledge); and (c) flexible means of engagement (e.g., how students are motivated to learn). For example, students with ASD and/or students with severe intellectual disabilities may not be able to “access” content in core academic areas presented through printed materials;

therefore, these students miss out on an opportunity to learn grade aligned content (Wehmeyer, 2006). Students can be provided with other means of representing the content through text-to-speech, video, audio, or other multimedia. In addition, students can show what they have learned by expressing themselves through augmentative communication devices, voice recordings, graphic displays, or a dramatic performance. Finally, students can become more fully engaged in the learning process when the levels of challenge and support are varied for the individual, and when students are given choices.

UDL is based on “universal design” (UD), a concept developed by architect Ron Mace. UD is built on the notion that features designed to accommodate a particular user may be of benefit to the majority of users. For example, curb cuts, automatic doors, video captioning, speakerphones, and other features intended to increase access for individuals with disabilities benefit many users. One of the benefits of this model is that when features are designed from the beginning to be accessible, the need for time consuming and costly retrofits is reduced; thus benefiting all users. Similarly, curricula can be universally designed such that goals, methods, materials, and assessments are created to benefit the widest range of users (Meo, 2008; Rose, 2001; Rose & Meyer, 2002; Rose et al., 2005).

Advocates of UDL see the potential for technology as a vehicle for reducing barriers to the curriculum (e.g., flexibility of digital text, text to speech options built in). Lending well to the UDL conceptual framework, technology has the power to transform teaching strategies and materials into ways that are flexible, individualized, and adaptable. The advantage of the UDL framework should be distinguished from simply using assistive technology (AT) to provide access to the general curriculum for students (Rose, Hasselberg, Stahl, & Zabala, 2005). Rose, Hasselberg, et al. (2005) view AT and UDL as two different categories, but the two are complementary in that the development of AT can enhances UDL, and vice versa. UDL considers students needs *before* curriculum development, with careful planning for material use and teaching techniques. In contrast, assistive technology considerations are usually discussed *after* curriculum goals, materials and assessments have been made (Rose, et al., 2005). Historically, technology has played an obvious role in promoting access for individuals with disabilities (e.g., Wehmeyer, 2006). For example, the role that assistive technology, such as augmentative or alternative technology has played on the lives of individuals with disabilities in home, school, and community settings is well documented in the literature (Bauch, Mittler, Hasselbring, and Cross, 2005; Rose, Hasselbring, et al., 2005; Tincani & Boutot, 2005). One of the reasons AT is strongly recommended in the literature may be the incorporation of research-based practices into the teaching of AT. Without application of evidence-based teaching practices, the use of technology will likely not engender access in and of itself for many students with low incidence disabilities (Boone & Higgins, 2003; Higgins & Boone, 1996).

UDL has been recommended by experts in the field of special education for a number of years, but the research on UDL is considerably sparse. Experts have advocated for the use of UDL to reduce curriculum barriers and increase access for individuals with high incidence disabilities (e.g., Rose, 2001; Rose & Meyer, 2002), for students with intellectual disabilities (Wehmeyer, 2006; Wehmeyer, Smith, Palmer, & Davies, 2004), and for students with ASD (Hart & Whalen, 2008). Specifically in the content areas, Curry, Cohen, and Lightbody (2006) and Dymond et al., (2006) recommend UDL as an approach for more inclusive science classes, while Meo (2008) promotes the use of UDL for high school students' comprehension of social studies material.

In addition to recommendations from the literature on the implications of UDL, there is an increase in federal support for use of UDL principles. With the reauthorization of the HEOA (National Universal Design for Learning Task Force, 2008), teachers in preparation programs must be trained in UDL methods. Two studies may provide guidance in how to prepare teachers for this shift in thinking, specifically with students with significant cognitive disabilities. In the first study Spooner, Baker, Harris, Ahlgrim-Delzell, and Browder, (2007) examined the effect of a one hour training session on the ability of 72 undergraduate and graduate students in a teacher preparation program (i.e., special and general education programs), to create universally designed lesson plans. First, participants were provided with the three principles of UDL and supporting examples. Then, using a case study of a student with either mild or severe disabilities and state competencies in either math, ELA, or science, teachers were explicitly shown how to plan for a general education lesson by incorporating the UDL principles into the lesson plan. Teachers from the control and treatment groups were given a posttest consisting of novel standards-based general education lesson plans and new case studies of a student. Results from the group experimental design show statistically significant differences were found in favor of the treatment group, indicating that both special and general education teachers acquired the skills for writing universally designed lesson plans. These results are encouraging because of the short amount of time the teachers needed to gain these skills (i.e., 1 hour), the minimal amount of time needed to write the lesson plans (i.e., 20 minutes), as well as the fact that participants studying to be general education teachers were as successful as the individuals in the special education teacher preparation program.

In a similar investigation on the effects of planning for UDL for students with severe disabilities, Dymond et al. (2006) used a qualitative method (i.e., case study method and participatory action research approach) to describe the experiences of school personnel involved in the process of incorporating a UDL framework into a general education high school science course. Researchers were interested in the process of assisting students with and without significant cognitive disabilities (SCD) to gain access to the general curriculum using UDL as a model for curriculum redesign. The course was redesigned in the areas of curriculum, instructional delivery/organization, student participation, materials, and assessment. Data were triangulated using multiple sources (e.g., interviews, documents), and multiple researchers in the assessment process (e.g., researchers directly and indirectly involved in the study). One of the primary outcomes discussed was the impact of UDL on relationships and interactions among students with SCD and typical students, including learning to work together effectively together and developing friendships. On the other hand, while the goals for students with SCD changed from socialization to learning science content during the course of the study, teachers hardly mentioned students with SCD learning science content. Overall, the findings suggest that teachers developed more of a collaborative relationship, and changed their perceptions of the roles and responsibilities to include students with SCD. Practical implications of the study reveal the following with respect to a course redesign: (a) create a realistic time frame for change; (b) involve all stakeholders in the redesign process; (c) use lesson plans to develop and communicate the UDL changes; (d) ensure appropriate supports are available to create changes; (e) provides structure to support students in redesigned activities; and (f) evaluate the impact of the redesign. Unlike the study conducted by Spooner et al. (2007), researchers found the areas of curriculum and assessment were determined to be the most difficult areas to redesign, and underestimated the amount of time needed to create change in the science course. Researchers suggest that additional information is needed about the support schools require (e.g., resources, time, incentives) to change from traditional curriculum delivery to methods that align with UDL principles.

Considering the current federal support and investment for UDL, teachers of preparation programs will likely see a shift from traditional approaches to more universally designed approaches. Unfortunately, there is scant research in the area of UDL in general, and even less research pertaining specifically to individuals with severe disabilities to guide teacher preparation programs. Only two studies in the area of UDL pertaining to students with severe disabilities have been conducted, and these two have shown mixed results. For example, the study conducted by Spooner et al. (2007) demonstrated that both general and special education teachers can learn the principles of UDL, and apply the principles efficiently and effectively to lesson plan development as part of a college course. In contrast, Dymond et al. (2006) found when UDL was applied as a programmatic change in a high school science course, additional challenges and considerations must be addressed.

2.3 Technology

Undeniably, technology has revolutionized the way that we live, work, and play. “Students must prepare for an environment where they will spend more time reading and using information on the Internet that they will reading from a printed book” (Leu, 2002). Today’s children need to be trained in the use of technology in order to become successful workers in the future (Lefever-Davis & Pearman, 2005). According to the National Center on Educational Statistics (NCES, 2001), approximately 90% of children and adolescents ages five through seven use computers. In contrast, students with disabilities are significantly less likely to use computers than their typical peers. Furthermore, individuals with cognitive disabilities are the least likely of all disability categories to have access to technology (NCES, 2001; Wehmeyer et al., 2004).

In the recent past, when the term technology was used in conjunction with the term severe disability, it was usually associated with assistive technology (AT, e.g., augmentative and alternative communication, switches to activate the computer; (Braddock, Rizzolo, Thompson, & Bell, 2004). AT has been used to increase communication and for learning academic content for students with a range of disabilities (Edyburn, 2000, 2001, 2007). While the research on the benefits of AT for individuals with disabilities is robust, there is an increased interest on researching and developing other technologies which may have the potential to increase autonomy and quality of life for individuals with disabilities by learning academic content (Braddock et al., 2004). The focus of this section will be to examine the existing literature base related to technologies (i.e., electronic and information, such as CBI, digital texts, and supported electronic text) to promote access to academic areas for individuals with disabilities. Students with severe disabilities will be the population of focus for this section;

specifically, students with ASD who also have a moderate or severe intellectual disabilities.

Rationale for Use of Technology with Students with ASD

Technology has been used to teach students with ASD for over 35 years (Colby, 1973). Colby (1973) conducted one of the first studies examining the use of computers to teach students with ASD was used a computer program consisting of various computer games organized at various levels of complexity with 17 non-verbal students with ASD. For example, in one game, the child pressed a letter on the computer and simultaneously heard the computer say the letter; in another game, the child pressed a letter (e.g., H.) and then saw a horse moving across the screen and heard the sound of horses' hooves. The purpose of the study was to increase students understanding of how letters (and sounds) form words, and how words can form expressions. Results claim that 13 of the 17 children showed an increase in involuntary speech, enjoyment and motivation. Despite these promising results, several limitations of the study warrant discussion. For example, the experimental design was not mentioned; information regarding the participants' ages and method of diagnosis was not given; and details on the length of sessions used or how long intervention lasted was not presented.

More than a decade after this study, Panyan (1984), published a review on the use of computers technology for children with autism. Although few systematic studies had been reported, Panyan reported the use of technology to promote responsiveness, attention, performance, and verbal interaction; and to improve social skills and interactions with peers. Further, Panyan offers that technology can be used to capitalize on the learning characteristics of students with ASD. Specifically, the nature of technology can (a) benefit students with ASD due to their differences in attention and motivation, (b) decrease stereotypic behaviors, (c) provide students with consistent feedback, and (d) increase language. Finally, he advocates for the use of technology as it can increase active student responses, by "allow[ing] the student to be in control of the learning situation, rather than [being] a passive participant" (p. 381).

Little has changed in the past 25 years since this initial review of the literature; well controlled studies of the effect of technology (e.g., computers) on learning for students with ASD are still lacking. The lack of research-based literature combined with the zeal of an appealing practice has lead researchers to continue to debate about the promises and limitations of technology for this population (Mineo, Ziegler, Gill, & Salkin, 2009). Some researchers caution that although there is some preliminary evidence supporting technologies for skill development, one pitfall in the field of ASD is the use of mythical practices which are not empirically based (Mineo et al.). Tincani and Boutot (2005) suggest that researchers and practitioners in the field of ASD determine the efficacy of technology for children with ASD and their families before embracing the practice with intensity. One argument against technology may be that the effects on skill development seem to be the same whether delivered by a computer or a teacher; however, the implications of this are an increase in autonomy for the student as well as an additional tool for teachers to provide one-to-one instruction (Higgins & Boone, 1996).

Despite cautions, several researchers advocate for the need of additional empirical studies on the effect of technology for students with ASD. The following section will provide information on the use of technology to support academic instruction.

Technology to Support Academic Instruction

Reviews on the efficacy of technology to support academic instruction are mixed. First, in a review of the research related to literacy (i.e., word identification, text comprehension, writing) and technology instruction, MacArhur, Ferretti, Okolo, and Cavalier (2001) suggest “cautious optimism” (p. 298) about technology’s ability to increase skills in literacy for students with disabilities. The reviewers propose that while the some of the research demonstrates that electronic texts can facilitate comprehension for a variety of students, not all attempts to do so were successful (i.e., 3 studies in favor of electronic text, 2 studies with no effects, and 1 study was inconclusive). Authors suggest the following considerations for further research: characteristics of the design, instruction that accompanies the design, the manner in which the instruction is used, and the characteristics of students using the instruction are factors to consider in further research (MacArhur et al.). In relation to electronic text and comprehension in particular, the effects may be related to the type and quality of the support as well as the extent to which the students use the enhancements. In contrast to these recommendations, Labbo and Reinking (1999) offer technology as a means to transform literacy instruction and argued for research addressing the impact of technology on student learning. Finally, Strangman and Dalton (2005) believe that the promise of technology to support literacy remains relatively unexplored, but there are emerging studies to suggest that technology can be effective in promoting vocabulary, fluency, phonics and word recognition, phonemic awareness, and comprehension. Authors recommend evaluation of technology as a means to integrate multiple approaches to representation, expression, and engagement into literacy instruction. Strangman and Dalton state that the true advantages of technology may be revealed by the more practical and flexible teaching approach it can offer teachers.

One limitation to these reviews is the lack of students with ASD in the studies evaluated. Although Edyburn (2004) found a 229% increase in the number of articles devoted to reading and technology in 2003 (*n*=16) *vs.* 2002 (*n*=7), few, if any, of these studies are specific to the population of students with ASD. Even though there has been an increased focus from NCLB (2001) on reading and other content areas (e.g., math, science), the research to support technology for academic instruction for students with ASD is lacking. Specifically, Tincani and Boutot (2005) report few studies on the effects of computer-assisted instruction for children with ASD on academics, despite the increasing presence of computers in the classroom.

Computer-based instruction for academic instruction. An emerging research base indicates Computer based instruction (CBI), also called computer assisted instruction (CAI), or computer-mediated instruction (CMI), may be used to teach academic content to students with severe disabilities, including students with ASD, specifically in the area of literacy. For example, Heimann, Nelson, Tjus, and Gillberg (1995) examined the effects of CAI, including multimedia environment, to teach reading and writing skills to students with ASD. Using a quasi-experimental design, researchers examined reading, sentence imitation, phonological awareness, and verbal behavior/motivation of three groups of students aged 6-13: (a) 11 children with ASD; (b) 9 children with “mixed” disabilities (i.e., cerebral palsy and/or cognitive disabilities); and (c) 10 typically developing children. Students used a Swedish version of a program called Alpha (Alpha Interactive Language Series/Gator Super Sentences), which used voice, animation, and videos to promote basic reading and writing skills (e.g., vocabulary development, creation of simple sentences). Using a t-test for analysis, findings suggest that all 3 groups of students made gains. Specifically, in reading and phonological awareness, there was a significant difference in the pre and post tests for students with ASD, but no significant differences in the follow up test. In addition, statistically significant effects were noted for verbal behavior, motivation and asking for help; however, sentence imitation scores were not statistically significant for students with ASD. Some limitations included the loss of data and subjects, small sample size (and therefore lack of generality to other students), and the length of intervention for students with ASD and was twice as long as the typical students. Authors recommended the computer program as a motivating program to foster reading and communication for students with ASD and multiple disabilities, and suggested that teachers, parents, and other stakeholders must prepare and monitor technologically based interventions. Finally, authors recommended the need to examine the possibilities and limitations of computer-assisted instruction for students with ASD.

In a follow-up study, Tjus, Heimann, and Nelson, (2001) observed the interactions between students and teachers using the same CBI program (i.e., a Swedish version of the Alpha). Using a quasi-experimental design, the behaviors of 11 students with ASD and 9 students with “mixed intellectual disabilities” (i.e., motor impairments, sensory impairments, and Down syndrome) were correlated to teacher behaviors. Measures of student behavior included complying with directions, ignoring directions, and verbally expressing ones’ self; measures of teacher behaviors included procedural or content comments, directions, praises, and enjoyment. Results of this study were analyzed using non-parametric statistics, such as a Wilcoxon and Mann-Whitney. Findings showed that all students increased verbal expressions, but students with ASD also increased enjoyment and willingness to ask for help. In addition, teachers reduced the programming prompts over time, especially with the students with ASD. Authors recommend additional CBI studies to include students with varying degrees of language ability.

Hetzroni and Shalem (2005) extended the evidence for students of varying degrees of language ability by examining the effects of CBI on acquisition and maintenance of preferred food symbols of preferred food items for 6 nonverbal students with autism aged 10-13. Using a multiple probe across participants to design, researchers used a seven step multi-fading procedure to teach the symbols, beginning with the original logo and ending with a standard format of the word. When students made a correct match they received a smiley face as reinforcement; and when they matched the logos accurately two consecutive times, instruction on the next logo was given. Measures of student acquisition of the 8 food items were determined by student's ability to match the words to actual food items. Results demonstrated a functional relationship between the CBI and acquisition of food item symbols for all students. Authors suggest additional studies using computer-assisted feigning procedures, as well as studies which include additional fading steps and generalization of food items.

Similarly, Coleman-Martin, Heller, Cihak, and Irvine, (2005) evaluated computer-assisted instruction using the nonverbal reading approach (NRA) on word identification by three students with severe speech impairments and varying disabilities (i.e., cerebral palsy, autism, and brain injury). All students could read at a minimum of a first grade level and none of them had received training on the NRA prior to the investigation. Using a multiple conditions design, examiners compared the effects of three conditions (a) teacher instruction only, (b) teacher and CAI, and (c) CAI only on word identification of 15 target words. The NRA uses systematic instruction to teach students a meta-cognitive approach for using internal speech to decode words. In this study, the target words were presented on the computer using power point software in combination with an auditory component. For each word, the first slide showed the student the word and modeled sounding out the word. Consistent with other studies on the efficacy of the NRA, results demonstrated that all 3 students were able to acquire target words using the NRA during all conditions. Further, teachers reported the use of the technology to be as effective, or even more effective than teacher delivered instruction, which freed the teachers' time, and permitted students to work autonomously. Teachers felt that the efficacy of the CAI delivered NRA was due to the consistency in presentation of materials, exact script, and inherently motivating computer instruction. One limitation of this and other CAI studies is the tendency for technology to be slow or unreliable.

Although these and other CBI approaches have focused on word and symbol identification and sentence imitation, one study examined the effects of CBI on the complex skill of sentence construction. Yamamoto and Miya (1999) studied the effects of computer based instructional program to teach 3 Japanese students with ASD aged 6-10 sentence construction using a quasi-experimental design. All students used one to two word utterances and had limited reading and writing skills. After students were trained on computer operating skills, researchers assessed the students' ability to: (a) vocally produce a correct sentence, and (b) construct a sentence on the computer in response to a picture sample on the computer. Students were required to construct a sentence which consisted of a subject, object, and a verb (e.g., Mr. Yamamoto washes an apple"). Results indicate that all students were able to generalize the construction of 24 untrained sentences from three trained sentences and to generalize the verbal construction of sentences; however, students were not able to generalize the use of particles in the sentences. In Japanese, particles are used to specify the object and the subject of nouns. In response to this need, researchers used a second experiment to explicitly teach the role of particles. Findings indicated that students were able to learn and apply complex rule relationships to sentence construction, and for 2 of the 3 children, the results generalized to written sentence constructions. Future research should determine if computer based instruction is effective is effective for students with less verbal ability.

Limited conclusions can be drawn from these few studies for the following reasons: (a) lack of experimental control, (b) lack of analysis of the components of a multi-component treatment package on the dependent variable, and (c) lack of generality of the findings due to small sample sizes. These conclusions are consistent with prior research reviews on the efficacy of technology to support academics for students with ASD. For example, Blischak & Schlosser (2003) examined the evidence of speech generating devices and talking word software in supporting spelling for students with ASD, and concluded that while there are emerging data to suggest that technology can support independent spelling, design limitations of the studies (e.g., pre-experimental designs) prevent authors from reaching definitive conclusions. In addition, further studies in which the components of treatment package are isolated (e.g., speech output or visual feedback) are needed. Tincani and Boutot (2005) suggested that while there is mixed evidence on the effectiveness of CAI for students with ASD, the following tentative conclusions can be made: (a) for students who have limited speaking and writing skills, CAI may be a beneficial alternative for the expression of literacy skills; (b) children with ASD may prefer CAI, as it may seem like a game, (c) CAI may be more cost effective, because the teacher can work with a greater number of students. Finally, the heterogeneous nature of the population of individuals with ASD (e.g., verbal, nonverbal, cognitive disabilities) needs to be considered when making instructional decisions. Tincani and Boutot (2005) recommend current research is warranted to investigate the use of computer-assisted instruction for children with ASD in all content areas. Further, they offer that future studies should explore the use of computer-assisted instruction to teach various academic skills; student preference of computer-assisted instruction versus traditional instruction; and the generalization of skills from the computer-assisted instruction to other skills and settings (Tincani & Boutot, 2005).

As the research on the effects of CBI on the academic behaviors of students with severe developmental disabilities, including students with ASD and/or severe cognitive disabilities, is relatively new and inconclusive, examining the literature base from the field of high incidence disabilities may provide guidance. For example, Fitzgerald, Koury, and Mitchem (2008) reviewed the research on CMI for students with high incidence disabilities from 1996- 2007, in the skill areas of reading, writing, math, as well as the content areas of science and social studies. Authors concluded that the while the research on CMI is beneficial for students with learning disabilities, it is the design of the software to incorporate the use of explicit strategies that makes the practice successful. For example, authors found that when software contained specific supports and customizable features consistent with research-based practices, students made greater gains. In addition, Fitgerald et al. found that students enjoy computer mediated learning and can learn complex curriculum content. The authors caution that although there are benefits to CMI for increasing academic skill areas for students with high incidence disabilities, the use of CMI even when combined with effective instruction does not narrow the gap in achievement for students with mild disabilities.

Electronic texts. Electronic texts, including CD-ROM storybooks are one example of how teachers can use technology to promote reading and access to grade level content. CD-ROM storybooks are similar to traditional based storybooks, in that they use text and illustrations to present children's literature. CD-ROM storybooks may include additional components to improve reading experience for beginning readers; however the manner in which the books support readers is varied (Lefever-Davis & Pearman, 2005). According to Lefever-Davis & Pearman, researchers have different opinions as to the advantages and disadvantages of electronic text formats. Some investigators contend the following benefits of the electronic format on literacy skills: (a) control over the learning environment by self-selecting the level of assistance needed, (b) removal of the barriers to decoding the text by having the text read aloud, (c) assistance in setting the author's mood and in comprehension of the story though the use of animated graphics paired with audio, and (d) enhancement of vocabulary development through the use of CD-ROM story books. Other researchers caution that students may become overly dependent on the supportive resources to decode text, thereby hindering literacy development. Since instruction is delivered via a computer versus a teacher, the ability to make instructional decisions on the type of assistance needed cannot be made from the computer, and therefore students may not be pushed to reach their potential to the extent they would with teacher-delivered instruction.

Although the experimental research on the effects of electronic text is a recent endeavor, most studies have found them to be beneficial for literacy development (Lefever-Davis & Pearman, 2005; Horney & Anderson-Inman, 1999). In a review of the literature on the efficacy of electronic books on reading and comprehension of young children, Grant (2004) found interactive electronic books advantageous for typically developing students and students with disabilities in promoting reading comprehension and word recognition, especially when used to supplement traditional, printed text. In addition, the authors recommended electronic books for reading and comprehending expository texts, "where students are engaged in learning new terminology and constructing knowledge" (p. 307). Additional experimental studies investigating the use of electronic text on literacy skills support the findings from Grant (e.g., Horney & Anderson-Inman, 1999; Lefever-Davis & Pearman, 2005; Matthew, 1997).

For example, Matthew (1997) compared the effects of a traditional print version and a CD-ROM version of the same story on the reading comprehension of typically developing third grade students in two similar experiments. In the first experiment, 37 matched pairs were randomly assigned to either the print version or the CD-ROM version. Following the readings, students were asked to write a story retelling and answer 10 open ended comprehension questions. Results of the first study indicate that the students in the CD-ROM condition scored significantly higher in the story retellings, but not on the open ended comprehension questions. In the second investigation, 15 pairs of students were assigned to both conditions to compare the CD-ROM condition and the print condition. Students were only asked to retell the story. Findings show a significant difference between the conditions in favor of the CD-ROM storybook condition.

Additionally, students stated a preference for the CD-ROM storybooks. Recommendations from both of studies in this investigation suggest teacher support is needed to minimize potential distractions from the CD-ROM features (e.g., animations) and to remind students to use the help features.

In a similar investigation, Pearman (2008) evaluated the effects of an interactive, CD-ROM story book on the independent reading comprehension of 54 second grade students with varying degrees of reading ability. Using an experimental, within subjects, paired samples research design, researchers exposed all students both the traditional and electronic text conditions, but the order of the two reading treatments was randomized for each student. For each condition, the following steps were conducted: (a) the instructor discussed the title of the story with the students; (b) students were told they were going to read and then re-tell a story; (c) students were told they could read aloud or silently, and (d) after the reading the story, students were asked to orally retell it. If the student stopped retelling, he/she was prompted with “Can you tell me more?”; however, prompts were not given on the content for either condition. Before participating in the electronic text condition, students were given training on the mechanics of the computer, such as how to use the mouse, turn the pages, and access animations. Researchers measured comprehension based on the oral retellings as well as student behaviors (e.g., engagement). Results of this study indicate that comprehension scores (i.e., oral retellings) were significantly higher for all students in favor of the instruction via electronic text. Further, in the electronic text condition: (a) students with ADHD were found to be more engaged, (b) more students discussed setting than in the traditional condition (45 as compared to 28), and (c) more students read the text aloud than in the traditional text condition (13 as compared to 0).

Williams, Wright, Callaghan, and Coughlan (2002) extended the evidence on the effects of traditional printed books versus computer based books to 8 young children with ASD aged 3-5. Researchers of the pilot study compared the two conditions on students' attending behaviors, adult interactions, and word reading ability. The computerized book included the following options (a) a text to speech option which highlighted the words as they were read, (b) a function which turned the pages of the digital book, (c) clickable sounds on the images, and (d) an auto narrate option. Dependent variables were operationally defined and measured using direct observation (e.g., attention was measured as time on task). Results of the pilot study indicate that all students spent more time attending in the computer condition, and 5 of the 8 participants learned 3 new words. Further, stereotypic behaviors were reduced in the computer condition for 6 of the 8 children. One major limitation of the study was the lack of an experimental design. Another limitation according to the authors was that the children may have improved as a result of maturation, or quality teaching versus the intervention. The authors recommended a large scale study with similar research questions for students with ASD, and to examine whether or not computers can support social skills for individuals with ASD.

Other researchers have started to examine specific design features of the electronic text which may enhance literacy development. First, Lewin (2000) used a group pretest, posttest quasi experimental design to compare two versions of talking book software on the word recognition of three groups of 5-6 children in a primary school classroom: low, medium, and high ability readers. One software version was considered "basic," and included features such as whole word pronunciations, highlighting words or phrases as they are spoken, reading the story aloud and page turning facilities. The other software version was "enhanced," and included the same features as the "basic" version, as well as segmented feedback, reinforcement activities, and hints. Sixteen pairs of children were matched on reading age, class, teacher, and gender; then were randomly selected to either the basic or enhanced software condition. Data from pre and posts tests were analyzed using a repeated measures ANOVA; results showed no significant differences between the groups on sentence reading measure, but the enhanced software users showed more gains on the reading test and on key word recognition as compared to the basic software group. Although one limitation was the lack of a control group, researchers concluded that both versions of the software improved reading outcomes. Authors state that the most beneficial aspects of the software for the students in the low reading ability group were exposure to the vocabulary within the text and computer supported word pronunciations (offered in both versions). Additional features offered as part of the enhanced version were not perceived by learners as beneficial, but were seen as additional academic tasks requiring more effort.

Similarly, Lefever-Davis and Pearman (2005) conducted a study investigating specific designs features to determine the interaction of the electronic features and tools on student behaviors, such as tracking, electronic feature dependency, distraction, and spectator stance. Each of the eleven 6-7 year olds read two CD-ROM story books. During the reading, researchers provided assistance to get the reader back on track or to focus, but did not provide any instructional reading prompts. Researchers collected a running record of the behaviors, which were later analyzed by grouping similar behaviors and collapsing them into six main categories. Results indicate that the features varied by type of reader. For example, struggling readers used the tools to support the reading process, such as pronunciations to help learn the word and gain meaning from the text, while the experienced readers used the pronunciation tool as a model for voice inflection and expression. Authors recommend CD-ROM storybooks to promote reading for young students, but caution against some features, such as page turning which can be frustrating, or the activation of graphics can be viewed as a game. Specifically, authors note that teachers should determine the purpose of the reading activity prior to reading using electronic text. For instance, if the purpose of the reading is for comprehension, then graphics can be beneficial; however, if the purpose is to decode text, the graphics may be distracting.

Design considerations for CBI and electronic text. Two considerations are important when designing CBI for students with ASD. First, designers must consider the remediation versus compensation argument presented by Edyburn (2007). Second, designers, such as educators and researchers need to consider the instructional design of the materials; CBI and digital materials are most effective when research-based practices from the field of special education are incorporated into the media.

Edyburn (2007) challenges educators to see the relationship between a student with a physical disability (i.e., a child who has lost an arm), and a student with a cognitive disability with respect to compensation versus remediation. In the first example, the child who has lost an arm is given compensatory strategies, such as assistive technology, to handle the physical challenges he might encounter. In the second example, the child who is struggling to read is given remedial strategies even after years of receiving varying instructional approaches. Still, the student does not acquire the skills to become proficient reading skill areas, such as fluency and comprehension. Edyburn encourages educators to see the similarities in the two students and challenge the double standard that we hold. He asks teachers to determine the point at which we move from remediation to compensation strategies (e.g., use of assistive technologies). This is a valid argument for students who are in middle school, when the focus of reading moves from “learning to read” to “reading to learn” (Gajria, Jitendra, Sood, & Sacks, 2007). Students who are still struggling with decoding are not yet reading for understanding. Even students who have some degree of fluency in their reading may not comprehend the text as they read. Further, the author states that the common solution to reading challenges among educators is to continue to remediate, but he encourages consideration of remediation to be based on student data. Finally, Edyburn confirms that because the use of technology to improve literacy is a relatively new endeavor, there is a pressing need for significant empirical research on the use of assistive technology to improve reading skills.

In addition to compensation and remediation strategies, it may be argued that for students with severe disabilities, there is another option. With the recent passage of NCLB (2001) and IDEA (1997, 2004), many students with severe disabilities have just started receiving instruction in content areas, such as science. If students have never been given the opportunity to learn science material, it would neither be compensation or remediation, but *acquisition*. This argument may be analogous to the argument of rehabilitation versus habilitation (Gold, 1973).

According to Strangman and Dalton (2005), literacy development can be enhanced in both a compensatory (e.g., by providing access to text) and remedial manner (e.g., by assisting in reading for understanding) with support from digital technologies. Digital technologies can promote reading performance using text to speech, images and videos, and hypertext. Authors suggest that although technology has the potential to assist in every critical reading skill, larger groups and appropriate control groups are needed to strengthen research in the field. Finally, future research should investigate flexible approaches, such as digital learning environments, aligned with the principles of UDL to enhance literacy instruction.

After remediation versus compensation is considered, educators and researchers must consider the instructional design of the digital materials (Boone & Higgins, 2003; Higgins & Boone, 1996). Many authors propose that the incorporation of research-based instructional design features is the key to ensuring that technology mediated instruction is effective (e.g., (Boone & Higgins, 2003; Higgins & Boone, 1996). For example, Boone and Higgins (2003) offer suggestions for designing digital text. Their main idea is founded on the Rose, Hasselbring, et al., (2005) premise that access to information is not the same as access to learning. Authors recommend that informational content, even when delivered via accessible technology, will have little to no value without consideration of instructional design. In fact, Boone and Higgins note that when the digital environment is poorly designed, this can outweigh the benefits of sound instructional design. The combination of accessible text provided by technology, along with the research-based, instructional design strategies based on UDL may provide access to learning for individuals with disabilities. Instructional design features can simulate empirically-based teacher-directed practices for students who are engaged in directed reading activities.

Boone and Higgins (2003) suggest specific strategies for improving reading which can be incorporated into e-books and electronic readers including: (a) digitized text-to-speech; (b) pictures, recordings, or video; (c) abridged material (e.g., chapter outlines, summaries, graphic organizers or study guides); (d) key vocabulary (e.g., links to reference materials, text-to-speech pronunciation of the word); (e) content organization and modification of days (e.g., font size and pagination can organize content and more readable units); and (f) study skills (e.g., electronic note taking underlying and bookmarking). Finally, authors realize the symbiotic evolution of technology and instructional design; as technology changes, alterations in the instructional design may need to be considered.

Supported electronic texts. When electronic texts have been modified to include instructional design elements, learners may be better supported in comprehension. Supported electronic texts (i.e., supported eTexts) can incorporate the elements of instructional design as it can include eText that has been modified to support learners in comprehension or learning (Anderson-Inman & Horney, 1997; Anderson-Inman & Horney, 2007). To enhance meaning of the electronic text, supported eText, is electronic text which can either be linked to additional text or media, or be structurally represented in various ways to meet a wide range of learning needs. These additional supports can assist learners in overcoming the inherent barriers (e.g., conceptual and comprehension) that exist in most text-based resources. A review of the literature pertaining to supported eText conducted by Anderson-Inman and Horney (2007) found the beginnings of research in this area in the 1980s when researchers started examining augmentations to electronic text, such as text to speech or graphics, to improve reading skills for struggling readers. From these and other research efforts, Anderson-Inman and Horney (2007) developed a typology of the supports based on the functionality of the support for the reading process, which includes the following resources: presentational, navigational, translational, explanatory, illustrative, summarizing, enrichment, instructional, notational, collaborative, and evaluative.

Despite the strong appeal for the use of supported eText to promote literacy skills for students with disabilities, most of the research in this area is emerging. For example, a collection of studies on the use of graphics as an illustrative resource has been studied and found to be effective, but the review also found that use of the no graphics was preferable to the use of the inappropriate graphics (Anderson-Inman & Horney, 2007). In addition, according to Anderson-Inman and Horney, the use of text to speech has been evaluated, and found to be the most effective for students with whose performance on reading rate and comprehension measures is the lowest. On the other hand, even this well supported area of technology support is mixed, (e.g., Anderson-Inman & Horney). Further, a review conducted by MacArthur et al. (2001) on technology applications to support students in literacy also suggest that research on the enhancements, such as text to speech, has not produced reliable results. Experimental research of the other resources on components of literacy, such as fluency, vocabulary development, comprehension, or acquisition of grade appropriate academic content through text has not been systematically evaluated over a long term basis. Results of these studies clearly suggest that the research on supported eText is “fragmented and inconclusive on many, if not most dimensions" (MacArthur et al., p. 156), and indicate a need for additional empirical studies in the area of supported electronic text.

Although there are gaps in the research on supported electronic text, the ideology of supported eText is aligned with the framework of UDL. Supported eText can offer multiple means of representation, expression, and engagement, thereby reducing barriers from traditional text-based curricula. General and special educators must consider the changing face of literacy instruction during this technological age. Students live in a face paced, stimulating, multimedia world, where they can retrieve information at the click of a mouse. This technology-based world is in contrast to the inflexible methods of learning to read primarily through print-based formats during the school day (Leu, 2002).

Supported eText offers flexible means of representation. For example, materials can be represented in various formats, can be customized, and can be scaffolded for individual learners. In addition, supported eText promotes the use of multiple means of expression in that students can express what they know via multimedia. Finally, supported eText can facilitate student engagement through motivating media such as virtual reality and the game-like nature of some instructional formats.

Supported eText in content areas. As mentioned, the research on supported eText in general is emerging; however, there is a notable lack of empirical research in the area of supported electronic on students' reading comprehension and content area reading. In addition, there is a need for further investigations of supported electronic texts exploring the degree to which individual components as well as instructional packages facilitate the reading comprehension for struggling readers and students with disabilities (Anderson-

Inman & Horney, 2007). In addition to the studies in this review, at least three studies have evaluated the effects of electronic text on comprehension of social studies content.

First, a study conducted by Horton, Boone, and Lovitt (1990) investigated the effectiveness of a computer-based study guide using hypertext software on comprehension of social studies content from a textbook. Four students with learning disabilities aged 14 to 16 who were part of a remedial high school social studies class participated in the study. The intervention consisted of a hypertext software program in which three levels of prompting were used to assist students in answering comprehension questions from the text. Feedback on students correct and incorrect responses were given as part of the computer program. A pretest/posttest, quasi- experimental design was conducted to evaluate the data at both group and individual levels. In addition, authors state that control items were used on the pre and posts tests in place of a control group. According to the authors, results of the this study indicated that the students with learning disabilities improved on the comprehension questions from pre to post text when compared to the control questions. Further, they maintain that students who read the slowest in the beginning of the intervention required the highest number of instructional prompts and made the greatest gains from pre to post tests. An important aspect to this study is that the instructional procedures used in the computer program were research-based, and were similar to strategies used in other studies on CAI for students with disabilities, such as: self-pacing, frequent responding, correction, feedback, and sequenced instruction. Although not explicitly stated by the authors, limitations to this investigation include a lack a design showing experimental control and a small sample size.

Second, a study conducted by Boyle et al. (2003) examined the effects of a CD-ROM audio textbook, both alone and combined with complementary strategy (SLiCK) on the academic performance of secondary students in history content. Using a pretest, post test, true experimental design, 95 students with mild disabilities who were enrolled in self-contained special education history classes were assigned to one of three conditions (a) audio text combined with the SLiCK strategy, (b) audio textbook alone, or (c) a control condition. The SLiCK strategy includes four tasks to assist students in taking a functional set of notes: Set it up, Look ahead, Comprehend, and Keep it together. Evaluation of student progress was measured using a pretest and post test on cumulative content acquisition, and five section quizzes as short-term measurement. Results of the study indicated a statistically significant difference in favor of the two groups who used the audio texts; however, there was no statistically significant differences between students who used the audio text and students who use the combined audio text plus SLiCK procedure. Findings of this study were in contrast to previous findings from the literature because the audio textbook was found to be an effective tool for increasing content acquisition of academic content over time. Limitations to the study included the short delivery period of the strategy and the lack of generality of the findings to students without learning disabilities. One benefit of the audio text was that it provided students access to expository texts, and allowed additional time for teachers to provide assistance to students experiencing difficulties.

Finally, Twyman and Tindal (2006) investigated the effects of a computer adapted history text on the comprehension and problem-solving skills of twenty-four, 11th and 12th grade students with learning disabilities in self-contained social studies classes.

Using a pretest, posttest, random classroom assignment, quasi-experimental design, students skilled in the use of computers were measured using three CBMs (a) a vocabulary matching probe, (b) concept maze was used to assess content knowledge, and (c) an extended-response essay was used to evaluate problem solving skills. Consistent with the framework of UDL, the opening page of each web-based chapter contained a table of contents consisting of four links where students could choose from options such as: an overview, a list of the concepts, simplified text, a graphic organizer, or assessments. Moreover, students could choose pages, have sections of the text read aloud, and click on hyperlinked glossary definitions. The control group was taught identical content using the district's adopted textbook. Results showed no statistically significant differences between the two groups on comprehension measures of content knowledge; however, statistically significant differences in favor of the treatment group were found for the extended response essay. Limitations to this study included the random assignment at the classroom versus the individual level, the small sample size (i.e., corresponding to a lower effect size), and the use of a new measurement of content comprehension (i.e., concept maze). Authors caution teachers against thinking that lack of skills in the text structure of expository content is equal to the inability to learn the information. Further, they recommend CBI as way to explicitly illustrate the critical concepts and rules which define the concepts. Finally, researchers stated that the computer can be used to deliver content in a universally designed manner, as it can promote multiple means of representation, expression, and engagement, such as student self-monitoring.

In summary, there is a need for additional research on the efficacy of supported eText to promote literacy skills, specifically in the content areas such as social studies and science. Experimental research on the construction and designing of digital materials is also required, especially in relation to determining how to use the extant research-based knowledge of instructional design components in digital formats to increase skills for students with a wide range of abilities and needs. Further, despite the current national focus on scientific literacy and use of technology for all students, there are no published studies on the effects of technology on the science content comprehension for students with low incidence disabilities. Finally, Rose, Hasselburg, et al. (2005), offer this caveat, "although the existing benefits of technology for students with disabilities are already widely recognized, the potential benefits are likely to be even more profound and pervasive than present practices would suggest" (p. 507).

2.4 Comprehension

Effective Instruction in Reading Comprehension

Comprehension of expository text. Reading expectations for students change as they progress through school because of the divergence of more easily understood narrative material to more challenging expository text (Carnine, & Carnine, 2004; Carnine, Silbert, Kame'enui, & Tarver, 2007). In the early grades, students are expected to engage with narrative text (i.e., fictional), while in middle and high school, students must learn strategies to understand expository information (i.e., non-fiction) in content areas.

Most reading necessary for success in work and everyday life is also through expository information. As we strive to become a scientifically literate society, written expository material becomes increasingly important (Gersten et al., 2001). Not only does the type of text change as students shift from elementary to secondary education, but the focus of instruction changes as well. The focus in the primary grades is on "learning to read" whereas the emphasis shifts in later grades to "reading to learn" (Gajria et al., 2007).

Research shows that readers are often more challenged by comprehension of expository material than narrative texts. Many students experience difficulties with expository text due to the large volume of unfamiliar and technical vocabulary, as well as differences from narrative texts in terms of text structure and level of difficulty (Gajria et al., 2007). Gersten et al. (2001) summarize the reasons why expository text can be challenging: (a) expository text involves reading long passages without prompts from a conversational partner (e.g., dialogue), (b) expository text structure is often more abstract than narrative structure, and (c) expository texts use more complicated and varied structures than do narratives. In addition to the style of expository text, Carnine et al. (2007) suggest additional characteristics of expository material which may pose problems for the learner, such as vocabulary, content, and special features. Vocabulary in content areas is often more difficult to decode and pronounce, may be absent from the students' listening or speaking vocabulary, and terms are often presented in rapid succession. Content is usually new and unfamiliar to the student, going beyond their everyday experiences. Science content, for example, includes many unfamiliar concepts and in higher density than found in narrative materials. Special features of expository text can present challenges as well; science texts often contain graphics and illustrations that contribute directly to the information presented in the text. Students with disabilities will likely need a careful introduction of the graphics to determine the interrelationships between the concepts presented in the illustration. Students with disabilities will need explicit preparation in order to handle the vocabulary, concepts, and special features of content based information (Carnine et al., 2007). Despite the challenges many students face in understanding expository information, research has shown that students with disabilities can learn to comprehend expository text using both content enhancements and strategy instruction (Gajria et al., 2007; Gersten et al., 2001). Content enhancements are instructional devices (e.g., graphic organizers, computer assisted instruction) are used to facilitate the selection, organization, and presentation of difficult to understand material and make the text more meaningful and accessible. In contrast, strategy instruction teaches students how to learn methods of actively processing and learning from the text (Gajria et al.; Gersten et al.).

Gajria et al. (2007) examined 29 experimental studies, categorized as either content enhancements or strategy instruction interventions, to improve comprehension of expository text for students with learning disabilities. Overall, researchers found strong support for both types of instruction, and recommended either type depending on the purpose of instruction. For example, if the purpose of instruction is to assist students in actively processing the content, then content enhancements would be effective; however, if the instructional goal is on “how to learn” when generating main ideas, summarizing information, predicting, questioning, or clarifying text, a cognitive strategy approach may be more beneficial. Authors suggest that the use of computer assisted instruction may enhance students’ motivation and text comprehension; however, overall treatment effects for computer assisted instruction were comparatively low. In all studies, strategies were used in combination with other effective teaching practices (e.g., modeling, feedback). Future research should explore the maintenance and transfer effects of various text comprehension instructional approaches. Authors suggest practical considerations of working in secondary schools where the focus is often on breath over depth, and the need for effective strategies which students can learn to use quickly and apply independently. Finally, researchers and educators need to consider strategies which maximize time and resources available to classrooms.

Based on these and other recommendations from the research, Carnine et al. (2007) suggest that content area lessons "should be designed to promote mastery of the salient information" (p. 266) by including the following steps: (a) teacher preparation for instruction, (b) pre-reading activities, (c) reading activities, and (d) post reading activities. First, lessons should be prepared by determining which ideas, vocabulary, concepts, and details are essential for student learning. Second, pre-reading activities can include direct instruction teaching approaches to vocabulary instruction, such as teaching through examples (i.e., discussed in a previous section). Third, depending on the type of reading activity as well as students' reading comprehension skills, reading activities can range from teacher-directed procedures to student-directed, independent strategies. For example, guided reading is suggested as one option for students who have difficulty with comprehension and who are new to content area materials. During guided reading, teachers can model self-questioning techniques for the students to encourage this when reading independently. The following steps can facilitate guided reading: (a) question generating (i.e., students are asked the topic of the section); (b) summarizing (e.g., students are asked to summarize the most important information reported about the topic); (c) clarifying (e.g., students clarify any confusing aspects of passage); and (d) predicting (e.g., students are assisted in predicting subsequent sections of the text). Fourth, post reading can help students to integrate the information that has been read. Research shows particularly effective post reading activities include answering written questions, and writing a summary of the content. Each of these activities gives students the chance to study and practice the relevant information from the content selection.

To maximize learning, Carnine et al. (2007) suggest that questions can be written according to the following criteria: (a) questions should stress major concepts presented material versus insignificant facts; (b) questions should include literal and inferential comprehension questions; (c) questions should go beyond yes and no responses; (d) questions should be well worded to promote ease of interpretation; and (e) majority of questions should be "passage" dependent (e.g., answers based on reading the text versus experiential background).

Vocabulary instruction. There is a strong and indisputable relationship between reading comprehension and vocabulary knowledge. In order for students to be successful in comprehension of materials, they need to know the meanings of the words they are reading. In addition, comprehension is less challenging when students have a broad vocabulary and when students can apply background knowledge to the topic (Gersten et al., 2001). To ameliorate the challenges students with disabilities have in both comprehension and understanding of vocabulary, Bursuck and Damer (2007) recommend modeling examples and non-examples directly as the word is taught. First, modeling can be used to present a series of positive examples and non-examples of the new vocabulary word or concept. Second, students can be tested on the understanding of the examples by determining examples and non-examples independently. Third, when students can correctly answer the structured testing questions, they can be asked an open-ended question and requiring them to integrate the new word with review words. Finally, teachers can incorporate “wh” questions (e.g., who, what, where, when) after the example and non-example questions, such as “This word is magma. What is the word?” and “Magma means melted rock inside a volcano. Is this a picture of magma or not magma?”

In addition to teaching vocabulary explicitly, Carnine et al. (2007) suggest a helpful strategy for writing a clear comprehensive definition. Authors describe definitions as having two key elements: a small class to which the word belongs, and a statement of how the word differs from other members of the class.

The method of error correction is an important area to consider with respect to effective instructional practices to promote comprehension and vocabulary. Marchand-Martella et al. (2004) suggest that immediately following the error, the correction procedure should consists of (a) modeling (i.e., demonstrating the correct answer), (b) testing (i.e., asking students to respond to the original item), and (c) retesting (i.e., giving several other items, then test the item that was missed).

Research on Comprehension for Students with Mild Disabilities

Direct instruction has been used for over 45 years with other populations, lending strong empirical support for practice (Marchand-Martella, Slocum, & Martella, 2004; Project Follow Through, 1968). Research has shown that direct instruction, including effective and explicit instructional strategies, has been used to teach reading comprehension to students with diverse learning needs (e.g., students receiving special education services or who are at risk of academic failure), students from diverse language backgrounds, and students from preschool to adulthood (Marchand-Martella et al., Project Follow Through). Rosenstein and Berlinger (1970) described effective instruction (i.e., direct instruction) as:

> A set of teaching behaviors focused on academic matters were goals are clear to students; time allocated for instruction is sufficient and continuous; content coverage is extensive; student performance is monitored; questions are at a low cognitive level and produce many correct responses; and feedback to students is immediate and academically oriented. In direct instruction, the teacher controls instructional goals, chooses material appropriate for students' ability level, and paces for the instructional episode (p. 7).

Given that research on reading instruction has been underemphasized for students with ASD, the potential impact of instructional strategies to increase comprehension skills is not well understood. Direct Instruction, specifically the use of model-lead-test, and modeling using examples and non-examples may be beneficial for students with ASD (see Table 1 for examples of these strategies from the research). Based on the lack of research-based information for promoting comprehension specific to the population of students with ASD, two seminal reviews pertaining to students with mild disabilities may provide insight.

Table 1. Examples of Direct Instruction and Components: Model-lead-test and Use of Examples and Non-Examples

Instructional Support	Example References from the Research Literature
Research Reviews of Direct Instruction	• Adams & Engelmann (1996)

	• Prychodzin-Havis et al. (2005)
Model-lead-test	• Bursuck & Damer (2007) • Kame'enui & Simmons (1990) • Watkins & Slocum (2004)
Examples and Non-examples	• Engelmann & Carnine (1991) • Kame'enui & Simmons (1990) • Watkins & Slocum (2004)

First, in a review of the literature on reading comprehension for students with learning disabilities, Gersten et al. (2001) describe effective instructional methods for improving comprehension of both narrative and expository text. Gersten et al. recommend several factors critical for comprehension: (a) knowledge of text structures, (b) vocabulary knowledge, (c) using background knowledge, (d) the role of fluent reading, and (e) the importance of task persistence. Analysis of the studies indicated the use of strategy instruction, including modeling and extensive feedback, can promote student comprehension performance; however, effects of these strategies on maintaining and applying strategies across materials is questionable. Authors suggest that effective strategies may be different for narrative versus expository texts. For example, expository texts, which are sometimes more challenging for students, may require the use of multiple comprehension strategies as well as longer durations of intervention to ensure lasting effects.

Second, Sencibaugh (2007) conducted a meta-analysis of 15 studies from 1985 to 2005 on reading comprehension interventions for students with high incidence disabilities. Findings from this synthesis reveal that auditory language dependent strategies (e.g., summarization and main idea strategies; summarization combined with self-monitoring; self-questioning, and text-structure based strategies) are more effective for improving reading comprehension skills than visually dependent strategies (e.g., such as illustrations in the text and semantic organizers). The most effective strategies appear to be questioning strategies, such as self-instruction and paragraph restatements along with text-structure based strategies.

Challenges in Comprehension for Individuals with ASD

Individuals with developmental disabilities, including individuals with ASD and cognitive disabilities, often have challenges in comprehending text (Flores & Ganz, 2007). The difficulties for individuals with ASD in reading comprehension were first recognized by Kanner (1943), who observed that although reading skills were acquired rather rapidly, students appeared to view a story as discrete portions, rather than a coherent narration. Since this time, however, few studies have examined reading abilities for students with ASD. One study, conducted by Nation, Clark, Wright, and Williams (2006) assessed 41 students with ASD aged 6 to 15 on the following reading skills: word recognition, non-word decoding, text reading accuracy and text comprehension. Researchers found extreme variability across students in reading abilities. For example, some students could decode words, but had challenges with comprehension; others had difficulty decoding. A total of 65% of the students scored at least one standard deviation below the mean in reading comprehension.

Some researchers have examined the components of reading comprehension and related reading skills. Nation et al. (2006) found that vocabulary and oral language comprehension scores were highly correlated with scores on the measure of reading comprehension (.72 and .67 respectively), suggesting that deficits in reading comprehension may accompany impairments in comprehending oral language. Moreover, students with ASD and low verbal ability demonstrate significantly poorer reading comprehension levels than controls of matched decoding ability (Snowling & Frith, 1986). Many studies show that students with ASD are skilled word decoders, but they have a seemingly contradictory challenge in reading comprehension (e.g., Goldberg, 1987; Patti & Lupinetti, 1993). Snowling and Frith (1986) compared students with ASD (mean IQ=78), students with intellectual disabilities (mean IQ=75), and typically developing students matched for "mental" and reading age on factual recall questions and general knowledge questions. Although overall, students with ASD or intellectual disabilities scored lower than matched controls, "high verbal ability" students with ASD or intellectual disabilities showed commensurate scores on the general knowledge questions, but "low verbal ability" students with ASD or intellectual disabilities performed significantly lower than matched controls. Authors concluded students with "lower verbal ability" had a more difficult time applying relevant background knowledge and comprehending text. The challenge for students with ASD in applying background knowledge has also been confirmed by Wahlberg and Magliano (2004). Assessing the reading comprehension of 12 high functioning individuals with ASD compared to 60 matched peers based on IQ, researchers found that students with high functioning autism had deficits in applying background knowledge to understand the text. Furthermore, individuals with high functioning autism had difficulty making global and abstract connections, especially with respect to more ambiguous text. In addition to background knowledge, O'Connor and Klein (2004) discussed additional problems with comprehension that individuals with ASD may experience, such as difficulty integrating information, understanding and resolving anaphoric reference, and monitoring comprehension. Further studies have shown that students with Asperger syndrome could comprehend factual information, but had challenges in making inferences from the text (e.g., Griswold, Barnhill, Myles, Hagiwara, & Simpson, 2002; Myles et al., 2002). Finally, according to the American Psychiatric Association (2000), many individuals with ASD have difficulty in comprehending abstract or figurative language (e.g., use of metaphor) which can impede reading comprehension skills beyond literal and recall types of questions.

Overall, students with ASD show variability in performance of decoding and reading comprehension skills. For most students in this population, however, performance in reading comprehension is typically poorer than performance in decoding. In addition, reading comprehension scores are usually lower for students with ASD than matched controls (Frith & Snowling, 1983; O'Connor & Klein, 2004; Snowling & Frith, 1986). Nation et al. (2006) suggest caution when trying to apply a mean score for the population, due to the heterogeneous nature of the reading ability across individuals with ASD. Although students with ASD have variable challenges in reading and understanding text, little research has been conducted on the most effective interventions for this population. In the next section, a review of the research pertaining to reading comprehension will be examined to determine possible implications to listening comprehension of electronic text for students with ASD.

In addition to these specific challenges to comprehension for students with ASD, Bursuck and Damer (2007) suggest comprehension for all learners can be influenced by these additional factors: (a) reader characteristics (e.g., prior knowledge, a students' background, language and knowledge of vocabulary); (b) the nature and purpose of the reading task (e.g., reading for pleasure or to gain information); and (c) context (e.g., the amount of support from parents and teachers).

Research on Reading Comprehension Instruction for Students with ASD

Reading comprehension is considered to be "the most important academic skill learned in school" (Mastropieri & Scruggs, 1997, p. 1). The inability to decode text or read text with fluency should not be a barrier for access to the information; students need compensatory strategies so that they can interact and make meaning from grade appropriate texts. Understanding text can increase access to educational, vocational and recreational activities for individuals with ASD and intellectual disabilities; however, limited research has been conducted investigating instructional practices to remediate or compensate for these comprehension challenges (Browder et al., 2006; Chiang & Lin, 2007)

For example, a literature review of reading comprehension instruction for students with ASD was synthesized by Chiang and Lin (2007) and evaluated interventions for both text and sight word comprehension. Of the 11 studies which met criteria for inclusion, only four studies evaluated instructional methods to enhance text comprehension. Instructional strategies included in the four studies were peer tutoring, cooperative learning groups, and procedural facilitation. Authors suggested a direction for future research may be to incorporate additional National Reading Panel (NRP) identified strategies for text comprehension, including: (a) comprehension monitoring; (b) cooperative learning; (c) graphic and semantic organizers; (d) story structure (e.g., students ask and answer questions about the text); (e) question answering; (f) question generation (e.g., students ask wh- questions to themselves); (g) summarization; and (h) multiple strategy teaching. Reviewers concluded that although comprehension is a weakness for many students with ASD, the studies demonstrate that with appropriate interventions, students with ASD can gain reading comprehension skills. Findings also demonstrate that the majority of the students with ASD in the studies had below average IQs, and yet they could still learn comprehension strategies, suggesting that level of intellectual functioning should not preclude students from interacting with text in meaningful ways. Future research should address instructional methodologies to promote reading comprehension skills for students in general education classes and content.

In a more general review of reading interventions, Whalon, Otaiba, and Delano (2009) examined 11 studies encompassing one or more of the NRP's components of reading (i.e., phonemic awareness, phonics, reading fluency, vocabulary, and comprehension strategies). Five of the 11 studies related specifically to reading interventions targeting vocabulary development and comprehension. Of these, interventions included peer delivered instruction (e.g., cooperative learning groups) and one to one instructional delivery (i.e., prompting system to teach a student to act out single directions, procedural facilitation). In addition to these strategies, authors recommended that students with ASD may benefit from additional reading strategies recommended from the NRP. For example, students may be able to use a question generating strategy, in which they learn to ask questions from the text. Authors suggest incorporating research-based practices, such as visual cues or self-monitoring into the instruction to facilitate learning of these additional strategies. In addition, Whalon et al. suggest the use of an anaphoric cuing system, in which students can learn to identify pronouns and corresponding referents, to increase their ability to determine important elements of the story. Additional research is essential to extend the current literature base on effective reading interventions for students with ASD; in the meantime, reviewers emphasize the use of interventions which address all five areas of reading recommended by the NRP. In particular, reviewers recommend additional research on the use of a computer-assisted instruction reading program to supplement a comprehensive reading program.

Finally, although not targeting students with ASD in particular, a review of the research on reading instruction for students with significant cognitive disabilities conducted by Browder et al. (2006) found that although there was strong support for teaching sight words using systematic instruction, less than one fourth of the studies measured or taught comprehension (i.e., 23 of 128 studies). Eleven of these studies included individuals with ASD or developmental disabilities. Studies which met criteria for quality addressed comprehension by having students use sight words in context or match a word to a picture. Evidence-based practices used to teach comprehension included use of a massed trial format, systematic prompting strategies, and pictures. Only one of the eight NRP recommended strategies for comprehension (i.e., question asking) had been used for students with significant cognitive disabilities. The authors reported a need for additional research in the other areas of NRP's components of reading, especially in the area of comprehension. Clearly, more research is needed to identify reading strategies specific to students with ASD to facilitate the understanding of text in a comprehensive literacy program.

Two studies were not included in the preceding reviews may offer additional guidance on how to teach reading comprehension to students with ASD. First, Flores and Gantz (2007) evaluated the effects of a direct instruction reading program on the comprehension skills of 4 elementary students (i.e., 2 students with ASD, 1 student with mild mental retardation, and 1 student with ADHD) at a private school for students with ASD and intellectual disabilities. Three of the 4 students who participated in the study demonstrated substantial differences between their decoding and reading comprehension skills. For example, student performances in letter and word identification ranged from 61 to 98, and performances in passage comprehension ranged from 28 to 84. Researchers used three of the four strands from the Direct Instruction reading program, *Corrective Reading Thinking Basics: Comprehension Level A*, including statement inference, using facts, and analogies. Procedures adhered to the instructional procedures from the manual, with the addition of a visual cue during the facts condition. First, to probe students on the statement inference, the teacher read a statement, students repeated the statement, and then were asked to respond to questions related to the statement. Second, to probe students on the use of facts, the teacher read a fact to the students, students repeated the fact, and were then read a series of scenarios and asked questions to explain which facts explained which events. Last, to probe students on analogies, the instructor read the first part of an analogy and the student was asked to complete the missing word. Using a multiple probe across behavioral conditions (i.e., statement inferences, use of facts and analogies), results demonstrate not only a functional relationship between the DI intervention and the comprehension skills, but maintenace of these skills over a month after the end of the intervention. Limitations to this study include the following: a small sample size, lack of a comparision to another intervention, lack of generalizibility to other components of the program or with a comprehensive implementation of the program, and lack of generalizibility to a public school setting. Authors note the scant reseach avialble in the area of reading comprehension for students with developmental disabilities, including ASD, and suggest additional research to measure other aspects of reading comprehension such as passage comprehension in content areas.

Extending the literature on comprehension, Gantz and Flores (2009) examined the extent to which DI can assist in more difficult and complex tasks, such as picture analogies, inductions, deductions, and overall reading comprehension as measured through curriculum-based assessments. Four students (i.e., 2 students with ASD and 2 students with developmental disabilities), aged 11-13, with student performance in the area of word and letter identification ranging from 61 to 98, and performance in the area of passage comprehension ranging from 28 to 84 participated in the multiple probe across behaviors study. Three strands from the *Corrective Reading Thinking Basics: Comprehension Level A,* were chosen for this study, and included: (a) picture analogies, in which the students completed an analogy using pictures; (b) inductions, in which the students decided whether an event was true, false, or possible; (c) deductions, in which students generated rules of a phenomenon based on facts; and (d) opposites, in which students restated a sentence using the opposite of one word in the sentence. Results show a functional relationship between the DI intervention and more complex comprehension skills. Limitations of the study include generality to other students and lack of typical intervention agents implementing the study. This and the preceding study recognize the need for additional empirical research on reading comprehension for students with ASD.

Summary of Research

Students with severe disabilities have access to, and make progress in content areas, such as science (IDEA, 1997, 2004; NCLB, 2001). Systematic instructional strategies are effective for increasing access to science content and processes (e.g., Courtade et al., 2007). Further, UDL may increase student access to the general education curriculum by offering multiple means for students to see information presented, multiple means for students to express what they know, and multiple means for students to engage in materials (e.g., Rose and Meyer).

Technology may be used to reduce barriers from traditional curricula and is an important aspect of UDL. Although research on the efficacy of technology for students with ASD began over 35 years ago (e.g., Colby, 1973), additional rigorous investigations are essential to demonstrate the causal relationship between technology and student outcomes studies (Wehmeyer, Smith, & Davies, 2005). Support for the use of CAI to teach academic content to students with ASD exists, but no investigation has evaluated the use of CAI to teach science content to students with ASD. Moreover, research on computer assisted strategies to support comprehension of expository material for students with mild disabilities is weak, suggesting the need to incorporate research-based strategies via supported eText into the materials. Systematic instructional approaches have been used to teach science content to students with severe disabilities and explicit strategies are effective for teaching comprehension to students with high incidence disabilities; however, the use of these research-based practices to design software has not been evaluated.

There is a notable lack of research on interventions for promoting comprehension for students with ASD. Although there is a promising literature base on reading comprehension of expository text in the content areas for students with high incidence disabilities, the applicability of these strategies is unknown for students with low incidence disabilities. Finally, there is no research available on the effects of interventions to facilitate comprehension of expository text from content areas, such as science, for this population.

CHAPTER 3: METHOD

The purpose of the study was to investigate the effects of supported electronic text using the Book Builder™ program on the number of correct responses on science comprehension and vocabulary probes by middle school students with ASD who are eligible for an alternate assessment based on alternate achievement standards. This chapter discusses the methods used to investigate the research question(s). Specifically, the chapter will describe participants, research design, variables, data collection, and intervention procedures.

3.1 Participants

Students. Four middle school students were asked to participate in the single subject investigation evaluating the impact of the Book Builder™ program on the number of correct responses to a science comprehension and vocabulary probe. Selection of participants was based on the following inclusion criteria: (a) having a diagnosis of autism consistent with the DSM-IV criteria; (b) eligibility for an alternate assessment based on alternate achievement standards (AA-AAS); (c) adequate vision and hearing to interact with the computer; (d) basic computer skills (e.g., ability to manipulate the mouse); (e) having a vocal verbal response; (f) low comprehension scores (e.g., low measures on a Maze; Fuchs & Fuchs, 1992); (g) consistent attendance record (no more than 2 absences per month); and (h) enrolled in grades 6-8. The teacher was asked to nominate the students based on the selection criteria, and the researcher verified the inclusion criteria for all students. Parents of the nominated students, as well as the students themselves received an informed consent to participate in the study accompanied by a letter explaining the purposes and risks of the study. The researcher used the approved format from the Institutional Review Board (IRB) at the University of North Carolina at Charlotte (UNC Charlotte) to create an informed consent to participate form for the parents and students in the study. The informed consent forms were signed and returned before the researcher began the investigation.

The following sections will describe the four students in paragraph form, including information on ages, grade, gender, diagnosis/disability, participation in alternate assessment based on alternate achievement standards including rationale, and standardized reading scores (if available). Students were in 6th through 8th grade, aged 11-14, male and female, and their IQs ranged from 53-67. In addition, a measure of students' oral reading fluency and passage comprehension was attained through Maze fluency measure (Fuchs & Fuchs, 1992) and the ERCA will be described. Finally, a description of students' computer skills will be included.

Antonio was an 11 year old, African-American, 6th grade male who was independently diagnosed with autism spectrum disorder (Childhood Autism Rating Scale; CARS, Schopler, Bourgondien, Wellman, & Love, 1980), in the mild-moderate range. Antonio also had a moderate intellectual disability (IQ 55, Differential Ability Scale-School age). His IEP team determined his eligibility for an AA-AAS (i.e., also called an Extend 1 in the region) based on global delays in reading, writing, and math. Based on the Woodcock Johnson, Antonio's broad reading score was a 55. Further, his raw score on the Maze fluency measure (Fuchs & Fuchs, 1992) was a 3.00, and his corrected score was 43%. On the ERCA, he scored 85.7% for the first section, 100% for the second section, and 69.7% for the last section for a combined total of 85.5% across sections. Antonio had a vocal verbal response, greeted peers and adults independently, and was usually willing to participate in the science lessons. Antonio also had adequate computer skills for the study. For example, he was able to log into and out of a computer independently, manipulate a mouse, had basic word processing skills, and enjoyed computer games

Rachel was an 11 year old, African-American, 6th grade female who was independently diagnosed with autism spectrum disorder (Childhood Autism Rating Scale; CARS, Schopler, Bourgondien, Wellman, & Love, 1980), in the mild-moderate range. Rachel also had a moderate intellectual disability (IQ 53, Stanford Binet V). Her IEP team determined her eligibility for an AA-AAS (i.e., also called an Extend 1 in the region) based on global delays in reading, writing, and math during the course of the 2009-2010 school year. In past years, she had been on the AA-MAS (i.e., also called the Extend 2 in the region), but had not been successfully passing. Based on the Woodcock Johnson, Rachel's reading comprehension score was a 51. Further, her raw score on the Maze fluency measure (Fuchs & Fuchs, 1992) was a 2.00, and her corrected score was 25%. On the ERCA, she scored 100% for the first section, 90% for the second section, and 69.7% for the last section for a combined total of 86.7% across sections. Rachel had a vocal verbal response, greeted peers and adults with prompting from a teacher, and had difficulty when her routine was disrupted. Rachel had adequate computer skills for the study including the ability to log into and out of a computer independently, manipulate a mouse, and basic word processing skills.

Ethan was a 12 year old, African-American, 7th grade male who was independently diagnosed with autism spectrum disorder (Childhood Autism Rating Scale; CARS, Schopler, Bourgondien, Wellman, & Love, 1980), in the mild-moderate range. Ethan also had a mild intellectual disability (IQ 63, Leiter R). His IEP team determined his eligibility for an AA-AAS (i.e., also called an Extend 1 in the region) based on global delays in reading, writing, and math. Based on the Woodcock Johnson, Ethan's broad reading score was a 72. Further, his raw score on the Maze fluency measure (Fuchs & Fuchs, 1992) was a 4.00, and his corrected score was 31%. On the ERCA, Ethan scored 71.4% for the first section, 77.1% for the second section, and 60.6% for the last section for a combined total of 69.9% across sections. Ethan had a vocal verbal response, but verbalized very infrequently without prompting from an adult. Ethan also had adequate computer skills for the study, including the ability to log into and out of a computer independently, manipulate a mouse, and basic word processing skills.

Dave was a 14 year old, African-American, 8th grade male who was independently diagnosed with autism spectrum disorder (Childhood Autism Rating Scale; CARS, Schopler, Bourgondien, Wellman, & Love, 1980), in the mild range. Dave also had a mild intellectual disability (IQ 67, Leiter R). His IEP team determined his eligibility for an AA-AAS (i.e., also called an Extend 1 in the region) based on global delays in reading, writing, and math. Based on the Woodcock Johnson, Dave's broad reading score was a 68. Further, his raw score on the Maze fluency measure (Fuchs & Fuchs, 1992) was a 3.00, and his corrected score was 43%. On the ERCA, Dave scored 97.1% for the first section, 94.2% for the second section, and 84.9% for the last section for a combined total of 92.2% across sections. Dave had a vocal verbal response and greeted others in response to their greetings. Dave also had adequate computer skills for the study, including the ability to log into and out of a computer independently, manipulate a mouse, and basic word processing skills. In addition, he enjoyed searching the internet for websites and playing games on the computer during his free time.

3.2 Setting

The intervention took place in a middle school in a large, urban school district in North Carolina. Teachers and students were members of Charlotte-Mecklenburg Schools (CMS). In the 2008-2009 academic year, a total of 1,077 students were enrolled at the middle school. Of this number, 27.3% were African American, 6.3% were Hispanic, .5% were American Indian, 2.7% were multi-racial, and 62.4% were white. Fifty-two percent of the student population was male, and 48% were female. Seventy-one percent of the students paid for their lunches, while 29% received a free or reduced-cost lunch. Ten percent of the total number of students had disabilities. One special education teacher and one general education science teacher were recruited for this study.

The special education teacher was recruited from a group of educators who teach classes for students with autism. Holly Scheen was a 36 year old female, with 10 years of teaching experience, who had a BA in Special Education, and was working on her Master's degree in Special Education. The general education teacher was recommended by the special educator. The classroom was in general education school and was designed to meet the needs of students with ASD. The total number of students in the class was 6, there was one classroom teacher, and one paraprofessional for a student to teacher ratio of 3:1. Students rotated classes for all core academics (i.e., Math, ELA, Science, Social Studies). Students alternated science and social studies units each semester. All students, with the exception of Dave, had also attended keyboarding skills class with their regular education peers, with the support of a teaching assistant for one full semester during the 2009-2010 school year. The classroom was equipped with 2 student computers. Computer time was part of students' daily routine during center time in all classrooms. During computer time, students used programs such as DT Trainer, Study Island, watching assigned videos on Discovery Streaming.

3.3 Interventionist

The interventionist for this study was a graduate assistant for a federally funded grant called the Reading Accommodations and Interventions for Students with Emergent Literacy (i.e., *RAISE*) grant at the University of North Carolina at Charlotte. The GA had his Master's degree in Counseling. He had been working for RAISE for the past 3 years. All instructional and assessment sessions were conducted by the GA.

3.4 Second Observers

There were two second observers for this study who collected data on the independent and dependent variables. The second observers also collected procedural fidelity data on the independent variable by observing Book Builder™ intervention sessions, and reliability data on dependent variable (i.e., probes of science comprehension and vocabulary).

One observer was a special education doctoral student who also worked as a Research Scientist (RA) for the Project MASTERY grant at the University of North Carolina at Charlotte. The RA had her Master's degree and teaching license in Special

Education, and was in the dissertation phase of pursuing a doctorate degree. She had over 10 years of experience with students with ASD and other significant disabilities as both a teacher and autism behavior specialist. The interventionist also held a Bachelor of Arts degree with a major in Biology.

The second observer was a graduate assistant (GA) who was enrolled in the special education doctoral program and was working as a GA on the Project MASTERY grant. The GA had her Master's degree in Special Education and was in her first year as a doctoral student in the Special Education program at the University of North Carolina at Charlotte. She had worked as a classroom teacher for students with ASD for 2 years, and as a teacher of students with multiple disabilities for 2 years. She had her BA in Psychology from the University of North Carolina at Chapel Hill, with a focus on childhood developmental disorders.

3.5 Materials

Expository texts using Book Builder™. The researcher used the Book Builder™ program to present the expository science text to the students during baseline and intervention. Book Builder™ is a free, online authoring tool which allows educators and other individuals to create electronic books using a variety of text, images, and audio files. After the books have been created, they are shared on the website, and are available for any student or teacher using a simple log-in process. According to the CAST website, the digitally created books are universally designed to motivate and support students based on their abilities and interests. The website also offers users additional resources for teachers regarding the principles of UDL to enhance student comprehension (NCSeT, 2009).

Supported electronic text can be accessed using the Book Builder™ program. According to Anderson-Inman and Horney (2007), supported electronic text is "…text that has been altered to increase access and provide support to learners" (p. 153). Supported electronic text has been changed to promote content area learning and comprehension (Anderson-Inman & Horney, 2007).

For the purposes of this study, the researcher developed all electronic books based on grade-appropriate science standards from the *Read to Achieve: Comprehending Content Area Text* by Drs Nancy Marchand-Martella and Ronald Martella (SRA/McGraw-Hill, 2009). Each book was designed to include the supports recommended on the Book Builder™ website.

To understand the supports recommended by the Book Builder™, a conceptual framework of supported electronic text is warranted for discussion. A typology of resources related to supported electronic text has been developed by Anderson-Inman and Horney (2007) as part of their work at the National Center for Supported Electronic Text (NCSeT), and is based on the function of the particular support, rather than the type of media used to modify the text. The typology can be used as a conceptual framework to guide educators towards enhancements which facilitate student comprehension, rather than providing superficial enrichments which may or may not benefit student understanding of the text.

Supports which may be included as part of the Book Builder™ program are (a) explanatory resources, (b) illustrative resources, (c) translational, (d) summarizing, (e) enrichment, and (f) instructional. Explanatory resources clarify the "what, where, how, or why of some concept, object, process, or event" (NCSeT, 2009). Illustrative resources support comprehension of the content through visual representations of the text (e.g., drawings, photos, videos, music). Translational resources give readers an accessible example of the text by providing such resources as a synonym, definition, and text to speech. Summarizing resources give readers a synthesized version of the book; examples include a table of contents, graphic organizer, and list of key concepts. Enrichment resources add to the readers' enjoyment of the text or knowledge of the importance of the concept; examples may include background information or footnotes. Instructional resources teach some feature of the text, how to read the text itself, or how to infer meaning from the text. Instructional resources provide the learner with prompts, questions, or strategies, and may include self-monitoring comprehension questions, instructional prompts, or embedded study strategies. Book Builder™ is designed so that any of the resources can be used; however, the author of the text can enhance the electronic text using all, some, or none of the supports.

This investigation used all of the resources available from the Book Builder™ program, and as recommended by the CAST (2009) website. In other words, the researcher designed all science electronic books to include all of the recommended resources by the Book Builder™ website. Specifically, each science electronic book included the following resources: (a) explanatory resources (e.g., hyperlinks to vocabulary definitions, embedded coaches); (b) illustrative resources (e.g., drawings, photos, sounds, and typical examples of a concept in the text); (c) translational (e.g., hyperlinks to vocabulary definitions, text to speech, simplified text at a lower reading level), (d) summarizing (e.g., concept map, list of key ideas), (e) enrichment (e.g., background information); and (f) instructional (e.g., embedded coaches).

In addition to using the resources offered in the Book Builder™ program, the science electronic books were developed using the recommendations from CAST (2009) for embedding the following comprehension strategies in the form of instructional resources (i.e., coaches): (a) predicting, (b) questioning, and (c) summarizing (see CAST for a comprehensive description of each comprehension strategy). The default coaches were used. The first coach, "Pedro" was used for *prompts*, and asked questions such as, "Let's make a prediction. What do you think this book will be about?" The second coach, "Hali" gave students *hints,* such as, "Look at the picture and read the title. This will help you make a prediction." The last coach, "Monty" offers *models* of the comprehension strategy; for example, Monty might say, "I see that the title is Plants, and the picture shows a plant in the soil. I predict this story will be about plants."

Camtasia Studios. According to the website, Camtasia Studios allows the user to record the desktop activity, voice, and Web camera video to create "…compelling video tutorials, training presentations, and rich sales demonstrations for Web and CD-ROM delivery" (TechSmith Corporation, 2010). The user can choose to capture full or partial screens, windows, or regions. In this study, Camtasia Studios was used to record the desktop activity of the students' use of the Book Builder™ program, including where the students clicked, which coaches they used, etc. In addition, the program recorded the students via webcam simultaneously, so that an observer can review the students' screen activity at the same time he/she is observing the actions of the student. So for example, if the student turns the page of the electronic book, finds the picture interesting, and says, "cool picture!" then the observer can see which picture the student is excited about and what the student clicked on to obtain the picture.

Wondershare Quiz Creator. To create digital quizzes, the interventionist used Wondershare QuizCreator V3.2.3 (Wondershare Software Co., Ltd., 2010). This flash quiz maker makes it possible to create quizzes for use on-line, allowing the integration of multimedia objects, images, audio, and narration into the quizzes. In this study, the program was used to deliver the probes to the students via 7 multiple choice questions using text to speech. Although pictures could have been used, the interventionist did not want students to attend to irrelevant stimuli. Additionally, the program has a separate Quiz Management System (Wondershare Software Co., Ltd., 2010), which can track and analyze quiz results. This feature was not used in the study as the interventionist kept data on the probes.

3.6 Independent Variables

Book Builder™. The first independent variable was the supported electronic science text delivered to the student via the Book Builder™ program. The independent variable included all of the resources offered as part of the program. Specifically, the supported electronic texts included the following resources (a) explanatory resources, (b) illustrative resources, (c) translational, (d) summarizing, (e) enrichment, and (f) instructional as described above in the materials section (Anderson-Inman & Horney, 2007). In addition, the resources were provided in a manner consistent with the recommendations from CAST (2009; see Procedures section for a thorough description). A figure showing the elements of Book Builder™, such as the coaches and text to speech option, is presented in Appendix A.

Book Builder™ with explicit prompts. The second independent variable was the supported electronic science text delivered to the student via the Book Builder™ program as described in the preceding section. One difference was that the coaches were modified to provide explicit prompting to the students (see the Procedures section for a full description of the prompting procedures). Another difference was that the text will be altered to provide students with examples and non-examples of the vocabulary words and concepts. All other resources offered with Book Builder™ will be provided in the same fashion as the first independent variable.

Book Builder™ with explicit prompts and referring to the definition. The second independent variable was the supported electronic science text, including the use of explicit prompts delivered to the student via the Book Builder™ program as described in the preceding section. One difference was that the coaches were modified so that students needed to refer to the definition (see the Procedures section for a full description of the prompting procedures). As in the second independent variable, the text was altered to provide students with examples and non-examples of the vocabulary words and concepts. All other resources offered with Book Builder™ were provided in the same fashion as the first and second independent variable.

3.7 Dependent Variable

Number of correct responses on science vocabulary and comprehension probes. The dependent variable was the number of correct responses on science vocabulary and comprehension probes. Each electronic book had a corresponding probe which assessed science vocabulary, comprehension, and generalization of learned content. Each probe had a total of seven questions consisting of three vocabulary, three literal comprehension, and one application question. All probes were conducted using the Wondershare

QuizCreator software (Wondershare Software Co., Ltd., 2010) as described in the materials section.

A correct response for vocabulary questions was defined as the students' clicking on the correct word out of an array of four when asked the question on the digital quiz. For example, using the Wondershare QuizCreator software and text to speech, the researcher asked the students, "When water falls from the clouds to the ground, it is called what?" A correct response in this case would be the student clicking on the word "precipitation" out of an array of four words. A correct response for literal comprehension was defined as the students' clicking on the correct answer based on literal, factual information from the text. An example of a literal comprehension question is, "What happens when air cools?" Finally, correct responses for the application question were defined as when the students' clicked on the correct answer based on an untaught exemplar of the vocabulary word. These were applications of the vocabulary or comprehension questions, but with new examples. For instance, the digital quiz might ask students, "Which one is an example of 'condensation'?"

Vocabulary, comprehension and application questions had one correct answer and three incorrect answers (i.e., distracters) for a total of four options. Students were given a score of 0 for an incorrect response or no response, and a score of 1 for an independent, correct response at the request of the teacher. Response options were word only and were read aloud via text to speech. Distracters included the following for all questions: (a) a close-in distracter from the same lesson; (b) a science term, but not necessarily from the lesson, and (c) a word the students might be familiar with, but did not relate to science. For example, if the lesson was on Sponges: a Type of Invertebrate, the correct answer to the question “What are animals which have no backbone called?” was “invertebrates, the following distracters were used: (a) sponges; (b) experiment, and (c) holes. An example of the assessment is shown in Appendix B. The researcher and the second observer used the same assessment to score the students’ responses on the vocabulary and comprehension probes.

Appendix C includes the dependent variables by component: (a) number correct over total on vocabulary, (b) number correct over total on comprehension questions, and (c) number correct over total on application questions.

Interobserver reliability. Interobserver reliability was collected for all Phases of the investigation. The second observers and interventionist were trained on the operational definitions and received an answer key for correct responses on probes. The experimenter and second scorers will score a probe, discuss any discrepancies, and continue until they reach at least 90% agreement on the probe. The second scorers scored a minimum of 30% of probes distributed evenly across all Phases of the study. Probe results from the researcher and second observer were compared using an item by item analysis (i.e., compare each correct and incorrect response on probes). The reliability coefficient will be calculated by dividing the number of agreements by the total number of agreements and disagreements).

Content validity. Since the text from the science electronic books was taken directly from the *Read to Achieve: Comprehending Content Area Text* (SRA/McGraw-Hill, 2009), the validity of the content as aligning with state/national science standards was implicit. In addition, all probe questions for vocabulary, comprehension, and application were taken from the text.

Instructional validity. The electronic books were evaluated by an expert on explicit instruction to ensure the procedures used in the book are consistent with explicit instruction from the direct instruction literature (e.g., use of modeling to teach examples and non-examples; referring to the definition). The researcher showed the expert examples of the coaches for each phase of the intervention before the books were introduced to the student. The expert made recommendations for changes based on these examples, and the researcher used the examples as a template for future lessons.

Social validity. Social validity refers to the practical, or social significance, of the goals, procedures, and outcomes of the intervention (Baer, Wolf, & Risley, 1968; Wolf, 1978). Social validity data are indicative of whether or not interventions will be used by typical intervention agents, such as teachers (Kennedy, 2005). These data are of particular importance to the field of autism, due to the "near absence of social validity research, especially studies addressing multiple intervention components associated with successful programs for school-aged students" (Callahan, Henson, & Cowen, 2008, p. 678). In this investigation, a formal social validity data measure was used with relevant consumers to determine the social importance of the supported electronic text for students with ASD (Kazdin, 1977; Wolf, 1978). Students and teacher perceptions were measured using both open-ended and close-ended questions (found in Appendix E-G).

Students with ASD were asked to rate the supported electronic text intervention, including a question of electronic text as compared to traditional text (see Appendix E). Materials for the social validity measure were read to the students. The second observer was responsible for asking the social validity questions of the students.

Teachers were asked the following on a questionnaire: to rate the intervention as socially important, the degree of need for this types of science instructional methods in middle schools for all students, and whether or not the intervention was feasible, practical and/or cost-effective. The general education and special education teachers were also shown a demonstration of the program, as described previously. General education teachers will also be asked to rate the intervention on usefulness in general education science classrooms, and for which population (s) of students the program might be beneficial for.

3.8 Experimental Design

The effects of supported electronic text using the Book Builder™ program on students' science vocabulary and comprehension was assessed using a multiple-probe-across-students design (Horner & Baer, 1978; Kennedy, 2005; Tawney & Gast, 1984). When conducting research with a low incidence population, such as students with ASD, a single subject design (e.g., multiple baseline) may be preferable to a group design due to the limited student population and the variability in characteristics of students with ASD (Horner, Carr, Halle, Odom, & Wolery, 2005). Like group designs, single subject designs can also demonstrate a causal inference (i.e., functional relationship) when manipulation of the independent variable(s) produces a change in the dependent variable(s) (i.e., the intervention caused the change in student behavior or performance). In contrast to group designs which demonstrate the efficacy of an intervention by comparing the treatment and control group, participants themselves provide the comparison as the unit of analysis in a single subject design (Kennedy, 2005; Tawney & Gast, 1984).

A multiple-probe-across-participants design was used for this investigation. Horner and Baer (1978) introduced the multiple probe design as an alternative to the multiple baseline design. In a multiple baseline design, data are collected on a continuous basis during the baseline Phase; however, in the multiple probe design, data are collected intermittently using probe trials during the baseline Phase. In this investigation, a multiple probe design is considered to be a practical alternative to the multiple baseline design for the following reasons: (a) continuous baseline probes were unnecessary; (b) intermittent probes can avoid negative behaviors which can occur during continuous baselines (e.g., fatigue, learning from the baseline probes); and (c) a strong assumption of baseline stability can be made (Kennedy, 2005; Tawney & Gast, 1984). Because the students in this investigation had limited or no exposure to supported electronic text in a content area of science, an a priori assumption of a stable baseline was made. Data were collected on the number of correct responses to the science vocabulary and comprehension probes for all students across all conditions and Phases. Probe data were collected every other school day.

Baseline included a minimum of three data points, or until a stable or descending trend was established for all students. When a stable or descending path across all students was established for the first student, the training on how to use the Book Builder™ program was implemented for the first student. Data collection continued throughout the training Phase. Intervention using supported electronic text via Book Builder™ was be implemented with the first student based on the lowest and most stable baseline data and success with the training. As the first student received the intervention, data collection continued for all remaining students in the baseline or training Phase.

When the data for the first student showed a clear change in level, trend, or variability of at least three to five data points, the second student received the training on Book Builder™. When the data for the second student showed a clear change in level, trend, or variability, the third student entered into the training Phase. The third and remaining students received training based on the same criteria. Implementation of the independent variable occured for all students using the same methods described for the training.

3.9 Procedures

General procedures. During all conditions, the students were provided with illustrative resources (e.g., drawings, photos, sounds, and typical examples of a concept in the text), and one type of a translational resources (i.e., text to speech; Anderson-Inman & Horney, 2007). Further, throughout all conditions and Phases, students listened to the audio recording of the electronic book 2 times. On the first day, the student listened to the electronic book 1-2 times, and on the second day, the student was probed. Following the second listening of the electronic book on the second day, the students were probed to determine the number of correct responses to the vocabulary and comprehension questions.

All data (i.e., probes, IRR and procedural fidelity) were collected by graduate assistants and research assistants from UNC Charlotte. Probe data was plotted on a daily basis using a graph, and visual inspection of the data was used to determine when to start intervention (i.e., only if the data points are stable or show a descending trend).

Pre-baseline training: Before students enter baseline, they were trained on how to use the Book Builder™ supports which were available to them during baseline. Specifically, students were provided with text-to-speech and illustrations. In addition, students were trained on how to use the basic operations of the program (e.g., turning the pages; see Appendix D for pre-baseline procedures). During this training, students were not provided with training on how to use supports in the intervention Phase.

Following the training, the students were given an assessment on the supports and basic operations of the Book Builder™ program. For example, the researcher told the student to "Turn to the next page of the book." When all students demonstrated proficiency (90-100%) on the training assessment, the researcher began baseline. The training assessment on the pre-baseline training is included in Appendix D.

Baseline. During baseline, no additional electronic resources were provided, with the exception of those described in the general procedures section (i.e., text to speech and illustrations). The rationale for inclusion of these supports during the baseline condition was based on a number of factors. First, these supports were chosen because the some of the students were not able to read independently, and therefore not able to access the text. The researcher did not want the students' reading level to hinder their access to the science content. Text to speech would allow access to the text in a similar fashion to traditional read alouds, which the students receive as part of their daily instruction. In a traditional instruction using a read aloud strategy, the teacher would read the text and show illustrations. Therefore, the only difference between the traditional "read aloud" instruction and the electronic instruction during baseline conditions was that the instruction would be provided by the computer. Because of the similarities in the functions of support (i.e., illustrative and translational; Anderson-Inman & Horney, 2007), these resources may not provide enough support for students to learn new science content. Third, typical instruction using a computer (i.e., CD-ROM) would have TTS and illustrations available. Finally, the researcher was interested in the other supports offered (i.e., coaches, hyperlinks to text) as they relate to the typology suggested by Anderson-Inman and Horney (2007). Specifically, the researcher was interested in (a) explanatory resources (i.e., hyperlinks to vocabulary definitions, embedded coaches); (b) translational resources (i.e., hyperlinks to vocabulary definitions, simplified text at a lower reading level), (c) summarizing resources (i.e., concept map, list of key ideas), (d) enrichment resources (e.g., background information); and (e) instructional resources (e.g., embedded coaches). Information related to the probes is described in the general procedures section.

As described in the general procedures section, data were collected on the dependent variable. A minimum of three baseline probes were obtained before intervention. Further, the lessons used for the baseline probes were nit used in the intervention Phase. When students demonstrated mastery with the other lessons during the intervention Phase, the lessons used in the baseline Phase were probed again.

Pre-Intervention training on Book Builder™. After students had a stable or descending trend during baseline, students were instructed on how to use the Book Builder™ program individually before they started intervention. Students were instructed on the use of the program using a training manual created by the researcher. In addition, the researcher also demonstrated the program, provided assistance and clarification to the students, and answered questions the students might have. Students accessed the training manual using the Book Builder™ program itself. The training manual provided instructions on how to use the mechanics of the program as well as how to access the resources from the electronic book. First, the training explained the mechanics of electronic text, such as how to turn the pages, how to use the mouse to click on the support the student wants to access, etc. Second, the training provided information on how to use each of the resources offered by the Book Builder™ program (e.g., translational resources, explanatory resources). Students were asked to give a verbal response after the computer prompt so that the researcher will know whether or not the student understands the support offered. For instance, if one of the embedded coaches asked, "What do you think this book will be about?" the student was asked to state the answer. "I don't know" will be considered a response. If students did not respond, the researcher prompted the student using a least to most prompting strategy. Supports not offered by the program (e.g., additional cues to the text, answers to the questions from embedded coaches) were not given by the interventionist to the students under any condition. Students were asked to use all supports during training, even if the student did not need all of them. For example, the embedded coaches offer varying levels of support, and students may respond correctly after the least intrusive level of support; however, for training purposes, students were to use the other increasing levels of support.

Following the training, the students were given an assessment on the mechanics and resources of the electronic text. For example, the researcher told the student to "Turn to the next page of the book." When the first student demonstrates proficiency (90-100%) on the training assessment, the researcher began intervention with the first student. The pre-intervention training on Book Builder™ is included in Appendix D.

Phase 1: Instruction with Book Builder™. When a student's data path showed a stable or descending trend during baseline, and a minimum of three baseline data points, the researcher intervened with that first student. As described in the general procedures section, the students in the intervention phase were provided with the illustrative and translation resources (in the form of text to speech). The intervention consisted of the following; (a) electronic science texts created by the researcher and validated by a science content expert; (b) electronic science texts delivered to the student using the Book Builder™ program; and (c) electronic science texts with all of the supports recommended by the Book Builder™ website available to the student. Students determined the level of supports and types of supports needed during all sessions. On the other hand, when the interventionist determined from the students' verbal responses that the student needed additional supports, the student was prompted. If the student needed more than three prompts during the session, then the student was given a booster session. The booster session reminded students of the mechanical supports needed and how to determine the level of support they needed. If students required more than three booster sessions, then the second phase of the intervention was implemented (i.e., described in the following section). In addition, if students scored lower than 70% on the comprehension and vocabulary probe for 2 consecutive sessions, then students moved to the second phase of the intervention (i.e., instruction with Book Builder™, explicit instruction and additional prompting). A figure showing the elements of Book Builder™, such as the coaches and text to speech option, is presented in Appendix A.

Phase 2: Instruction with Book Builder™ and explicit instruction. When the changes in the level or trend did not show substantial improvement during Phase 1 of the intervention, a phase change was necessary. Phase 2 of the intervention used modified coaches to provide explicit instruction and additional prompting (e.g., model-lead-test). For example, Pedro "modeled" the answer by saying something like, "To break down is to biodegrade." Then, Halo led the students by saying, "Say it with me. To break down is to biodegrade." Finally, Monty "tested" the student by asking a question such as, "To break down is to what?" In addition, examples and non-examples of the concepts were presented in the electronic text. For example, one page of the text might show a picture of magma, and the text would state "This is magma." The next page would show a close-in non-example, such as lava; the text would state "This is not magma." Three examples and one non-example were shown for each of the vocabulary questions.

Phase 3: Instruction with Book Builder™, explicit instruction, including referring to the definition. When the changes in the level or trend did not show substantial improvement during Phase 2 of the intervention, another Phase change was necessary. The third phase of the intervention used the same modified coaches to provide explicit instruction and additional prompting (e.g., model-lead-test) as in the second phase of the intervention. Examples and non-examples of the concepts were presented in the electronic text as well as in the second phase of the intervention. The difference was that the coaches explained the reason "why" one was an example and one was a non-example. In the magma example from the previous section, Pedro would say, "This volcano has magma." Then, Hali would say "The volcano has liquid or molten rock coming out from it. Does the volcano have magma?" Finally, Monty would say, "Yes, the volcano has magma. How do you know?" This last coach required the students to refer to the definition and provide a rationale. In this Phase, only one example and one non-example were shown for each of the vocabulary questions, as the books were starting to take over 20 minutes for the students to complete.

Demonstration of Book Builder™ for teachers. Prior to collection of social validity data from teachers, general education and special education teachers were shown a demonstration of the supported electronic text using the Book Builder™ program, including the electronic books created by the researcher and other authors. In addition, the teachers were shown how they can create their own electronic books using the Book Builder™ program.

Procedural fidelity. Procedural fidelity measured both the training of the Book Builder™ program and accurate implementation of the assessment probes. First, a second observer attended training sessions for the Book Builder™ program and used a procedural fidelity checklist to determine the presence or absence of each step included by the researcher (see Appendix I-J). The checklist was used to record whether or not the researcher showed the students how to use the content enhancements, hyperlink to vocabulary definitions, turn the digital pages, etc. Second, the second observer also measured procedural fidelity during baseline and intervention probes using + for present and – for absent for each vocabulary and comprehension question. At least 30% of the trainings and probes were assessed by another observer. Procedural fidelity was calculated by dividing the number of steps the researcher performs by the total number of steps for the Book Builder™ training and the probe data (see Appendix I). Appendices have checklists for the training and probe sessions. Third, procedural fidelity was also taken on the prompting from the instructor needed during a lesson (see Appendix J).

3.10 Method of Data Analysis

To evaluate the impact of supported electronic text via Book Builder™, data on the number of correct responses on the science vocabulary and comprehension was graphed for every session across four students using Microsoft Excel®. To determine whether or not a functional relationship existed between the independent and dependent variables, data were evaluated based on the "strength or magnitude of the target behavior (mean and level) across conditions and the rate of these changes" (trend and latency; Tankersley, Harjusola-Webb, & Landrum, 2008, p.87). Visual analysis of the graphs was used to determine both the strength and rate of the changes in the dependent variable across all conditions and Phases of the investigation. Experimental control was demonstrated using a multiple probe design if students' data show changes in mean, level, trend, or variability replicated across tiers as a result of the individual application of the supported electronic text and/or supported electronic text with explicit prompts.

CHAPTER 4: RESULTS

4.1 Interobserver Reliability

Interobserver reliability was collected during baseline and all Phases of the investigation for all students on the probes, pre-baseline training assessments, and pre-intervention training assessments. Second observers scored 40.5% of the baseline probes, 35.8% of the instructional probes across Phases, 66.7% of the pre-baseline training assessments, and 25% of the pre-intervention assessments. Overall interobserver reliability was 100%; including baseline probes, instructional probes, pre-baseline assessments, and pre-intervention assessments for all students.

Interobserver reliability on baseline probes. Second observers evaluated 66.7% of the baseline probes for Antonio. For Rachel, second observers evaluated 33.3% of the baseline probes. Second observers also evaluated 42.9% of the baseline probes for Ethan. Finally, second observers evaluated 30% of the baseline probes for Dave.

Interobserver reliability on instructional probes. For Antonio, second observers evaluated 25% of the instructional probes for Phase 1, 28.6% of the instructional probes for Phase 2, 40% of the instructional probes for Phase 3, and 50% of the instructional probes for the maintenance Phase for Antonio. For Rachel, second observers evaluated 33.3% of the instructional probes for Phase 1, 25% of the instructional probes for Phase 2, 33.3% of the instructional probes for Phase 3, and 33.3% of the instructional probes for the maintenance Phase. For Ethan, second observers also evaluated 20% of the instructional probes for Phase 1, 50% of the instructional probes for Phase 2, and 75% of the instructional probes for Phase 3. Finally, for Dave, second observers evaluated 33% of the instructional probes for Phase 1, 50% of the instructional probes for Phase 2, and 100% of the instructional probes for Phase 3.

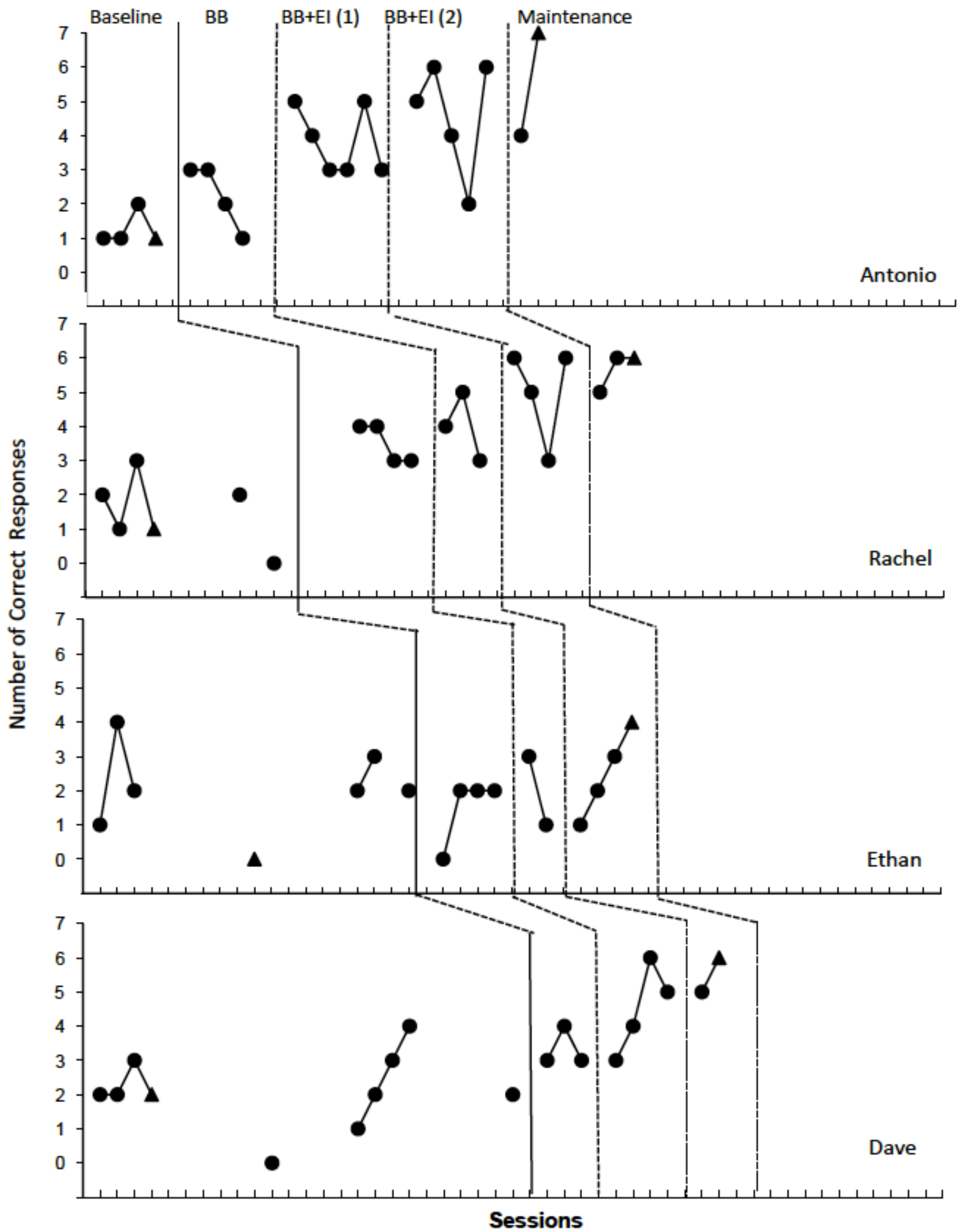
Pre-baseline and pre-intervention training assessments. Second observers evaluated 66.7% of the pre-baseline training assessments for Antonio, Rachel, Ethan, and Dave. Second observers evaluated 50% of the pre-intervention training assessments for Antonio and 100% of the pre-intervention training assessments for Rachel. Second observers also evaluated 33.3% of the pre-intervention training assessments for both Ethan and Dave.

4.2 Procedural Fidelity

Since the instruction and probes were delivered by a computer program, procedural fidelity measured the training of the Book Builder™ program during pre-baseline and pre-intervention by the interventionist (see Appendix D), prompting from the instructor during a lesson (see Appendix J), and prompting from the instructor during the probes (see Appendix I). During pre-baseline and pre-intervention trainings, throughout the lessons, and during the probes, the interventionist used a checklist to monitor procedural fidelity and second rater observed 56.1% of sessions to establish reliability. Interobserver agreement for the pre-baseline trainings was collected on 66.7% and reported with 100% agreement of steps completed. Interobserver agreement for the pre-intervention trainings was collected on 45.8% and reported with 100% agreement of steps completed. Throughout the lessons, interobserver agreement was collected on 45.2% of baseline lessons, 25% of Phase 1 lessons, 50% of Phase 2 lessons, 60% of

Phase 3 lessons, and 100% of maintenance lessons. Throughout all Phases, there was 100% agreement of steps completed. Although the interobserver agreement may seem high, the reason for the consistency was that the baseline probes, instructional probes, pre-baseline assessments, and pre-intervention assessments were delivered by the computer. The GA monitoring the probes and assessments only prompted students when necessary, and followed a system of least to most prompts consistently.

Figure 1. Number Correct on Comprehension and Vocabulary Probes for Antonio, Rachel, Ethan, and Dave



*Note: BB=Book Builder™, EI= Explicit Instruction, (1)= Examples and non-examples, MLT, (2)= Examples and non-examples, MLT, and referral to the definition, Triangles= same lesson.

4.3 Results for Question 1

What is the effect of supported electronic text using the Book Builder™ program on comprehension and vocabulary of middle school science content for students with ASD?

Figure 1 presents the number of correct responses on vocabulary and comprehension probes across students and for all Phases. Phase 1 of the intervention delivered instruction using the Book Builder program and supported electronic text as suggested by CAST (2010). All four students received intervention in Phase 1. As seen in Figure 1, two out of four students increased the number of correct responses from baseline to Phase 1 of the intervention. During baseline, students' number of correct responses on the probe was low and stable. In Phase 1, or when Book Builder™ using the supports as recommended by CAST was introduced, two of the four students' responses improved, but remained relatively low (i.e., majority of probes were below 50% correct). Visual analysis of the graph indicated replication of the positive effects of using the Book Builder™ program for only two students, as the preceding students' data remained stable in the baseline Phase. The lack of replication of effect prevents a functional relationship between Book Builder™ and correct responses on vocabulary and comprehension probes.

Table 1. Means and Ranges for Number of Student Responses Across Phases

	Baseline	IV Phase 1	IV Phase 2	IV Phase 3	Maintenance
AG	*M*=1.25 (range=1-2)	*M*=2 (range=1-3)	*M*=4 (range=3-5)	*M*=4.6 (range=2-6)	*M*=6 (range=4-7)
RC	*M*=1.5 (range= 0-3)	*M*=4 (range=3-4)	*M*=4 (range=3-5)	*M*=5 (range=3-6)	*M*=5.6 (range=5-6)
EM	*M*=2 (range= 1-4)	*M*=2 (range=0-2)	*M*=2 (range=1-3)	*M*=2.5 (range=1-4)	n/a
DM	*M*=2 (range= 0-4)	*M*=3 (range=3-4)	*M*=4.5 (range=3-6)	*M*=5.5 (range=5-6)	n/a
Overall	*M*=1.7	*M*=3	*M*=3.6	*M*=4.4	*M*=5.8

Means:	(range=0-4)	(range=0-4)	(range=1-6)	(range=1-6)	(range=4-7)

4.4 Results for Question 2

What is the effect of a modified version of Book Builder to include the use of explicit instruction on the science comprehension and vocabulary of middle school students with ASD?

Figure 1 presents the number of correct responses on vocabulary and comprehension probes across students and for all Phases. Phase 2 and 3 of the intervention delivered instruction using the Book Builder program and supported electronic text using explicit instruction. Phase 2 of the intervention provided explicit instruction using a model-lead-test format for the vocabulary and comprehension questions and provided examples and non-examples of the vocabulary words. Phase 3 used these supports as well, but added the need for students to refer back to the definition when explaining examples and non-examples (see Chapter 3 for a thorough description). All four students received intervention in Phase 2 and 3. As seen in Figure 1, three out of four students increased the number of correct responses from baseline to Phase 2 of the intervention, and three out of four students increased the number of correct responses from baseline to Phase 3 of the intervention. Visual analysis of the graph indicated replication of the positive effects of using the Book Builder™ program with explicit instruction, since three out of four students' number of correct responses improved following implementation of the Book Builder™ program with explicit instruction, while the preceding students' data remained stable in the baseline Phase. Therefore, a functional relationship between Book Builder™ using explicit instruction and increased correct responses on vocabulary and comprehension probes was demonstrated. Means and ranges for all students across Phases can be found in Table 1. Information on the dependent variables is provided in Tables 2-5, including an item analysis of vocabulary, comprehension, and application questions.

Antonio. During baseline, the number of correct responses on the probe was low and stable, with a range of 1 to 2, and a mean of 1.25. During Phase 1, when the Book Builder™ with supports as recommended by CAST was introduced, there was a temporary change in level and trend. In Phase 1, his responses ranged from 1 to 3, with a mean of 2. From Phase 1 to Phase 2, when the explicit instruction was introduced, there was a change in level, but the data were variable, and his responses ranged from 3 to 5 with a mean of 4. In Phase 3, when the coaches were modified to refer to the definition, Antonio's responses improved again but there was a variable trend. Overall, his responses remained relatively high; in Phase 3 his responses ranged from 2 to 6 with a mean of 4.6. Finally, during maintenance, Antonio's responses ranged from 4 to 7 with a mean of 6.

Rachel. During baseline, the data pattern showed a decelerating trend, with a range of 0 to 3, and a mean of 1.5. During Phase 1, when the Book Builder™ with supports as recommended by CAST was introduced, there was a temporary change in level and trend. In Phase 1, her responses ranged from 3 to4, with a mean of 4. From Phase 1 to Phase 2, when the explicit instruction was introduced, there was no change in level and the data were variable. In Phase 2, her responses ranged from 3 to 5, with a mean of 4. In Phase 3, when the coaches were modified to refer to the definition, Rachel's responses improved again, in that there was an immediate change in level and trend, followed by a variable trend. Overall, her responses remained relatively high in

Phase 3; in this Phase, her responses ranged from 3 to 6 with a mean of 5. Finally, in maintenance, Rachel's responses ranged from 5 to 6 with a mean of 5.6.

Ethan. During baseline, the number of correct responses on the probe was low and stable, with a range of 1 to 4, with a mean of 2. During Phase 1, when the Book Builder™ with supports as recommended by CAST was introduced, there was no change in level or trend. In Phase 1, his responses ranged from 0 to 2, with a mean of 2. From Phase 1 to Phase 2, when the explicit instruction was introduced, there was no change in level or trend, and his responses ranged from 1 to 3, with a mean of 2. In Phase 3, when the coaches were modified to refer to the definition, Ethan's responses ranged from 1 to 4, with a mean of 2.5. Overall, his responses started to steadily increase in Phase 3.

Dave. During baseline, the number of correct responses on the probe was variable, with a range of 0 to 4, and a mean of 2. During Phase 1, when the Book Builder™ with supports as recommended by CAST was introduced, there was no change in level or trend. In Phase 1, his responses ranged from 3 to 4, with a mean of 3. From Phase 1 to Phase 2, when the explicit instruction was introduced, his responses ranged from 3 to 6, with a mean of 4.5. In Phase 3, when the coaches were modified to refer to the definition, Dave's responses remained relatively high; in Phase 3 his responses ranged from 5 to 6, with a mean of 5.5.

Table 2. Percentage of Correct Vocabulary Questions Across Phases

	Baseline	IV Phase 1	IV Phase 2	IV Phase 3
AG	8.33%	22.22%	50%	66.67%
RC	22.22%	41.67%	33.33%	73.33%
EM	19.05%	25%	16.67%	16.67%

DM	33.33%	44.45%	66.67%	100%
Overall Means:	20.73%	33.33%	41.66%	64.16%

Table 3. Percentage of Correct Comprehension Questions Across Phases

	Baseline	IV Phase 1	IV Phase 2	IV Phase 3
AG	16.67%	44.44%	55.56%	60%
RC	22.22%	50%	77.78%	80%
EM	33.33%	25%	50%	50%
DM	40%	55.56%	66.67%	50%
Overall Means:	28%	43.75%	62.5%	60%

Table 4. Percentage of Correct Application Questions Across Phases

	Baseline	IV Phase 1	IV Phase 2	IV Phase 3
AG	50%	33.33%	66.67%	80%
RC	16.67%	75%	66.67%	40%
EM	42.86%	0%	0%	50%
DM	10%	0%	50%	100%
Overall Means:	29.88%	27.08%	45.83%	67.5%

Table 5. Overall Percentages Across Students From Baseline to Intervention Phase 3

	Vocabulary		Comprehension		Application	
	Baseline	IV3	Baseline	IV 3	Baseline	IV 3
Overall Means:	20.73%	64.16%	28%	60%	29.88%	67.5%

4.5 Results for Question 3

How do students evaluate the supported electronic text used in this study?

Students responded to a survey evaluating the supported electronic text used in the study. The survey was read aloud to all students by the second observer. The survey contained both close-ended and open-ended questions. Tables 6 and 7 present the item, participant, and student responses to the open-ended and close-ended questions. Overall, all students enjoyed using the computer to learn about science, thought that having the meanings to the words helped them to learn science, and most students thought that the coaches helped them to learn science. In addition, all of the students thought that either the meanings to the words (hyperlinks to vocabulary) or the coaches were the most beneficial. The question, "Would you rather use the computer or read a book to learn about science?" may have been confusing for the students, as the science lessons were referred to as "books." Using pictures, the question was rephrased as, "I would rather read a science book: (a) on the computer with a teacher; (b) on the computer by myself; (c) on paper with a teacher; and (d) on paper by myself." In response to this question, students varied in their responses (See table 6)

Table 6. Student Survey Close Ended Questions

Item	Participant	Response
Did you enjoy using the computer to learn about science?		
	AG	Yes
	RC	Yes

	EM	Yes
	DM	Yes
I would rather read a science book: (a) on the computer with a teacher; (b) on the computer by myself; (c) on paper with a teacher; and (d) on paper by myself.		
	AG	On the computer with a teacher
	RC	On the computer with a teacher
	EM	On the computer by myself
	DM	On paper with a teacher
Do you think that the pictures helped you to learn the science information?		
	AG	Yes
	RC	Yes
	EM	Yes
	DM	No
Do you think that having the words read aloud helped you to learn science?		
	AG	Yes

	RC	Maybe
	EM	Maybe
	DM	Maybe
Do you think that having the meanings to the words helped you to learn the science words?		
	AG	Yes
	RC	Yes
	EM	Yes
	DM	Yes
Do you think that the coaches (Pedro, Hali, and Monty) helped you to learn science?		
	AG	Yes
	RC	Maybe
	EM	Yes
	DM	Yes
Which do you think helped the most: (a) pictures; (b) words read aloud; (c) meanings to words; or (d) coaches.		

	AG	Coaches
	RC	Meanings to words
	EM	Meanings to words
	DM	Coaches

Table 7. Student Survey Open-Ended Questions

Item	Participant	Response
Would you want to use the computer in other subjects, like social studies? Why or why not?		
	AG	Yes, because I think it would help
	RC	Yes, in ELA.
	EM	Yes
	DM	Yes
What did you learn from having science on the computer?		
	AG	Words
	RC	Mammal, environment, precipitation

	EM	No response
	DM	Pollution, clouds, mammals, environment
Would you want to keep using the computer to learn science? Why or why not?		
	AG	Yes
	RC	Maybe
	EM	Yes
	DM	Yes, helps

4.6 Results for Question 4

How do general education teachers evaluate the supported electronic text used in this study?

One general education science teacher evaluated the supported electronic text used in the study. First, she was shown a demonstration of the Book Builder™ program, including the supports used across the Phases, and how they differed. Then, she was asked to complete a 20 question survey consisting of 20 items; 14 of which were close-ended questions and the remaining six were open-ended. The general education teacher strongly agreed that (a) the Book Builder™ program would help her students increase science vocabulary, (b) the Book Builder™ program would help her students increase science comprehension, (c) the Book Builder™ program would be practical and easy to use, (d) she would be more likely to use a free program, such as Book Builder™ to create digital books rather than a program she would need to purchase, and (e) the Book Builder™ program would be beneficial for students in other content areas. Further, she agreed that (a) the use of the Book Builder™ program as designed (with supports recommended by CAST) would be beneficial for her students, (b) the use of the Book Builder™ modified with explicit prompts (e.g., with supports such as model-lead-test) would be beneficial for her students, and (d) she would use it as a supplementary aide to her science instruction. With respect to the resources as delineated by Anderson-Inman and Horney (2007) the general education teacher strongly agreed that the: (a) the explanatory resources (e.g., hyperlinks to vocabulary definitions, embedded coaches); (b) illustrative resources (e.g., drawings, photos, sounds, and typical examples of a concept in the text); (c) translational resources (e.g., hyperlinks to vocabulary definitions, text to speech); (d) summarizing resources (e.g., concept map, list of key ideas); and (e) enrichment resources (e.g., background information) as being the most beneficial for her students. She agreed that the instructional resources (e.g., embedded coaches) would be the most beneficial for her students. A description of the open-ended questions is included in the Results for Question 6 section.

When asked the open-ended questions, the general education teacher stated the most helpful resources for her students would be the summarizing resources, because "…all children have difficulty summarizing what they read." She also stated that "…the response section would be valuable and that [she] would utilize it along with allowing them to build their own books as an assessment." In response to the question, "Which type of student do you think would most benefit from using the Book Builder™ program in science," the general education teacher stated, "all students, as this could be a great way to differentiate instruction." In addition, she said she would use Book Builder™ to create her own books. She also said "…it would be a great assessment tool used after they read books created on Book Builder™, then they could preview and grade the quality of their classmates' books." Other useful applications the general education teacher recommended would be "a tool to differentiate instruction." She also stated that the "…leveled coaches that model, have students imitate and then allow students to answer is an excellent way to gain attention and content knowledge." One follow up question was emailed to the general education teacher which stated, "Do you think that Book Builder™ could promote inclusive practices? Why or why not?" The general education teacher responded by commenting, "I think book builder is an excellent tool to be utilized during inclusion. As it is a wonderful way to differentiate instruction and modify not only the method of instruction, the Lexile level of the material but also the program would allow for students of all levels to work together. For example, the higher level students can create books while the lower level students can interact and read them. They can work in pairs and independently."

4.7 Results for Question 5

How do special education teachers evaluate the supported electronic text used in this study?

One special education teacher evaluated the supported electronic text used in the study. The questionnaire consisted of 20 items; 14 of which were close-ended questions, and the remaining six were open-ended. The special education teacher agreed that (a) the Book Builder™ program helped her students increase science vocabulary, (b) the Book Builder™ program helped her students increase science comprehension, (c) the use of the

Book Builder™ program as designed (with supports recommended by CAST) was beneficial for her students, and (d) she would use it as a supplementary aide to her science instruction. In addition, she agreed that (a) the Book Builder™ program was practical and easy to use, (b) she was more likely to use a free program, such as Book Builder™ to create digital books rather than a program she would need to purchase, and (c) the Book Builder™ program would be beneficial for students in other content areas. With respect to the resources as delineated by Anderson-Inman and Horney (2007), the special education teacher strongly agreed that the (a) illustrative resources (e.g., drawings, photos, sounds, and typical examples of a concept in the text); (b) summarizing resources (e.g., concept map, list of key ideas); and (c) instructional resources (e.g., embedded coaches) were the most beneficial for her students. She also agreed that (a) the explanatory resources (e.g., hyperlinks to vocabulary definitions, embedded coaches) and (b) translational resources (e.g., hyperlinks to vocabulary definitions, text to speech) were beneficial for her students. She felt neutral about the enrichment resources (e.g., background information) as being beneficial for her students.

When asked the open-ended questions, the special education teacher reported that the most beneficial resource was the use of the coaches to provide model-lead-test. She stated that there was limited amount of verbal language and it repeated the information. As the special education teacher suggested, "picture cues above the text might be helpful if the program was used for students that are lower readers to increase understanding of science content." Students she thought might most benefit from the program included "students with high functioning autism, cognitive disabilities, and students with learning disabilities." She explained that she might use Book Builder™ to create her own books because the process seemed time consuming and she reported not being "great with technology and trying to record on MP3/ importing it is intimidating." The special education teachers stated that another application to the Book Builder™ program might be to teach definitions of vocabulary words. Finally, she suggested that the program would be beneficial if there was a way for the program to recognize/respond to student errors, as there was no way to guarantee they will follow the coach's directions.

4.8 Results for Question 6

Do general education teachers validate the strategy as useful for students in their classes?

Overall, the general education teacher seemed very intrigued by the Book Builder™ program, and validated the strategy as useful for all of the students in her class. Specifically, the general education teacher stated the most helpful resources in the Book Builder™ program for her students would be the summarizing resources, because "…all children have difficulty summarizing what they read." She also stated that "…the response section would be valuable and that [she] would utilize it along with allowing them to build their own books as an assessment." In response to the question, "Which type of student do you think would most benefit from using the Book Builder™ program in science," the general education teacher reported, "all students, as this could be a great way to differentiate instruction." In addition, she said she would use Book Builder™ to create her own books. She also replied, "…it would be a great assessment tool used after they read books created on Book Builder™, then they could preview and grade the quality of their classmates' books." Another useful application the general education teacher recommended was as a tool to differentiate instruction. Finally, she stated that the

"…leveled coaches that model, have students imitate and then allow students to answer is an excellent way to gain attention and content knowledge."

CHAPTER 5: DISCUSSION

The purpose of this investigation was to determine if supported electronic text, using a universally designed program was effective for teaching science vocabulary and comprehension skills to students with ASD who are eligible for the AA-AAS. A multiple probe across participants design was used to determine the impact of the independent variable on the dependent variable.

The following outcomes were found for the research questions that guided the investigation: (a) What is the effect of supported electronic text using the *Book Builder*™ program on comprehension and vocabulary of middle school science content for students with ASD? The findings of this study do not demonstrate a functional relationship between the Book Builder™ program and the number correct on the science comprehension and vocabulary probes; (b) What is the effect of a modified version of Book Builder to include the use of explicit instruction on the science comprehension and vocabulary of middle school students with ASD? The findings of this study demonstrated a functional relationship between the modified versions of Book Builder™ including explicit instruction and the number correct on the science comprehension and vocabulary probes; (c) How do students evaluate the supported electronic text used in this study? Overall, students enjoyed the supported electronic text, most indicated a preference for books in a supported electronic format over traditional print-based books, and all students felt that having the hyperlinks and coaches were the most beneficial resources; (d) How do general education teachers evaluate the supported electronic text used in this study?

The special education teacher found the program to be beneficial and believed that it helped to increase students' vocabulary and comprehension in science; and (f) Do general education teachers validate the strategy as useful for students in their classes? The general education teacher validated the strategy as being useful for all of the students in her classes, as a means to differentiate instruction, and useful for assessment.

In general, these findings are consistent with previous studies on the use of supported electronic text (e.g., Anderson-Inman & Horney, 2007; MacArthur et al., 2001). Findings are also consistent with extant research on teaching comprehension skills to students with ASD (e.g., Browder et al. 2006; Chiang & Lin, 2007). A discussion of more specific findings is presented below, organized by themes, followed by limitations of the research, suggestions for further research, and implications for practice.

5.1 Universal Design for Learning

The current investigation provides data to address a widely discussed theoretical learning approach, Universal Design for Learning (UDL) as a means to promote vocabulary and comprehension of science content for students with ASD. Literature suggests UDL as a means to include all students in grade aligned science content (e.g., Curry, 2006; Dymond et al., 2006). Specifically for students with ASD, Hart and Whalen (2008) recommend the use of UDL as a way to promote academic engagement and communication in inclusive settings, despite the lack of empirical research on the effects of using a UDL framework for instruction. CAST (2010) promotes the use of the Book Builder™ program as a universally designed program. Findings of this study suggest that the students with ASD made gains when explicit instruction was added to the Book Builder™ program. In contrast, students did not make gains during the initial phase of the study, in which students used Book Builder™ with supports as recommended by the CAST (2010) website.

From their case study of a participatory action research approach to UDL, Dymond et al. (2006) recommend additional research to determine the impact of UDL on outcomes using quantifiable methods. The current study addresses this recommendation in that it used quantifiable methods (i.e., number correct of vocabulary and comprehension questions) to determine the impact of a universally designed program on student outcomes.

5.2 Use of Supported Electronic Text

The existing research on supported electronic text is limited to a few studies, and results of the studies have not always produced reliable results (e.g., Anderson-Inman & Horney, 2007; Grant, 2004; MacArthur et al., 2001). Findings from Lefever-Davis and Pearman (2005) and Horney and Anderson-Inman (1999) suggest supported electronic text as a means to promote literacy skills (i.e., comprehension); in contrast to these studies, students increased comprehension skills when the supported electronic text was instructionally designed to include explicit instruction. Anderson-Inman and Horney suggested a need for additional research on the combined impact of the resources on the reading comprehension of struggling readers. Addressing this need, the current study examined the effects of the Book Builder™ package on the comprehension of students with ASD who were also struggling readers. Further, this study investigated the use of electronic books for comprehending expository texts, as recommended by Grant (2004) in his review on the efficacy of electronic books.

The findings from the current study both support and contradict the results from previous studies on supported electronic text in content areas. For example, Horton, Boone, and Lovitt (1990) investigated the effectiveness of a computer-based study guide using hypertext software on comprehension of social studies content from a textbook for students with learning disabilities. Similar to the current study, the intervention in the Horton et al. study consisted of a hypertext software program in which three levels of prompting were used to assist students in answering comprehension questions from the text. An additional similarity was the use of research-based strategies to promote comprehension; in the Horton et al. study, the instructional strategies of self-pacing, frequent responding, correction, feedback, and sequenced instruction were used. In the present study, self-pacing, frequent responding, and sequenced instruction were used. Consistent with the results of the current study, outcomes of the Horton et al. study indicated students with disabilities improved on the comprehension questions.

A study conducted by Boyle et al. (2003) examined the effects of a audio textbook both alone and combined with complementary strategy (SLiCK), on the academic performance of secondary students in history content. Results of this study showed that that all students who used the audio texts made gains, but the students who used the combined audio text plus SLiCK procedure did not make any additional gains. Findings of the Boyle et al. study are in contrast to the current study for two reasons. First, the audio (albeit used in combination with illustrations in baseline), did not impact the number of correct comprehension questions when compared to the addition of the hyperlinks and coaches in the current study. Second, the complementary strategies (i.e., explicit instruction) used in the current study seemed to make more of a difference than the audio and other features (e.g., illustrations). The phases in which students showed the most change in level and trend were Phases in which explicit instruction had been added.

Finally, in contrast to the findings from Twyman and Tindal (2006), who investigated the effects of a computer-adapted history text on the comprehension and problem-solving skills of students with learning disabilities, results of the current study showed that students improved on comprehension measures of content knowledge; however, students made gains in the current study when explicit instruction was added to the supported electronic text. Although both the Twyman and Tindal study and the current study used strategies consistent with the UDL framework, the Twyman and Tindal study allowed for more flexibility in the presentation and use of resources. For example, students could choose (a) from options on the table of contents, (b) whether or not to have sections of the text read aloud, and (c) whether or not to click on hyperlinked glossary definitions.

5.3 Instructional Design and Access to Learning

In the current study, a functional relationship did not exist between the Book Builder™ program using supports as recommended by CAST (2010) and the number of correct science comprehension and vocabulary questions answered by students with ASD. In contrast, when the supported electronic text was designed to include the use of explicit instruction (i.e., examples and non-examples of the vocabulary words, referring to the definition), three of the four students' showed marked improvement on the probes. Results of the current study seem to support the ideas proposed by many authors that the incorporation of research-based instructional design features is a key element for ensuring that technology mediated instruction is effective (e.g., Boone & Higgins, 2003;

Higgins & Boone, 1996; Mazzotti, Test, Wood, & Richter, 2010; Mazzotti, Wood, Test, & Fowler, 2010; Wood, Mustian, & Cooke, 2010), especially for the group of students for which "…*access to the medium of print* does not necessarily translate *access to comprehending print* (p. 42)." Providing an alternative format still does not address the concerns about textbooks raised by many teachers such as challenging vocabulary, poor organization, and distracting information (Boone & Higgins, 2007; Wood, Kelley, Test, & Fowler, 2010).

The results of the current study also support the premise that *access to information* is not the same as *access to learning* (Rose et al., 2005; Wood, Kelley, Test, & Fowler, 2010). For example, during the baseline Phase of the current study, it could be argued that students with ASD had equal *access to information*. That is to say, the text to speech equaled the playing field for the students who were not fluent readers just as the illustrations provided a reference for abstract or difficult concepts. These supports, while giving students *access to the information,* or access to the medium of print, did not by themselves provide *access to learning*. Even in the Book Builder™ alone condition, when students were given access to embedded coaches (i.e., providing comprehension strategies recommended by CAST, 2010 as being research-based) as well as hyperlinks to definitions, only a few students showed minimal improvement. *Access to learning* seemed to occur during Phase 2 and Phase 3 of the investigation, when students were provided with coaches who delivered explicit instruction. The combination of access to information (e.g., text to speech, illustrations, hyperlinks to vocabulary) and the consideration of research-based, instructional design strategies delivered via a universally designed program may provide access to learning for individuals with ASD. A quote by Boone and Higgins (2005) seems especially relevant to this argument:

> Certainly, Rose's (2000) notion of universal design for learning is an admirable goal. But it is just that, a larger goal and not a design principle or instructional tactic that can be applied to the design of specific materials for learners with specific learning disabilities (Boone & Higgins, 2005, p. 489).

A study by Koury (1996) on the effects of video anchors to support vocabulary in science for students with learning disabilities raised the same issue of instructional conditions for implementing computer-assisted instruction. Authors suggested that just because technology may be a novel approach, it does not mean that it will provide enough enhancements to improve learning of science information for special education or general education students.

Although studies to date have seemingly not used computer assisted instruction to promote comprehension in the content areas for students with ASD, several empirically based examples exist which used CAI to promote other academic skills for this population (e.g., Coleman-Martin et al., 2005; Hetzroni & Shalem, 2005). While additional research is needed on the particular CAI supports needed to benefit various populations of students (e.g., students with ASD or significant cognitive disabilities; Anderson-Inman & Horney), the extant CAI literature is replete with features associated with systematic and explicit instruction (e.g., Hetzroni & Shalem; Coleman-Martin et al.; Mazzotti, Test, et al., 2010; Mazzotti, Wood, et al., 2010; Wood et al., 2010). In fact, some studies suggest that the use of explicit instruction may be more critical for student understanding than audio supported text (e.g., Wood, Kelley, Test, & Fowler, 2010). The current study supports these studies in the use of systematic and explicit prompting strategies; however, in contrast to the some of the other studies (e.g., Hetzroni & Shalem; Mackiewitz, Wood, Cooke, & Mazzotti, 2010), the current study did not have a method to reinforce correct answers or a method of error correction, as these were not available as part of the Book Builder™ program.

Boone and Higgins (2005) discuss the concern that teachers are often constrained by the availability of resources from the software, and that they adapt their instruction to fit the inflexible software they want to use. This concern is worth noting in reference to the use of Book Builder™ in the current study because the social validity of the program from the teachers seemed overwhelmingly positive. Notwithstanding the fact that the features of reinforcement and error correction, which are critical to success for students with low incidence disabilities, were not built in to the program.

5.4 Teacher Prompting and Use of Embedded Supports

Similar to the results of the Matthew (1997) study, students in the current study needed teacher prompting to use the embedded supports, especially when students were required to verbally respond to the embedded supports (e.g., when the coaches asked the students a question and students were asked to respond verbally). A positive result of the current study was that all but one student required fewer teacher prompts over time; one student did require teacher prompting throughout the duration of the study. In contrast to the findings of the Matthew study, teacher supports were not needed in the current study to minimize distractions from the program's features (e.g., animation). In fact, most students seemed more engaged when the coaches were animated. For example, one student smiled when the coach, Monty asked him questions but did not smile during other sections of the program. In the current study, students needed prompting to remember to use the supports, or features. Another difference between the study conducted by Matthew and the current investigation was that in the Matthew study, students did not remember the definitions of the vocabulary words, and researchers stated it could have been because the definitions were dictionary definitions versus context definitions. In the current investigation, most students were able to recall the definitions in Phase 3 of the intervention. Two possible factors may have contributed to these results. First, the definitions were not dictionary definitions, they were context-based, and second, the students were taught using explicit instruction, including a verbal referral to the vocabulary definition. For example, within the context of the Book Builder™ book, after students were given the context-based definition of "mammal", an embedded coach would ask students the following type of question "Is the cat a mammal?" Students then went to the next coach, which said, "Yes, the cat is a mammal. How do you know?" If students could not answer this question, they were prompted to go back to the definition. According to Proctor et al. (2007), since embedded supports and help features are a common feature of informational technologies, future studies should include measures of students' use of supports and how this impacts student learning in these environments.

In the current study, it was encouraging that the students used the embedded vocabulary and comprehension strategies. Similar results have been reported in the literature for struggling readers and student who are ELL (e.g., Anderson-Inman, Horney, Chen, & Lewin, 1994; Horney and Anderson-Inman, 1999; Proctor et al., 2007). Although students did require teacher prompting in Phases 2 and 3 to use the supports, as the supports were required, in Phase 1, students determined the level of embedded supports they needed. In Phase 1, one student reduced the level of prompts he used over time (e.g., students who used the highest level of support in the beginning of the Phase began using a less intrusive level of support towards the end of the Phase). Two students used the highest level of prompts throughout Phase 1 of the intervention, and another student used the less intrusive prompt throughout Phase 1 of the intervention. It is difficult to ascertain if the self-fading of supports over time impacted learning of the information, due to the following: (a) only one student self-faded the used of supports, (b) there was limited time students were in Phase 1, and (c) the overall lack of progress on the comprehension probes in this Phase.

Proctor et al. (2007) discuss supports in terms of a push and pull relationship between the teacher and the student:

> We believe that some supports should be "pushed" at students, especially during the introductory stage when they are learning how to use the support system to their best advantage. However, given that choice is a key to engaged learning and the development of strategic learners, we assume that the "pulling" of supports represents a type of self-scaffolding and is a necessity in customizable, digital environments (p. 88).

This study supported the push and pull notion of supports. Students were taught to use all the supports during the pre-intervention training Phase (i.e., supports were "pushed" onto students), but in Phase 1, students use of supports continued as teacher prompting to use embedded supports faded over time (i.e., supports were "pulled" from students).

5.5 Comprehension for Students with ASD

It is well documented that students with ASD have challenges in reading comprehension (e.g., Flores & Gantz, 2007; Nation et al., 2006), yet there is a notable lack of research on how best to increase comprehension for students with ASD (e.g., Chiang & Lin, 2007). The current study lends support for the use of direct instruction to teach comprehension skills to students with ASD. Similar to the studies conducted by Flores and Gantz (2007; 2009), results of the current study suggest that comprehension of complex information increased when students were taught to read the facts and explain the facts.

Additionally, there is a lack of research on how to support comprehension of expository text for students with disabilities in general, and seemingly little research to date on strategies to support comprehension of informational text for students with ASD. Researchers have proposed that reading expository text may be more demanding for students than reading narrative text (Gersten et al., 2001; Proctor et al., 2007), and therefore, comprehension strategies that best “match” the text format should be used. Consistent with this idea, Gersten et al. (2001) suggest that comprehension of expository texts may require multiple comprehension strategies as well as longer durations of the intervention for maintenance of the skill. In the current study, the Book Builder™ program coupled with explicit instruction which provided a model, lead, text format and use of examples and non-examples of the concept was not as effective as the use of these strategies used in combination with a referral to the definition. Further, in the current study, two of the four students maintained the skill.

Carnine et al. (2007) suggest guided reading as a practice for students who have difficulty comprehending content area materials, and it includes the following steps: (a) question generating, (b) summarizing, (c) clarifying, and (d) predicting. Findings of the current study do not support these recommendations for students with ASD. In the current study, students were provided the steps recommended by Carnine et al. via the computer in Phase 1 of the intervention (the Book Builder™ only condition), and some students made minimal gains, while other students did not improve. Brigham et al. (2007) recommend another comprehension strategy for training students in expository text structure by showing students passages which include the following: (a) descriptions, (b) temporal sequencing of events, (c) explanations, (d) definitions-examples and problem-solution-effect structures. Students in the current study were not provided with this strategy per say; however, students were provided with comprehension strategies in an explicit manner, including descriptions, explanations, and definitions. Results of the current study lend support for this type of explicit instruction to increase comprehension of expository information.

Technology based instruction for students with ASD continues to garner mixed reviews in general (e.g., National Autism Center, 2009), and few, if any, studies have examined the use of technology to support comprehension for this population. According to Gajria et al. (2007), overall treatment effects for computer assisted instruction for students with high incidence disabilities were low; results of the current study provide additional empirical support for the use of computer assisted instruction. Further, a review of eText on literacy development recommends the need for additional research and for determining which students benefit from this instruction (MacArthur et al., 2001). Since the review, a number of studies have supported the use of eText on literacy development for students with high incidence disabilities (e.g., Boyle et al.). Most importantly, Fitzgerald et al., (2008) concluded that the research on CMI is beneficial for students with learning disabilities, but the design of the software to incorporate the use of explicit strategies is what that makes the practice successful. The current study lends additional research to promote the use of supported eText and explicit instruction to increase comprehension and vocabulary skills for teaching science to middle students with ASD, as measured by the scores on the comprehension and vocabulary probes.

5.6 Limitations

Several limitations must be considered when analyzing the results of the current study. First, the small number of participants and the use of a single subject design limited the generalization of the findings. In contrast, when considered against the overall lack of literature in the following areas: (a) UDL in practice for students with ASD and other disabilities; (b) science interventions for students with ASD and related disabilities (Spooner, Knight, Browder, Jimenez, & DiBiase, 2010), (c) lack of studies on CAI interventions, including supported electronic text on the academic outcomes for students with ASD; as well as (d) the overall lack of literature on strategies to promote comprehension for students with ASD; the study seems to make a novel and valuable contribution. On the other hand, additional research is needed to determine the impact of supported electronic text for students with ASD.

A second limitation was that one student (i.e., EM) made only minimal gains in the last phase of the intervention. After discussing possible reasons for the lack of progress with his classroom teacher, it was discovered that the students' family was from Africa and spoke a language other than English in the home. Another reason for the lack of progress may have been that there was not enough time in intervention to show a change. The study had to end because it was the end of the school year, but inspection of the graphed data reveals that the student was steadily increasing the number of correct responses in the last phase of the intervention (i.e., one correct on the first probe in phase 3, two correct on the second probe, three correct on the third probe, and four correct on the last probe), while during other phases, his responses were variable. Ethan may have been a student who needed additional time to understand the format of instruction. Lastly, the lack of an effect for this study may have been that the student had a difficult time generalizing from the instruction, which required a verbal response, to the probes, which required selection of an answer from four responses (i.e., one correct and three distracters). During intervention, Ethan correctly answered many of the same questions that he later answered incorrectly during the probe.

A third limitation was the fact that Book Builder™, with all of its' "bells and whistles," did not offer students error correction or reinforcement as part of the software package. Higgins and Boone (1996) provide software design guidelines guided by research and suggest that the following be considered: (a) communication attempts (e.g., when the student responds incorrectly to the software, something should still occur); (b) cognitive ability (e.g., computerized lessons should have a corresponding real-world application); and (c) prompts (e.g., the software should provide prompts if the student doesn't respond within a set time period such as the correct answer flashes or choices disappear). Further, behavioral packages are recommended by the NAC (2009) as one of the few established treatments to increase academic and learning readiness skills for individuals with ASD. A critical component to many of these interventions is the use of reinforcement and error correction. One study that examined the effects of CAI on the reading of logos for students with ASD used built in reinforcers for correct answers (e.g., smiley face; Hetzroni & Shalem, 2005). It is believed by the author and validated by the special education teacher that error correction and reinforcement offered within the design of the software would have provided additional assistance for students in the acquisition of science content in the current study.

In addition to the lack of error correction and reinforcement as part of the software package, the default coaches of the Book Builder™ program used in the current study may have been a limitation. The coaches in the Book Builder™ program mispronounced some of the science words (e.g., hyphae), because of the digitized speech. The second default coach (i.e., Hali) spoke very quickly, making it difficult to understand the definitions and challenging for the students to complete the lead portion of the instructional protocol (i.e., say it with me).

A fourth limitation to the study was the issue of generalization. Authors have proposed that an area of concern with respect to technology-based interventions for students with ASD is that the skills gained during the computer-assisted instruction can fail to generalize to novel environments (e.g., Goodwin, 2008; Stromer et al., 2006). Further, according to a review of computer-mediated instruction for students with high incidence disabilities, students were able to use explicit strategies on computers and in classrooms, but the generalization and maintenance were not automatic (Fitzgerald, Koury, & Mitchem, 2008). In the current study, generalization to other settings was not explicitly measured; however, in some cases students needed to use the computer in another setting. In one such case, the student scored much lower on the probe than his previous scores for that Phase. In another case, a different student seemed to have a difficult time generalizing from the instruction to the probe. This was possibly due to the fact that the quiz was in a different format than the Book Builder™ instructional format, or was possibly that the response mode required from the student differed from quiz to Book Builder™ format. On the other hand, one student recognized the instructional format when the classroom teacher began using model-lead-test strategy in her social studies lessons. The recognition was evident when the student responded, ”Why are you saying those things? That’s what me and [the GA] do on the computer.” Teaching using multiple exemplars and teaching loosely are suggested as means to promote generalization (Cooper et al., 2007). In the current study, multiple exemplars were embedded into the illustrative resources (e.g., different examples of prey). Further, both examples and non-examples were used to highlight the critical variables so that an irrelevant factor would not acquire stimulus control over the target behavior. Generalization, or application, was measured on 1/3 of the vocabulary questions (i.e., one vocabulary question per probe). In most cases, when Book Builder™ using explicit instruction was introduced, students were able to generalize the vocabulary concept to an untrained exemplar (see Tables 4-5). In baseline, the overall percentage of correct application questions across students was 29.9%, while in intervention Phase 3, the overall percentage of correct application questions increased to 67.5%.

A fifth limitation concerns the issue of feasibility. In the current study, over 20 books were created, with each book taking 1 to 2 hours to complete. Teachers likely do not have the time to create every science lesson into a digital book, so they may need to consider using the program for lessons which are especially challenging, which summarize the chapter, or which reinforce universal concepts, or big ideas, in science. One benefit to the Book Builder™ program is the virtual sharing of books; in this way, teachers across a district (or across the country) could collectively determine lessons to create, and divide up the lessons such that each teacher may only create 1-2 books.

On the other hand, teachers may need additional assistance to feel comfortable with the technology. Results of the social validity measure indicate the special education teacher was somewhat reluctant to use some of the supports as offered by Book Builder™ (i.e., the audio import function). This concern may be indicative of a more global challenge in providing personnel preparation on assistive and instructional technologies (Bausch & Hasselbring, 2004). In addition to the feasibility of creating the materials, the Camtasia screen-recording software used to record student responses required particular system requirements, which were not available on older computers. This may limit the data collection in many schools with older computers. In contrast, Camtasia is beneficial in that students can be recorded on the computer without the need for a verbal or written response and it can be used to monitor fidelity and interrater reliability.

A sixth possible limitation may have been the comprehension and vocabulary probe. As previously mentioned, the response mode required from the students differed from instruction to the probe. When students were using the Book Builder™ program, they were required to retell part of the definition to indicate their answers to the comprehension and vocabulary questions. On the other hand, during the probe, students selected the correct word out of an array of four after using text to speech to listen to the question and possible answers. If generalization was an issue, students may have had difficulty generalizing answers using different response modes. Oral retelling has been used as a student measure in other studies of computer assisted instruction (e.g., Matthew, 1997; Pearman, 2008); however, oral retelling as a measure was not used in the current study for two reasons. First, students with ASD who have deficits in reading comprehension also often have challenges in oral language comprehension (Nation et al., 2006), and second, oral retelling measures have been used as a comprehension measures of narrative text versus expository texts (Matthew, 1998; Pearman, 2008). Data from the current study suggest generalization may have an issue for one student in particular (i.e., Ethan), who could answer correctly with teacher prompts during instruction, but did not make the same gains on the probes as the other students in the study. Hart and Whalen (2008) suggest that all students benefit from the chance to show what they know multiple formats. Since students with ASD may become frustrated with tasks that are uninteresting or are demanding, teachers should accept a variety of response modes to demonstrate learning (Hart & Whalen). For example, students who do not communicate using a vocal-verbal response may point to a response or use eye gaze to indicate an answer; students who have a vocal-verbal response might say the answer. Since the author of the current study wanted to demonstrate experimental control, the dependent variable was consistent across students.

A final limitation may have been that students lacked flexibility in their ability to use the resources offered by Book Builder™. It is possible that students could have increased comprehension and vocabulary if they had more flexibility in their use of the resources as in the Twyman and Tindal study (2006). For example, although the default coaches were used in the current study throughout the intervention, Book Builder™

offers a variety of embedded coaches, including the availability to provide a picture of a familiar or preferred person. Students with ASD often have particular interests, also called “special interests,” which are particularly motivating. Mechling, Gast, and Cronin (2006) incorporated students “special interests” or high preference items into the computer-based program as a reinforcement for task completion. Additional research could examine using a student’s special interest as either a coach or reinforcement for a correct response as part of the Book Builder™ program. As suggested by Anderson-Inman and Horney (2007), removing control from students may have the following repercussions: (a) limits student access to the resources they find the most helpful; (b) risks limiting student engagement with the text; and (c) removes the possibility that students will develop an approach to reading that is personally-relevant and maintains in new environments.

5.7 Recommendations for Future Research

Results of this study lead to several recommendations for future research. The current study measured the effect of supported electronic text on the science comprehension and vocabulary skills of students with ASD. In general, future research should address the following: (a) additional strategies to promote comprehension of grade-aligned science content for students with ASD and related disabilities; (b) implementation of the Universal Design for Learning framework; and (c) effects of supported eText on various student behaviors (e.g., academic, on-task, engagement).

Future research should examine the use of supported electronic text in other content areas, on other student behaviors (e.g., time on task, generalization of learned vocabulary words and concepts, reduction of stereotypic behaviors, motivation, enjoyment, and verbal behavior), in the primary grades, and by students with various exceptionalities. For example, in the current study, the effect of supported eText on engagement by students with ASD was not examined. Some researchers have suggested that the resources offered can be too engaging, taking attention away from the core content (Anderson-Inman & Horney, 2007; Garner, 1992). As Anderson-Inman and Horney have stated, "…some students became entranced with the novelty of available eText supports, especially those involving sounds and animations, choosing them often and indiscriminately" (p. 42). In the current study, it was difficult to determine whether or not the software was too engaging or novel; however, the data from some of the students in Phase 1 and 2 indicate this may have been the case. For example in Phases 1 and 2, some students had a temporary change in level and trend, which may be "…a function of weak behavior consequences or reinforcer satiation (Gast, 2010, p. 218). The embedded supports may have been reinforcing initially, but students may have satiated over time (i.e., supports were novel). In addition to evaluating the novelty of supports on student outcomes, future research should also examine the impact of self-fading of supports over time on comprehension and vocabulary acquisition and retention of content. Finally, to address the framework of UDL when using supported electronic text, additional research is needed which examines the use of different response modes or modalities express learned information.

Future research should also examine embedding error correction and reinforcement into the intervention; either within the software or with the use of peers. Bransford et al., 2000 suggests, "Much remains to be learned about using technology's potential: to make this happen, learning research will need to become the constant companion of software development" (p. 230). The use of peers to provide modeling and feedback may be a solution to the inflexible Book Builder™ software. For example, in a study by Wood, Mustian, and Cooke (2010), a simultaneous treatment design was used to compare the effects of whole word and morphograph instruction. In the Wood et al. study, peers were trained to provide praise and corrective feedback using a computer-assisted program to teach morphographs and whole words to students with disabilities. In a similar study, Mackiewicz, Wood, Cooke, and Mazzotti (2010) examined the effects of peer tutoring with audio prompting on the vocabulary acquisition for students who were struggling readers. Naïve peers tutors in this study were trained to use a digital recording and playback device that delivered correct modeling and feedback. Peers could be used in combination with the Book Builder™ program in future studies to provide error correction and praise that the program lacks. Future research should also determine the individual and combined impact of the resources offered by Book Builder™ on the reading comprehension of students with ASD, and other students who have challenges in comprehension (Anderson-Inman & Horney, 2007).

In addition to research on the use of peers, future research should address the specific limitations to the current study. First, future empirical research is needed in which a larger sample size of students with and without ASD is used, such as in a randomized group study. Second, an alternating treatment design could be used to compare resources offered through the Book Builder™ program to determine the resources that make the most difference. Third, additional research could address the concerns of generalization to other settings and formats. Finally, although explicit instruction has empirical support for students with high incidence disabilities (e.g., Adams & Engelmann, 1996; Bursuck & Damer, 2007; Kame'enui & Simmons, 1990), the use of explicit instruction via supported eText on comprehension of expository text for students with low incidence disabilities has seemingly not been examined in previous studies; therefore additional research is needed.

5.8 Implications for Practice

There are a number of implications for teachers based on the findings of this study. First, many general education and special education teachers work collaboratively to adapt instruction for all students in inclusive environments. Results of the current study in combination with others indicate that supported electronic text and explicit instruction may offer a means for delivering effective instruction (e.g., Wood, Mustian, & Cooke, 2010) to a wide range of learners in general and special education settings. In doing so, practitioners should consider the application of evidence-based and research-based teaching practices when using computer-mediated instruction, as without such consideration, the use of technology will likely not engender access to learning in and of itself for many students with low incidence disabilities (Boone & Higgins, 2003; Higgins & Boone, 1996; Wood et al., 2010). For information on evidence-based practices in general for students with ASD, educators are encouraged to examine the National Autism Center's findings (2009). If teachers are specifically interested in effective strategies in science for students eligible for the AA-AAS, practitioners may use the recommendations found in Spooner, Knight, Browder, Jimenez, & DiBiase (2010). The research on interventions to promote comprehension for students with ASD is in its infancy, but practitioners can use the existing recommendations from recent reviews (e.g., Browder et al. 2006; Chiang & Lin, 2007). A practical, teacher-friendly summary of information regarding research-based strategies to promote reading comprehension be found in Brigham, Berkley, Simpkins, and Brigham (2007). Although these strategies are recommended for students with learning disabilities, teachers may wish to use the material to guide practice, but continue to collect efficacy data with individual students. Bringham et al. recommend the following basic principles of comprehension strategy instruction: (a) teach comprehension skills in the primary grades; (b) develop decoding skills in readers; (c) teach vocabulary to improve overall comprehension; (d) have students read both narrative and expository text; (e) teach students to relate prior knowledge to the text; (e) teach students to use validated strategies and provide instruction in the strategies; (f) teach students to self-monitor their own understanding of the text.

Second, in addition to using empirically based interventions, the use of authoring software, such as Book Builder™, allows educators to develop individualized computer-based instruction at the same time (Higgins & Boone, 1996). There are certain benefits that computer-assisted instruction can provide. For example, computer based instruction can be tailored to meet the needs of individual students, thereby serving a wide range of students in one classroom. Social validity measures from the current study reflect the idea that teachers can use supported eText to differentiate instruction for all students, and that it can be used to promote inclusive practices. Moreover, as in the Boyle (2003) study, the supported electronic text provided in the current study allowed students to access learning of expository texts in a one to one format, without the teacher providing the assistance. Practitioners should consider that there are negligible differences between instruction provided by a computer and instruction delivered by a teacher. This can allow teachers to give additional time to provide assistance to other students in the classroom (Boyle). In this way, the use of computers can be considered more cost effective, because the teacher can work with more students (Tincani & Boutot, 2005). Further, if a computer delivers instructional strategies, there is almost a guarantee that the instruction will be more consistent than teacher-delivered instruction. Mechling, Gast, and Cronin (2006) suggest that computerized instruction is recyclable in that the instruction can be reused, or delivered as many times individual students may need. Social validity measures from the current study reflect the idea that teachers can use supported eText to differentiate instruction for all students, and that it can be used to promote inclusive practices. A final consideration for practitioners when designing technology is that poorly designed technology may have adverse affects, (Anderson-Inman & Horney, 2007; Higgins & Boone, 1996). Taking these adverse effects into consideration, practitioners should consider the software design guidelines as recommended by Higgins and Boone.

Third, practitioners should consider that computer assisted instruction can also encourage engagement and autonomy. Although the current study did not measure engagement directly, most students did indicate a preference for computer instruction over traditional text. Other studies support the impact of supported electronic text on engagement for students with ASD (Williams et al., 2000). More importantly, as engagement with the text increases, it is possible that self-confidence and attitudes towards reading may improve (Anderson-Inman & Horney, 2007; Mineo et al., 2009). The use of supported electronic text may facilitate an approach to reading that is personally relevant and transferable to other contexts (Anderson-Inman & Horney).

In addition to motivation, computer-assisted instruction may be beneficial for students because as Panyan (1984) states, "…unlike much of the instruction provided in traditional classrooms, a computer enables a students to be in control of the learning situation rather than just a passive recipient of instruction" (p. 381). In the current study, most students reduced the need for teacher prompting over time, leading to an increase in autonomy, an important skill for students with ASD. As Proctor et al. (2007) suggest, when students' use of the supports are measured, this will lead to further investigations which can better prepare students to use the supports available, "…and in service of their own learning goals" (p. 88). Specifically in the Book Builder™ program, students can choose both the look and sound of the embedded coaches (i.e., various avatars, customized avatars, and voices are available in the program). Finally, when students are in control of the resources they wish to use, it may increase the likelihood that the students will use resources they find helpful (Anderson-Inman & Horney, 2007).

Fifth, as educators strive to provide grade-aligned content to students with ASD and related disabilities while promoting student engagement and autonomy, practitioners should consider that computer-assisted instruction has been used to teach a range of academic skills, from sentence creation to word identification (e.g., Heimann et al., 1995; Hetzroni & Shalem, 2005; Yamamoto & Miya, 1999). Additionally, computer-mediated instruction has been used to teach students with high incidence disabilities more complex content and allows for flexibility in expression of content knowledge (Fitzgerald et al., 2008). Previous research suggests that grade level science content is difficult for many students, especially students with disabilities, and that due to the complex concepts and vocabulary involved, students with disabilities will likely need explicit instruction

(Carnine et al., 2007). The current study examined the impact of supported eText on grade aligned content on comprehension for students with ASD; a population of students who vary widely in their abilities and needs, and many of whom have difficulty with decoding, comprehension, applying background knowledge, and abstract concepts (American Psychiatric Association, 2000; Nation et al., 2006; Wahlberg & Magliano, 2004). Reading complicated texts aloud to students who have poor decoding skills (e.g., using text to speech, a teacher, or peer) can provide access to levels of content that are typically inaccessible to them (Brigham et al., 2007). In the current study as well as in previous studies, computer assisted instruction was used both to read the text aloud as well as explicitly demonstrate the critical concepts and rules defining the concepts (Twyman & Tindal, 2006). One consideration is that students who have a difficult time pronouncing the words may be initially reluctant to verbalize with the computer, as was the case for some of the students in the current study. Over time, and with error correction from the computer, students may become more comfortable with challenging pronunciations.

Finally, practitioners and students will continue to be valuable resources as the field of special education continues to determine the effect of supported electronic text on academic skills (e.g., comprehension) for students with ASD. Feedback from stakeholders, such as special and general education teachers cannot be understated in this line of research, especially with respect to the feasibility of UDL, feasibility of implementation, and need for personnel preparation and training. Researchers need to incorporate evidence-based practices with the best available information of consumer needs when designing computer-assisted instruction. Feedback from students with ASD will continue to provide researchers with information on preference, motivation, engagement, and the supports most conducive for learning academic information. It is important to note that although research on the effects of technology-based interventions for students with ASD has been conducted for over 35 years, as a field, we know little more than we did then. As Hasslebring (2001) suggests, “We cannot predict the future of special education technology, but we can invent it” (p. 15).

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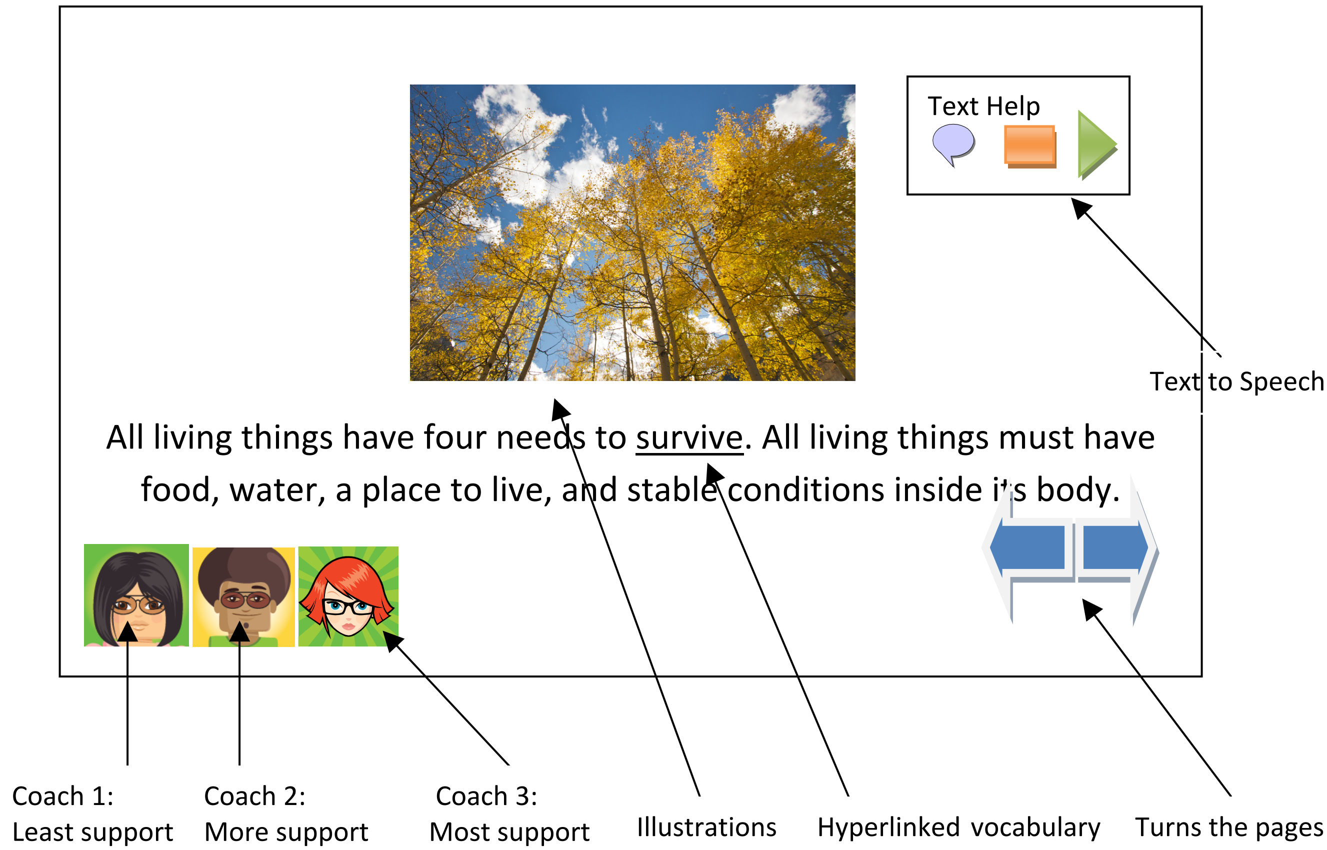
APPENDIX A: EXAMPLE OF SUPPORTS OFFERED THROUGH BOOK BUILDER™



APPENDIX B: DATA COLLECTION FORM

Date: School: SID:
Examiner: IRR observer: # Correct/7:
IRR score:

Directions: Mark answer as incorrect if no answer within 5 seconds or if student answer does not match the correct student response. Score each item as 0 = incorrect or no response, and a 1= correct, independent response.

Correct student response: For each question, the correct student response will be that the student points to or verbally selects the correct picture/word out of an array of 4 possible answers (1 correct and 3 distracters).

Objective:	**Correct Student Response**	**Score:**		**Notes**
	I. Vocabulary			
1. Computer asks student "Which is the (definition of ___________)?"	Selects the word: _________.	0	1	
2. Computer asks student "Which is the (definition of ___________)?"	Selects the word: _________.	0	1	
3. Computer asks student "Which is the (definition of ___________)?"	Selects the word: _________.	0	1	
	II. Literal Comprehension Questions			
4. Passage dependant question, such as "What happens when air cools?"	Selects the answer: _________.	0	1	
5. Passage dependant question	Selects the answer: _________.	0	1	
6. Passage dependant question	Selects the answer: _________.	0	1	
	III. Application Questions			
7. Application question "Which of these is an example of ____?"	Selects the answer: _________ (from untrained exemplars).	0	1	
	Total Correct:			

APPENDIX C: DEPENDENT VARIABLES TABLE

Student	Vocabulary		Comprehension		Application		Total	
	Baseline	IV	Baseline	IV	Baseline	IV	B	IV
Student A								
Student B								
Student C								
Student D								
Student E								
Overall Totals:								

APPENDIX D: PRE-BASELINE AND PRE-INTERVENTION EVALUATION

Date: School: SID:
Examiner: IRR observer: # Correct:
IRR score:

Objective:	Correct Student Response	Score:		Notes
PRE-BASELINE TRAINING				
1. Teacher asks student "Turn to the **next page** of the book"	Student uses mouse to select the right arrow	0	1	
2. Teacher asks student "Turn to the **previous page** of the book"	Student uses mouse to select the left arrow	0	1	
3. Teacher asks student "Show me how to **read the story aloud** (i.e., text to speech)"	Student uses mouse to select the speech bubble in the text help bar	0	1	
4. Teacher asks student "Show me how **stop reading the story aloud** (i.e., text to speech)"	Student uses mouse to select orange square in the text help bar	0	1	
PRE-INTERVENTION TRAINING				
5. Teacher asks student "Show me to find the **meaning of the word** (i.e., the hyperlinks to vocabulary)"	Student uses mouse to select an underlined word (e.g., hypertext)	0	1	
6. Teacher asks student "Show me how to use the coach '**Pedro**'" (or a little help)?"	Student uses mouse to select the coach the far left (i.e., the penguin)	0	1	
7. Teacher asks student "Show me how to use the coach '**Halo** (or more help)? '""	Student uses mouse to select the coach in the middle (i.e., the frog)	0	1	
8. Teacher asks student "Show me how to use the coach '**Monty** (or the most help?'""	Student uses mouse to select the coach on the far right (i.e., the dog)	0	1	

9.	Teacher asks the student "Show me how to go to the list of words and what they mean" (e.g., hyperlinks to vocabulary).	Student uses mouse to select the "ABC" on the top of the screen (i.e., the glossary)	0	1
			Total Correct:	

APPENDIX E: SOCIAL VALIDITY QUESTIONAIRE FOR STUDENTS

Directions: Please read these questions aloud to students. For yes and no questions, please have the students circle the answer they agree with. For open ended questions, please scribe the students' answers.

1. Did you enjoy using the computer to learn about science? (May point to computer screen if student does not respond to the question as stated.)

   YES MAYBE NO

2. Would you rather use the computer or read a book to learn about science? (May point to the computer and a book if student does not respond to the question as stated.)

   COMPUTER BOOK

For the next section, show the student the enhancement as you ask the question:

3. Do you think that the pictures helped you to learn the science information?

   YES MAYBE NO

4. Do you think that having the words read aloud helped you to learn science?

   YES MAYBE NO

5. Do you think that having the meanings to the words helped you to learn the science words?

   YES MAYBE NO

6. Do you think that the coaches (Pedro, Hali, and Monty) helped you to learn science?

   YES MAYBE NO

7. Which do you think helped the most?

   PICTURES WORDS READ ALOUD MEANINGS TO WORDS

   COACHES

8. Would you want to use the computer in other subjects, like social studies? Why or why not?

9. What did you learn from having science on the computer? (May give examples if student does not respond to question. Write the examples/prompts given)

10. Would you want to keep using the computer to learn science? Why or why not?

    YES MAYBE NO

APPENDIX F: SOCIAL VALIDITY QUESTIONAIRE FOR SPECIAL EDUCATION TEACHERS

Date: ___________

This questionnaire consists of 19 items. For the close-ended items, please indicate the extent to which you agree or disagree with each statement. Please indicate your response to each item by circling one of the five responses to the right. Please answer the open-ended questions to the best of your ability.

Questions	Responses				
1. I think that the Book Builder™ program helped my students increase science vocabulary	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
2. I think that the Book Builder™ program helped my students increase science comprehension	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
3. I think use of the Book Builder™ program as designed (with supports recommended by CAST) is beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
4. I would use the Book Builder™ as a supplementary aid to my science instruction.	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
5. I think that that the **explanatory resources** (e.g., hyperlinks to vocabulary definitions, embedded coaches- Pedro, Hali, and Monty) were beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
6. I think that that the **illustrative resources** (e.g., drawings, photos, sounds, and typical examples of a concept in the text) were beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
7. I think that that the **translational resources** (e.g., hyperlinks to vocabulary definitions, text to	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

	speech, simplified text at a lower reading level) were beneficial for my students					
8.	I think that that the **summarizing resources** (e.g., concept map, list of key ideas) were beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
9.	I think that that the **enrichment resources** (e.g., background information) were beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
10.	I think that that the **instructional resources** (e.g., embedded coaches) were beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
11.	I think that the Book Builder™ program was practical and easy to use	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
12.	I am more likely to use a free program, like Book Builder™ to create digital books rather than a program that I need to purchase	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
13.	I think that Book Builder™ would be beneficial for my students in other content areas					

Open-ended Questions:

14. Of the following resources, which do you believe were the most helpful for the students: explanatory, illustrative, translational, summarizing, enrichment, instructional? Please explain:

15. Do you think that your students may need additional prompts to increase understanding of science content using Book Builder™? If so, what additions would you suggest?

16. Which type of student do you think would most benefit from the Book Builder™ program in science?

17. Do you think you would use Book Builder™ to create your own books? Please explain why or why not.

18. What other useful applications, if any, can you see to using the Book Builder™ program for your students?

19. Do you have any additional comments?

APPENDIX G: SOCIAL VALIDITY QUESTIONAIRE FOR GENERAL EDUCATION TEACHERS

Date: ___________

This questionnaire consists of 19 items. For the close-ended items, please indicate the extent to which you agree or disagree with each statement. Please indicate your response to each item by circling one of the five responses to the right. Please answer the open-ended questions to the best of your ability.

Questions	Responses				
1. I think that the Book Builder™ program would help my students increase science vocabulary	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
2. I think that the Book Builder™ program would help my students increase science comprehension	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
3. I think use of the Book Builder™ program as designed (with supports recommended by CAST) would be beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
4. I would use the Book Builder™ as a supplementary aid to my science instruction.	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
5. I think that that the **explanatory resources** (e.g., hyperlinks to vocabulary definitions, embedded coaches- Pedro, Hali, and Monty) would be beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
6. I think that that the **illustrative resources** (e.g., drawings, photos, sounds, and typical examples of a concept in the text) would be beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
7. I think that that the **translational resources** (e.g., hyperlinks to vocabulary definitions, text to	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

	speech, simplified text at a lower reading level) would be beneficial for my students					
8.	I think that that the **summarizing resources** (e.g., concept map, list of key ideas) would be beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
9.	I think that that the **enrichment resources** (e.g., background information) would be beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
10.	I think that that the **instructional resources** (e.g., embedded coaches) would be beneficial for my students	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
11.	I think that the Book Builder™ program would be practical and easy to use	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
12.	I am more likely to use a free program, like Book Builder™ to create digital books rather than a program that I need to purchase	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
13.	I think that Book Builder™ would be beneficial for my students in other content areas					

Open-ended Questions:

14. Of the following resources, which do you believe would be the most helpful for the students: explanatory, illustrative, translational, summarizing, enrichment, instructional? Please explain:

15. Do you think that your students may need additional prompts to increase understanding of science content using Book Builder™? If so, what additions would you suggest?

16. Which type of student do you think would most benefit from the Book Builder™ program in science?

17. Do you think you would use Book Builder™ to create your own books? Please explain why or why not.

18. What other useful applications, if any, can you see to using the Book Builder™ program for your students?

19. Do you have any additional comments?

APPENDIX H: PROCEDURAL FIDELITY FOR STUDENT COMPUTER MECHANICS

Date:	School:	TID:
Examiner:	PF observer:	# Correct: PF score

Objective:	**YES/NO**		**Notes**
1. Teacher asks student "Turn to the **next page** of the book"	**YES**	**NO**	
2. Teacher asks student "Turn to the **previous page** of the book"	**YES**	**NO**	
3. Teacher asks student "Show me how to **read the story aloud** (i.e., text to speech)"	**YES**	**NO**	
4. Teacher asks student "Show me how **stop reading the story aloud** (i.e., text to speech)"	**YES**	**NO**	
5. Teacher asks student "Show me to find the **meaning of the word** (i.e., the hyperlinks to vocabulary)"	**YES**	**NO**	
6. Teacher asks student "Show me how to use the coach '**Pedro**'" (or a little help)?"	**YES**	**NO**	
7. Teacher asks student "Show me how to use the coach '**Hali'** (or more help)? '"'	**YES**	**NO**	
8. Teacher asks student "Show me how to use the coach '**Monty** (or the most help?'"	**YES**	**NO**	
9. Teacher asks the student "Show me how to go to the list of words and what they mean."	**YES**	**NO**	
TOTAL:			

APPENDIX I: PROCEDURAL FIDELITY FOR PROBES

Date: School: TID:
Examiner: PF observer: PF:

Objective:	YES/NO	
I. Vocabulary		
1. Teacher asks student "Which is the (definition of ___________)?"	YES	NO
2. Teacher asks student "Which is the (definition of ___________)?"	YES	NO
3. Teacher asks student "Which is the (definition of ___________)?"	YES	NO
II. Literal Comprehension Questions		
4. Passage dependant question, such as "What happens when air cools?"	YES	NO
5. Passage dependant question	YES	NO
6. Passage dependant question	YES	NO
III. Application Question		
8. Application question "Which of these is an example of ____?"	YES	NO
Total Correct:		

APPENDIX J: PROCEDURAL FIDELITY FOR BOOK BUILDER™ LESSONS

Date: School: TID:
Examiner: PF observer: # Correct:

Decisions for Prompting	YES/NO		Notes
1st prompt: If the student requires assistance with the mechanics of the program. For example, the student performs an incorrect operation or the student does not perform an operation within 10 seconds of the natural cue:			
THEN: The teacher prompts the student using a least to most prompting system for the incorrect/ no operation.	**YES**	**NO**	
2nd prompt: If the student requires assistance with the mechanics of the program. For example, the student performs an incorrect operation or the student does not perform an operation within 10 seconds of the natural cue:			
THEN: The teacher prompts the student using a least to most prompting system for the incorrect/ no operation.	**YES**	**NO**	
3rd prompt: If the student requires assistance with the mechanics of the program. For example, the student performs an incorrect operation or the student does not perform an operation within 10 seconds of the natural cue:			
THEN: The teacher prompts the student using a least to most prompting system for the incorrect/ no operation.	**YES**	**NO**	
If the student has gotten 3 prompts within 1 lesson, the teacher performs a booster	**YES**	**NO**	

If the student has gotten 3 prompts within 1 lesson, the teacher performs a booster session with the student. The teacher follow the procedures of the student computer mechanics lesson for the operation(s) needed.	**YES**	**NO**

PF score: