THE COMPARATIVE EFFECTS OF PRINT *VS.* DIGITAL TECHNOLOGY ON COMPREHENSION OF FUNCTIONAL COMMUNITY KNOWLEDGE AND ON-TASK BEHAVIOR FOR STUDENTS WITH LOW INCIDENCE DISABILITY

by

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A dissertation submitted to the faculty of
The University of North Carolina at Charlotte
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in
Special Education
2018

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ABSTRACT

COLLEEN ERIN ROBERTSON. The comparative effects of print *vs.* digital technology on comprehension of functional community knowledge and on-task behavior for students with low incidence disability.
(Under the direction of DR. FRED SPOONER)

Post-school outcomes in the areas of health, safety, and independent living are poor among students with low incidence disabilities who have complex communication needs. This study examined the comparative effects of print *vs.* digital technology instruction on participants' cumulative accuracy of answering WH (who, what, where) functional community knowledge comprehension questions as measured by the percentage of participants' on-task behavior during print and digital technology instructional sessions with four high school aged students with low incidence disabilities and autism. Using a single-case research, alternating treatments design, participants received instruction using a model-lead-test instructional procedure with color-coded vocabulary words, graphic organizers, and adapted stories following a Fitzgerald Key Format under both print and digital technology instructional conditions. Participants were also explicitly taught, using model-lead-test, how to create three-word sentences using color coded core vocabulary words from each adapted story and graphic organizers following the Fitzgerald Key Format to delineate parts of speech in order to promote comprehension and expressive communication. Results indicated improvement in comprehension for all participants in response to the intervention package. Participants' percentage of time on-task was higher during print instruction compared to digital instructional conditions. Contributions to the research literature, limitations of the study, recommendations for future research, and implications for practice are discussed.

DEDICATION

I would like to dedicate this dissertation to my family. First and foremost, to my sons, Taylor and Braeden, you are my reason "why" I have persevered through every obstacle to achieve this arduous goal; your constant encouragement, faith in my abilities, unwavering love, and incredible hugs have sustained me. To my sister, Kathy, you have been my champion and best friend who I have leaned on countless times for strength, clarity, and advice. I honestly would not have survived this journey without your selfless generosity and love. To my Mom, you have always been my greatest cheerleader in life. You raised me to believe that I am infinitely capable of achieving anything I set my mind and heart upon. To my Dad and my brothers Kevin, Patrick, and Tim, I pray that I have made you proud. Finally, to my ex-husband, Logan, and former mother-in-law, Sam, your continued friendship and support have meant the world to me. My family is my ballast and I love each of you beyond words and measure; I dedicate this dissertation to you.

ACKNOWLEDGEMENTS

I would like to acknowledge my role models and mentors who have shaped me into becoming a stronger teacher, leader, and researcher. The numerous examples of excellence in the field of special education you have provided have shown me the type of scholar I aim to become. To my advisor, Dr. Fred Spooner, your infinite knowledge of APA and seminal work in the field of special education is simultaneously intimidating and inspiring. To Dr. Diane Browder, co-teaching with you has helped me to hone my skills as a teacher educator; I am grateful for and humbled by those opportunities. To Dr. Charlie Wood and Dr. Vivian Correa, your seamless teaching styles and engaging courses provided teaching models I strive to emulate. To Dr. Wendy Wood, I am thankful for your friendship and the opportunity to have taught with you twice. I would also like to acknowledge Dr. David W. Test for your adept and succinct feedback throughout my doctoral studies. Additionally, I am immensely thankful for the Leadership Grant and GASP funding I received which made my doctoral studies possible. Last, I am grateful for the challenging education I received from the University of North Carolina at Charlotte; the faculty within the Special Education and Child Development department are renowned and have imprinted a powerful legacy of excellence upon the field of special education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 – INTRODUCTION

Many students with low incidence disabilities, particularly those with complex communication needs who rely on augmentative and alternative communication (AAC) to express themselves or to be understood by others, face unique health and safety challenges (i.e., chronic medical conditions; elopement concerns) after high school ends. The National Longitudinal Transition Study-2 (NLTS2, 2012), reported 50-60% of students with autism, intellectual disabilities (ID), or multiple disabilities (MD) are likely to have poor health, difficulty communicating, and challenges completing functional skills of daily living (i.e., dressing, self-feeding, toileting). The NLTS2 (2012) also suggested 50-62% of students with autism, ID, or MD respectively have trouble communicating by any means and 61-70% additionally experience trouble comprehending what others say to them. Concomitantly, research has shown a correlation between a lack of reliable means of communication and increased rates of challenging behavior (Carr & Durand, 1985; Durand & Merges, 2001; Wilkinson & Henning, 2007). Challenging behaviors, previously termed maladaptive, (i.e., hitting self or others; property destruction) were defined as behaviors that can impede learning and skills of daily living (Dawson, Matson, & Cherry, 1998; Fee & Matson, 1992; Gardner & Cole, 1990). These mitigating factors create troubling implications for the lives of students with low incidence disabilities after high school.

Students with low incidence disabilities comprise 1% of all school-age children in the United States. The Individuals with Disabilities Education Improvement Act (IDEA, 2004) define a low incidence disability as a visual or hearing impairment or a "significant cognitive impairment" which require highly specialized personnel to provide a free and appropriate public education (Erickson, Lee, & von Schrader, 2010). The term low incidence disability does not often exist as a stand-alone category in disability related statistical reports. Individuals with low incidence disabilities may have multiple disabilities, a moderate to severe intellectual disability, autism, or formerly, mental retardation with low cognitive functioning. The range and severity of needs are factors in each of the categories mentioned. To provide context, disability statistics from 2014, found 4.5% of non-institutionalized individuals ages 21-64 in the United States reported a cognitive disability (Erickson et al., 2014); this equaled 8,245,400 people out of 184,411,700. As mentioned, the post-school outcomes for these individuals are bleak. The NLTS2 (2011), reported individuals with mental retardation (severity levels not specified) were less likely to: (a) be employed after high school, 39% *vs*. 57-67% of their peers with other disabling conditions including other health impairment (OHI), speech and language impairments, learning disabilities (LD), and hearing impairments; and (b) less likely to live independently compared to those with LD, emotional behavioral disorders (EBD); or speech and language impairments (16% *vs*. 51-67%). Therefore, the majority of individuals with low incidence disabilities require life-long care and support to meet their daily needs.

To compound matters, Yu, Newman, and Wagner (2009) revealed 33% of individuals with low incidence disabilities concurrently have complex communication needs and require assistive technology (AT) in the form of augmentative and alternative communication (AAC) to be understood by others. Bouck and Flanagan (2016) conducted a correlational study investigating data from the NLTS-2 and found fewer students with severe disabilities received a continuation of their AT services post-school and AT services were under-utilized by adults with severe disabilities. Additional research was recommended to assess the post-school lives of individuals with severe disabilities. Further research may determine how many individuals with severe disabilities, who rely on ACC, have a functional form of communication to express their basic wants and needs after they have exited high school.

The following percentages provide a scope of the number of students being taught in separate settings across the country, more than likely, although not identified as such, these represent students with more severe disabilities. According to the U.S. Department of Education, Office of Special Education Programs (OSEP), 38th annual report to Congress, there were nearly 6 million students served under the Individuals with Disabilities Education Act (IDEA) in 2014, accounting for 13% of enrollment totals in public schools nationwide. Just over 13% of these students have multiple disabilities (MD) and 16.9% have intellectual disabilities (ID; severity levels unspecified); these students were served within the regular class environment for 80% of the day or more. This means that 70.3% of students with MD and ID are served in “other environments” in separate settings most of the school day and required specialized instruction to address their academic and functional needs. For the purposes of this study, this investigation focused on students with a moderate to severe intellectual disability, and/or autism, with IQ scores below 55 and are referred to as students with low incidence disabilities.

In recent years, much of the research involving students with low incidence disabilities has focused on adapted, grade-aligned curriculum content in the areas of English language arts, mathematics, and science due to the mandates of No Child Left Behind Act (NCLB 2001; 2006). The area of social studies instruction has been under investigated for students with autism and developmental disabilities (Schenning, Knight, & Spooner, 2013; Zakas, Browder, Ahlgrim-Delzell, & Heafner, 2013). Only 13 states currently require alignment for social studies according to the National Center for Special Education Research's report (Cameto et al., 2010). The National Council of Social Studies (2010) included five standard areas of focus: history, geography, civics and governance, economics, and psychology. Standards based curricula can be bridged with the support of evidence-based instructional practices (e.g., constant time delay, least intrusive prompting, task analysis) coupled with low tech, print-based picture symbol support or high-tech, digital AAC supports to teach students with low incidence disabilities. Students with low incidence disabilities require significant adaptations and substantial modifications to the curriculum to make the content material appropriate to meet their cognitive abilities.

One way to aid comprehension for students with low incidence disabilities is to minimize abstract information that require inference and higher order critical thinking to help students understand challenging text. To accomplish this, research supports the use of shared stories (Mims, Hudson, & Browder, 2012), adapted texts (Saunders, Spooner, Browder, Wakeman, & Lee, 2013), visual supports (Hudson, Browder, & Wakeman, 2013), and graphic organizers (Williamson, Carnahan, Birri, & Swoboda, 2014) to make challenging material easier to comprehend for students with disabilities. For instance, Zakas et al. (2013) incorporated modified graphic organizers to help three middle school students with autism and developmental disabilities extrapolate pertinent U. S. History facts from adapted expository text. For students with low incidence disabilities, the curriculum content may need to be further modified to meet functional and academic needs. The National Council for the Social Studies (NCSS; 2010) described the need for integration of social studies content to promote civic competence. One aspect of promoting civic competence involves building knowledge regarding people, places, and environments. Students with low incidence disabilities may require substantially modified social studies instruction to make these connections. Substantially modified social studies concepts were defined here as functional community knowledge; functional community knowledge includes issues of daily living that relate to health and safety (i.e., who do you visit when you are badly hurt? a doctor). In this way, functional and academic skills were simultaneously targeted for instruction. McDonnell and Copeland (2016), advocated for an individualized balance between teaching academic and functional skills to students with severe disabilities. Skills taught should align with students' post-school goals and positively impact their quality of life.

Well documented research in the field of special education over the years identified systematic instructional strategies undergirded by strong behavior analytic principles which helped to establish EBPs for teaching students with a range of disabilities (Billingsley & Romer, 1983; Browder & Cooper-Duffy, 2003; Collins, 2012; Cooper, Heron, & Heward, 2007; Courtade, Test, & Cook, 2014; Snell, 1978). For students with low incidence disabilities, systematic instructional procedures (i.e., constant time delay (CTD); system of least prompts (SLP); task analytic instruction; functional communication training (FCT); functional behavior assessment (FBA); and schedules of reinforcement) are common instructional techniques implemented in special education classrooms to teach a variety of academic and functional skills. Browder, Wakeman, Spooner, Ahlgrim-Delzell, and Algozzine (2006) showed how CTD can be used to teach students with moderate to severe intellectual disabilities to identify vocabulary words aligned to adapted grade-level content standards. After the accountability mandates stipulated in NCLB (2002), Browder, Ahlgrim-Delzell, Courtade-Little, and Snell (2006), wrote a practical General Curriculum Access (GCA) chapter as a guide for special education teachers who work with students with low incidence disabilities. The chapter provided a roadmap which illustrated how special educators can effectively address students' GCA and functional goals using systematic instructional procedures.

Pioneering research over the past decade has deemed many of the instructional strategies previously mentioned as EBPs (i.e., task analytical instruction, functional communication training [FCT], functional behavior assessment [FBA], constant time delay [CTD], visual supports). For instance, six middle school students with moderate to severe intellectual disabilities demonstrated the ability to learn to read sight words (Browder, Trela, & Jimenez, 2007) from adapted grade aligned literature (i.e., *Call of the Wild; The Cay; Island of the Blue Dolphins)* using picture supported text, a task analysis, and CTD; later in mathematics and science Browder, Trela, Courtade, et al., (2012) conducted a quasi-experimental study and taught 16 middle and high school students with moderate to severe disabilities to solve algebra, geometry, and data problems using picture symbol supports on response boards and 21 middle and high school students with moderate to severe disabilities to answer inquiry science questions using picture symbols, CTD, and response boards. Less research exists in the area of teaching social studies concepts to this population.

The research literature is still burgeoning in the area of providing models for adapting and aligning grade level content to state standards for students with low incidence disabilities in the area of social studies. As noted above, research has demonstrated effective practices to help students with disabilities access general curriculum content in the areas of English language arts, mathematics, and science. Zakas et al. (2013) used graphic organizers and print-based picture supported text with three middle school students with autism and mild to moderate intellectual disability to help them answer comprehension questions regarding United States History events. Participants used the print-based picture supports to identify salient social studies content to correctly answer questions concerning events, people, location, time, sequence of events, and outcomes from adapted social studies passages. McKissick et al. (2013) addressed functional skills in the area of social studies by teaching map-reading skills of common locations to three elementary age students with moderate to severe disabilities and/or autism. The researchers used CAI and an explicit model-test format ("my turn, your turn") to teach participants to identify areas on a map (e.g., exit, food, park, mall, and restroom). The results were promising. More research needs to be done to increase students' functional community knowledge to help improve their post-school outcomes in the areas of communication, independence, health, and safety.

Additionally, for students with low incidence disabilities and complex communication needs who use aided AAC, functional communication training (FCT; Durand & Carr, 1985) has effectively been used to teach students a means to express themselves beyond conveying basic wants and needs. B. F. Skinner (1957) described a hierarchy regarding language acquisition and manding (requesting or protesting) was the first form of verbal behavior identified. Conveying basic wants and needs could fall under the category of a mand. Using Skinner's verbal behavior continuum, the next language acquisition skill described in called a tact. A tact is used to identify and label objects in the environment. Due to deficits in verbal expressive language, aided ACC users may tact by touching (or eye gazing) a print or digital technology image to indicate a response to answer a question. According to Skinner, participating in a conversational exchange required higher order critical thinking skills and he called this back and forth dialogue intraverbal behavior. In order to build the capacity of students with low incidence disabilities and complex communication needs to demonstrate comprehension, tenets of Skinner's verbal behavior hierarchy must be explicitly taught. Although not explicitly stated as such, several of the studies described in the proceeding chapters in this proposal in regards to print or digital technology instruction, have utilized systematic instructional procedures to promote verbal behavior among students with intellectual disabilities (Browder, Ahlgrim-Delzell, Spooner, Mims, & Baker, 2009; McKissick, Spooner, Wood, & Dieglemann, 2013; Rivera, Wood, & Spooner, 2012).

For instance, Rivera et al. (2012) conducted a single-case, alternating treatment design research study with three Mexican American elementary age students with moderate intellectual disabilities who were English Language Learners (ELL). The comparison study investigated the effects of technology based instruction (interactive PowerPoint slides) in English and Spanish to teach science content vocabulary using a mode-lead-test instructional strategy. Rivera et al. (2012) asked student participants to answer comprehension questions in both English and Spanish from the antecedent prompt "What is this?"/ "¿Que es esto?" as images appeared on the computer screen. Results were mixed as some students performed better when provided instruction in English and others when taught in Spanish. Interestingly, although not expressly described as embedding Skinner's principles of verbal behavior, Rivera et al. (2012) used tacts for students to label and identify responses to promote comprehension when asked intraverbal behavior questions.

The benefits of print-based visual supports provide students with a range of intellectual disability is undisputed and date back over 50 years (Hourcade et al., 2004; Lancioni, 1983). Pennington (2010) considered picture-supported text in the form of computer-assisted instruction (CAI) akin to a "visual prosthesis" especially for students with autism spectrum disorder (ASD) in scaffolding abstract information into meaningful units. Interactive digital technologies have also been noted to increase student engagement and motivation to participate during instructional lessons. Results from a survey research study (Shane & Albert, 2008) have shown that students with ASD prefer CAI over low tech print technology options. The authors found students with ASD prefer electronic screen media over any other leisure activity. Motivation to interact with high tech digital screen devices are enhanced for students with ASD. This form of presentation "excites children with ASD… and research literature shows improved skill acquisition and learning" (p. 1507) using high tech digital instructional tools. Taking print-based tech supports and making them interactive, thereby transferring them to high-tech digital status with electronic voice output capabilities is becoming more commonplace in special education classrooms. Software companies such as Mayer-Johnson, who manufacture Boardmaker® products designed to create picture symbol supports for AAC users, has an interactive function built into their software that instantly transforms any two-dimensional, paper-based light tech support into high tech interactive digital voice output communication aide (VOCA). Many research studies have embedded print-based picture supported technologies to aid students with disabilities in conceptualizing abstract material with significant results (Browder et al., 2006, 2012; Schenning, Knight, & Spooner, 2013). Visual supports are one of the EBPs identified for supporting the learning needs of students with autism (Sam & AFIRM Team, 2015). Given the speed of technological advances, it is important to embed EBPs into the instructional design of an intervention rather than assuming the digital device itself will be a miracle cure-all to meet students' learning needs. One way to heighten the impact of integrating visual supports, such as graphic organizers, into quality instruction for students with complex communication needs can involve the use of a consistent and predictable system for identifying vocabulary words by part of speech. The Fitzgerald Key Format is an example of a visual support that uses a color coded organizational system (see Appendix B).

Fitzgerald Key Format

In 1927, Edith Fitzgerald, a deaf woman, designed a categorical system for organizing words into parts of speech using a consistent color-coding method (i.e., people=yellow, action words=green, objects=orange, places=purple). Her system was posthumously published in 1954 and used to teach the deaf how to construct semantic and syntactically correct sentences. At one point, 75% of schools for the deaf in the US were using the Fitzgerald Key Format in their schools to teach the deaf to write. This color-coding format is still used both in low-tech print-based means, as well as high-tech dynamic display digital AAC devices such as Tobii Dynavox®. Because the words are organized by color in predictable locations, students are able to locate words to communicate much in the same way we locate letters predictably organized on

QWERTY keyboards. Thistle and Wilkinson (2009) found that typically developing preschoolers were more readily able to locate print-based AAC icons on a page from an array of 12 more quickly using the color-coded format to scan and select their choices. Promising results have been discussed (Bruno & Trembeth, 2006) using the Fitzgerald Key Format in both low-tech print and high-tech digital conditions during a week-long pilot study at a children's summer camp for students with a range of severe disabilities. Despite promising findings, there is a paucity of research specifically investigating the effects of the Fitzgerald Key Format on writing and understanding parts of speech to improve comprehension skills for students with low incidence disabilities.

The purpose of this study was twofold: (a) to compare the differential effects of print *vs.* digital technology instruction on participants' accuracy rates of answering WH (who, what, where) functional community knowledge comprehension questions; and (b) to measure participants' on-task behavior during print and digital instructional sessions with four high school aged students with low incidence disabilities. Teaching students to communicate and demonstrate comprehension using print or digital aided AAC formats can positively impact the lives of students with low incidence disabilities, regardless of the mode of communication available to them. The goal was to teach the participants how to use an organized system for categorizing salient vocabulary by parts of speech, through print and digital means, so students with low incidence disabilities can communicate and demonstrate comprehension of basic who, what, and where concepts which can positively impact their health, safety, and independence (i.e., I smell smoke, call the fire department) after they complete high school.

In the current study, the following research questions were asked:

1. What are the comparative effects of using print *vs*. digital technology to teach functional community knowledge content on the accuracy of WH (who, what, where) comprehension questions for students with low incidence disabilities?

2. What are the comparative effects of using print *vs.* digital technology instruction on the percentage of on-task behavior among students with low incidence disabilities?

3. What are the opinions of teaching staff regarding the use of print and digital technology instruction to teach students with low incidence disabilities?

4. How do students with low incidence disabilities rate the use of print and digital technology instruction?

Significance of the Study

This study contributes to the existing research literature in several ways. First, although few studies have addressed adapted grade-level social studies content for students with moderate to severe intellectual disabilities (Schenning et al., 2013; Zakas et al., 2013) and one has addressed functional (map reading) modified social studies content (McKissick et al., 2013), none to date have specifically targeted students with low incidence disabilities. Second, while a number of studies have investigated computer-aided instruction across academic content areas for students with disabilities (Kim et al., 2006; Okolo, Englert, Bouck, & Heutsche, 2007; B. R. Smith, Spooner, & Wood, 2013; Wilkins & Ratajczak, 2009) none have investigated the use of large, interactive whiteboard (IWB) digital technology, such as SMART Board, for this population of students. Third, this was the first study to examine the role of using the Fitzgerald Key Format of color-coding vocabulary by part of speech in both print and digital technology instructional conditions to specifically target comprehension acquisition skills for students with low incidence disabilities. Fourth, this study revealed an increase in students' on-task behavior across conditions which indicates important data for special education teachers. Lastly, this study targeted functional health, safety, and communication goals which may positively impact students with low incidence disabilities post-school lives by providing another form of print and digital technology AAC to communicate their basic needs.

Delimitations

This single-case, alternating treatment design research study focused on teaching students with low incidence disabilities who have complex communication needs and require AAC to communicate and was not intended to generalize the findings to a broader population of students. Additionally, high tech digital technology in this study was solely focused on large, interactive whiteboard technology (e.g., SMART Board) and not on the myriad range of computer-aided instructional devices such as laptops, iPads, tablets, and desktop computers.

Definition of terms

Alternate learning technologies (ALT) - a phrase used to describe modified keyboards, touch screen computers, graphic organizing software, and voice recognition computer capabilities that allow individuals with disabilities to access learning material their nondisabled peers use (Khek, Lim, & Zhong, 2006).

Augmentative and alternative communication (AAC) – American Speech-Hearing Association (ASHA, 1989) define AAC as "an area of clinical and educational practice that attempts to compensate, temporarily or permanently, for the impairment and disability patterns of individuals with severe communication disorders."

Computer aided/assisted instruction (CAI) - CAI utilizes computers to teach academic skills and to promote communication. Computer modeling is an example of CAI (Collet-Klingenberg, 2009).

Digital technology – In this study, digital technology refers to high tech, aided augmentative and alternative communication (AAC) in the form of picture supported text presented in an interactive (i.e., sound, click and drag vocabulary icons, and corrective feedback) computer format (i.e., interactive whiteboard technology such as a SMART Board).

Fitzgerald Key Format (FKF) – Words are categorized by a specific color-code organization system to indicate different parts of speech to promote language acquisition and expressive language for individuals with complex communication needs (Fitzgerald, 1954).

Functional communication training (FCT) – FCT is an antecedent based intervention (e.g., communication) that is taught as a functionally equivalent replacement behavior for challenging behavior (Carr & Durand, 1985).

Functional community knowledge – Substantially modified social studies concepts that relate to health, safety, and issues of daily living (e.g., having someone call the police in the event of an emergency).

General Curriculum Access (GCA) – Browder, Ahlgrim-Delzell, et al. (2006) described GCA as a framework which embeds students' level of communication and symbol use (i.e., abstract symbols and sight words; concrete symbols such as pictures symbols; and pre-symbolic communication with concrete objects and gestures) and designs instruction to teach adapted, grade-aligned curriculum content for students with significant intellectual disabilities. Wehmeyer, Lattin, and Agran (2001), quoted U. S. Secretary of Education, Richard Riley's testimony before the U. S. House of Representatives Subcommittee for Early Childhood, Youth, and Families when he discussed the need to hold all students, including those with disabilities, to higher educational expectations and access in alignment with the general curriculum.

Interactive whiteboard technology **(IWB)** – H. J. Smith, Higgins, Wall, and Miller (2005) define IWB as large, touch-sensitive boards directly connected to a laptop computer and a digital projector which allow participants to use gross motor movements to access content on the screen via touch.

Intraverbal behavior – an intraverbal operant occurs when a verbal discriminative stimulus evokes a verbal response (Cooper et al., 2007). Intraverbal behavior can be viewed as a reciprocal communication exchange in the form of question and answer (i.e., Q - "What would you like to eat?" A - "Pizza.").

Low incidence disability – A visual or hearing impairment or a "significant cognitive impairment" which requires highly specialized personnel to provide a free and appropriate public education (Erickson, Lee, & von Schrader, 2017).

Mand – According to Skinner, a mand is the first form of verbal behavior most typically developing children learn to evoke intentional control over their environment and receive immediate reinforcement; a mand can be perceived as a request or a demand (i.e., cookie).

Print technology – In this study, print technology refers to low tech, paper-based aided AAC vocabulary words with picture supported text.

Tact - A tact is a verbal operant under the functional control of a nonverbal discriminative stimulus (Cooper et al., 2007) and acts to label or name something in the environment.

Technology aided instruction (TAI) – TAI is deemed an evidence-based practice for teaching students with autism spectrum disorder (Wong et al., 2014). The distinguishing feature of TAI is that technology acts as the central foundation which supports skill acquisition and goals of daily living, academics, vocational training, and recreation activities for the learner.

CHAPTER 2: REVIEW OF LITERATURE

This chapter presents the literature base which undergirded the current study by providing a review of research on: (a) the post-school outcomes for students who rely on AAC to communicate; (b) aided AAC, low tech/print technology and high tech/digital technology, supports and evidence-based teaching practices for accessing adapted, grade-aligned curriculum content; (c) the role of verbal behavior among aided AAC users; and (d) visual supports (e.g., adapted shared stories and color-coded vocabulary systems) to improve comprehension for students with low incidence disabilities who are nonverbal or minimally verbal. These components combined in the study created a thorough framework to teach students with low incidence disabilities, who rely on aided AAC to communicate: (a) to create three-word sentences (noun, verb, noun) to summarize adapted texts during shared reading; (b) identify salient vocabulary to improve comprehension; and (c) use print or digital aided AAC technology as a means to promote intraverbal communication and increase on-task behaviors. The combination of the intervention components has the potential to positively impact participants' abilities to communicate functional concepts related to health, safety, and independent living.

First, a description of the poor post school outcomes of aided AAC users is discussed. Next, a detailed look into the research literature involving print and digital instructional technology to access general curriculum content is reviewed. Then, a correlation between Skinner's (1957) verbal behavior operants, specifically tacts and intraverbals, and the potential impact on improving comprehension is posited. Last, evidence-based instructional and visual supports, in the form of color coded graphic organizers which delineate vocabulary icons by part of speech (Fitzgerald Key Format), are provided as a basis for the research intervention to bolster comprehension.

Augmentative and Alternative Communication (AAC) and Post-School Outcomes

Post-school outcomes for students who use AAC. The post-school outcome data for individuals who use aided AAC is scarce and not encouraging. Hamm and Mirenda (2006) conducted a survey research study in British Columbia and identified 79 individuals who used aided AAC services while enrolled in school and received communication technology systems upon exiting high school from 1998-2003. Only 30 viable survey participants were located and mailed survey packets. Survey packets included a Quality of Life Profile: People with Sensory and Physical Disabilities (QOLP-PD) and a Communication Survey. Eight packets were returned (27%) that were useable. Five of the eight respondents used aided AAC (i.e., communication books and computers) while one used a SGD. A parent described the dynamic SGD as “a toy and a joke” with abstract symbols her daughter could not understand. Three respondents reverted back to using unaided AAC (i.e., gestures and facial expressions) in the absence of aided AAC systems and support services. None of the respondents were employed or enrolled in educational programs. Some parents were frustrated by the lack of AAC support, services, or continued access to AAC resources for their young adult children after the completion of high school. One parent lamented the waste of 12 years teaching her child how to effectively use AAC then not being able to afford to purchase the device for continued use after graduation. Three respondents reported an increase in problem behaviors among their young adult children due to their decreased capacity to communicate without a functional form of aided AAC at home or in the community. The small sample size of this study may not be representative of the majority of aided AAC users after they exit high school. The study pointed out notable shortcomings regarding appropriate transition planning for AAC users. Similarly, Bouck and Flanagan (2016) conducted a correlational study investigating the data from the NLTS-2 and found fewer students with severe disabilities received a continuation of their AT services post-school and AT services were under-utilized by adults with severe disabilities.

Lund and Light (2006) conducted a study with seven young men (ages 19-23) who had been AAC users for at least 15 years, some of whom since preschool, to determine what define good post-school outcomes for AAC users. Up until 2006, no long-term data had been collected to document long-term post-school outcomes for this population. The authors assessed: (a) receptive language skills, (b) reading comprehension, (c) communicative interactions, (d) linguistic complexity, (e) functional communication, (f) educational and vocational achievement, (g) self-determination, and (h) quality of life. The results revealed a range of outcomes and highlighted the individualistic nature of defining "good" as it varies for each person. Two broad categories (a) factors intrinsic to the individual and (b) factors extrinsic to the individual, emerged to shape common outcome themes. Intrinsic individual factors included cognition, motor impairments that limited access to not only AAC but their surroundings (none were ambulatory), and personal characteristics such as motivation to succeed. Those who held higher expectations and goals for themselves scored higher on Quality of Life (QOL) rating scales. Extrinsic individual factors included environmental factors such as "where I live and spend my time," familial support, educational placement and early exposure to literacy. Of note, two of the young men were exposed to the same educational curriculums as their typically developing peers and received early literacy instruction starting from kindergarten and reported higher QOL satisfaction than the other participants. One recommendation for future research specifically targeted literacy instruction for AAC users to promote positive post-school outcomes and increased communicative competence. Further, McBride (2011) recommended proper AAC evaluations and trial periods with a variety of AAC options to determine the best fit for an individual's abilities, needs, and future goals. Falling prey to the latest technology advances and wide array of AAC apps available is easy; McBride cautioned consumers (e.g., families) to take the time to prioritize the evaluation process so that an aided AAC device does not become a leisure item rather than a means of communication.

Communication is a fundamental human need for expression, connecting with others, and sharing information. Communication is essential for meeting personal care needs, social relationships, learning, education, employment, living within a community, and demonstrating comprehension. Approximately four million people (1.3%) in the United States have complex communication needs and cannot communicate through vocal speech and rely on assistive technology (AT) in the form of augmentative and alternative communication (AAC) to interact with others (Beukelman & Mirenda, 2013). The American Speech-Hearing Association (ASHA) define AAC as "an area of clinical and educational practice that attempts to compensate, temporarily or permanently, for the impairment and disability patterns of individuals with severe communication disorders" (ASHA, 1989). AAC is comprised of two main categories: aided and unaided systems. Aided systems can encompass external materials such as paper based picture communication boards, photographs, line drawings, and a range of voice output communication aide (VOCA) devices and/or speech generating devices (SGD). Unaided systems do not require external materials for communication and may include manual signs, gestures, and facial expressions. AAC is used to supplement speech that is not functional for individuals with severe disorders of speech-language production and/or comprehension by providing aided or unaided supports. Beukelman and Mirenda (2013) suggested the primary aim of AAC is not to find a technological solution to repair communication problems but to allow individuals to effectively interact and communicate with others as they wish.

The effectiveness of aided AAC. Ganz et al. (2012) conducted a meta-analysis involving 24 single-case research studies from 1980-2008 regarding the impact of AAC on specific behavioral outcomes (e.g., communication, social, academic, and challenging behaviors) for 58 students with autism spectrum disorders (ASD). The authors noted 50% of individuals with ASD do not develop conventional speech or have limited speech and rely on AAC to communicate. The analysis specifically investigated the effectiveness of three types of aided AAC systems: (a) Picture Exchange Communication System (PECS, Bondy & Frost, 1994), (b) other picture-based systems, and (c) electronic speech-generating devices (SGDs). The researchers used the Improvement Rate Difference (IRD) to measure effect size across the single-case research studies and found the highest effect sizes for PECS and SGDs (0.99 for each) as compared to moderate effect sizes for other picture-based aided AAC systems (0.61). The IRD measure across targeted behaviors indicated the highest effect sizes (0.99) for communication outcomes; (.90) for social skills; (0.80) for challenging behaviors; and (0.79) for academic skills. The meta-analysis demonstrated the effectiveness of aided AAC for individuals with ASD and points to the importance of using aided AAC to teach students with complex communication needs. Specifically, bolstering communication promotes increased social interaction, improved academic outcomes, and decreases in challenging behavior. The authors noted the need for further research targeting the evaluation of effective instructional practices involving aided AAC on improving academic outcomes and decreasing challenging behaviors for students with ASD as the scores in these areas were not as high as the scores for communication.

Summary

Communication is a vital human need to relate to others and aided AAC has been shown to be an effective means of increasing communication skills (e.g., requesting preferred items/activities), enhancing social interactions, positively impacting academic performance (e.g., spelling), and simultaneously decreasing challenging behaviors (Ganz et al., 2012) among young children with ASD. Future AAC research investigating effective instructional practices targeting other academic skills beyond spelling and challenging behaviors not associated with gaining access to tangible items or activities was recommended. Limitations of the Ganz et al. (2012) meta-analysis include the small sample size; average participant grade levels ranged between preschool and elementary age students; and the investigation focused on students with ASD as opposed to the larger population of students with low incidence disabilities. Limited post-school outcome data exists for AAC users with low incidence disabilities (Bouck & Flanagan, 2016; Hamm & Mirenda, 2006; Lund & Light, 2006) yet reveal early literacy instruction and holding higher educational expectations for students with low incidence disabilities as important factors in determining improved QOL ratings among aided AAC respondents.

Promoting General Curriculum Access through the Use of Print and Digital Technology

One way of meeting the educational needs of students with low incidence disabilities who are minimally or nonverbal is through incorporating various forms of technology (Kim et al., 2006; Pennington, 2010; Wilkins & Ratajczak, 2009) into natural instructional opportunities. Technology-aided instruction and intervention (TAII) is deemed an EBP for teaching students with ASD (Wong et al., 2014). The distinguishing feature of TAII is that technology acts as the central foundation which supports skill acquisition and goals of daily living, academics, vocational training, and recreation activities for the learner. Research innovations utilizing technology devices to provide a platform for delivering meaningful functional and academic instruction to students with low incidence disabilities are rapidly emerging. Recent work (Higgins & Boone, 2016; McNaughton & Light, 2013); Pennington, 2016; Spooner, Kemp-Inman, Ahlgrim-Delzell, Wood, & Ley-Davis, 2015) has shed light on several novel technological instructional approaches for teaching students with low incidence disabilities. Yet more needs to be done to address the widening gap between research and practice. Often, high tech digital devices in special education classrooms are utilized as leisure items rather than instructional tools. The Office of Educational Technology (2016) report many special educators lack the skills, ease, and effectiveness of utilizing technology to deliver instruction which can decrease student learning outcomes. NEPT’s goal is to build the capacity of educators by leveraging technology and increasing “digital literacy” to transform the teaching profession by providing enhanced access and equity for students with low incidence disabilities. Unfortunately, according to Vernon-Dotson, Floyd, Dukes, and Darling (2014) many teacher preparation programs at universities across the country fail to grasp the potential for integrating technology into teacher development training.

Discussion associated with the role of technology in meeting the academic needs of individuals with intellectual disability is broad based upon how the word technology is used and intended. At the most basic level, technology is defined as a practical and systematic application of knowledge or methods for solving problems (Merriam-Webster, 2006). The primary aim of aided print and digital technology (typically referred to as light/low tech or high tech aided AAC) in special education is to provide a means of interacting with students with severe communication impairments to share knowledge, communicate ideas, demonstrate comprehension, and express opinions (Hourcade, Pilotte, West, & Parette, 2004) through the use of aided symbols, for instance, photographs, line drawings, and picture communication boards in the form of AAC.

A Brief History of Technology

Hourcade et al. (2004) discussed the history of technology systems in the realm of disability services and included aided AAC and assistive technology (AT) dating back to the 1950s in which communication boards were emerging as an instructional approach to teaching communication skills. According to Hourcade et al. early AAC pioneers focused instruction and training on teaching unaided symbol use to individuals with severe communication impairments. The prevalent assumption of the time was to teach individuals with severe communication impairments from a developmental perspective using unaided AAC to ultimately produce oral language (Hourcade et al., 2004; Reid & Hurlbut, 1977). Professionals in that era (1950-1970s) worked from the supposition that

AAC users needed the prerequisite skills of producing speech in order to be strong AAC candidates. The use of aided AAC systems and picture supports for individuals with severe communication impairments were rare.

As the Education for All Handicapped Children Act (P.L. 94-142) legislation was enacted in 1975 and students with disabilities began entering schools (later reauthorized as the Individuals with Disabilities Education Act [IDEA] in 1991) special educators began searching for effective means of teaching communication skills to students in need in public schools across the country. Later in 1986, an amendment to that legislation (P.L. 99-457) stipulated the inclusion of technology support for students with disabilities. Then in 1989, the Technology-Related Assistance for Individuals with Disabilities Act (P.L. 100-407) mandated AT which included AAC for students with disabilities such that "every reasonable attempt to provide AT" would be made for those who needed communication supports. Amendments to IDEA in 1997 then stipulated assessments for AAC consideration on student's Individualized Education Plans (IEP). Students with disabilities in need of AAC were now not only in need of appropriate means of communication but were included, to varying degrees, in general education classrooms and exposed to the general education curriculum. Along with greater inclusion of students with disabilities in public schools nationwide came accountability measures and legislation (NCLB, 2001, 2006; Every Student Succeeds Act, 2015) once again pushed the special education pendulum from more of a functional curricular focus to being grade aligned and adopting higher academic standards for all students.

Early research by Reid and Hurlbut (1977) explored the use of picture communication boards and behavioral training with six adults who were deemed non-vocal and multi-handicapped. Their results showed each participant was able to consistently indicate leisure activities and functional activities of interest with 100% accuracy after training (prior to training 0-67%) using the picture communication boards. These were powerful outcomes considering the adults had lived 30 years in residential facilities without the ability to adequately communicate or request personally meaningful leisure activities previously. Later, Lancioni (1983) demonstrated the use of discrimination training with three students with severe intellectual disabilities (then termed severe mental retardation) which enabled these children to actively communicate using thousands of pictorial representations to convey messages; a skill previously deemed implausible. The three young children were nonverbal with severe autism (IQ scores below 50) and exhibited inconsistent responses to four to nine manual, unaided signs, during five months of previous training.

These early studies revealed groundbreaking strides in the communicative power of aided, print technology AAC for individuals with moderate to severe intellectual disability. Often, communication using AAC focused solely on functional communication involving wants and needs (Hourcade et al., 2004; Lancioni, 1983; Reid & Hurlbut, 1977).

Print Technology in Academic Content

The prevalence of aided AAC need is high. Wilkinson and Henning (2007) note over two million Americans need AAC to be understood by others. The authors provided an explicit operational definition of print based, low technology for AAC users which involve aided symbols (e.g., alphabet boards, symbol-based boards, communication programs such as PECS and communication books) that do not offer voice output.

Typically, these print-based, low technology (hereafter referred to as print technology) options, are paper based. Mirenda (2001) further clarified low, print technology, aided symbols are “external to the user’s body” (p. 141).

Leading researchers in the field of special education have demonstrated how students with low incidence disabilities can access general education content by holding higher educational expectations for students. For instance, Browder, Trela, and Jimenez (2007) used print technology, paper based, picture supported vocabulary symbols and a task analysis to adapt grade aligned literature (i.e., *Call of the Wild; The Cay; Island of the Blue Dolphins)* with six middle school students with moderate to severe intellectual disability (IQ scores ranged from 42-50). Researchers used a multiple probe across participants design to provide structured literacy lessons using print tech technology supports to adapt eight grade level novels and introduced them as story based lessons. Dependent variables assessed both teacher and student behaviors. Teachers were scored on the number of steps performed correctly on a task analysis for the story based lessons involving evidence-based practices of systematic instruction (e.g., constant time delay). Students were assessed using a task analysis to gauge accurate response prompting towards learning content specific vocabulary and to answer comprehension questions using print technology AT. After receiving training and explicit steps of the task analysis during intervention, all teachers mastered and maintained correct responding using the task analysis. Additionally, all students met criterion during intervention, showing consistent gains in independent correct responses. Results demonstrated a groundbreaking shift from sight word instruction to increasing expectations for students with moderate to severe intellectual disability in accessing adapted, grade level academic content.

Extending the research base beyond English language arts instruction, Browder et al. (2012) conducted a quasi-experimental study using story based lessons supported with print technology, modified picture paired text symbols, to teach grade aligned mathematics and science content standards to middle and high school students with moderate to severe intellectual disability. The math study involved 16 middle and high school students with moderate to severe intellectual disability (IQ scores ranged from 30-54) and print technology adapted story based math lessons to address algebra, geometry, and data concepts. The science study involved 21 students with moderate to severe intellectual disability (IQ scores ranged from 33-53) and inquiry based instruction. Participants were provided with print technology picture paired with text response boards related to earth science concepts and vocabulary to answer inquiry questions such as "What do you know about it? What do you want to know? How can we find out? (KWHL). Results showed that using story based lessons with print technology graphic organizers to teach mathematical skills and inquiry based lessons to teach critical science concepts were effective for teaching this population of students. Researchers found pairing key vocabulary with print technology picture symbol support on response boards helped participants acquire grade level mathematics and science vocabulary and increased participants' abilities to answer content specific comprehension questions. One goal of the research team was to design an intervention template that could support grade level alignment across content areas to support students with moderate to severe intellectual disability.

The research literature is still burgeoning in the area of providing models for aligning grade level content to state standards for students with low incidence disabilities. As noted above, research has demonstrated several effective practices to help students with disabilities access general curriculum content in the areas of English language arts, mathematics, and science. Standards based curriculums can be bridged with the support of evidence-based practices of systematic instruction (e.g., constant time delay, least intrusive prompting, task analysis) coupled with print technology, picture symbol supported aided AAC to teach students with low incidence disabilities. As of 2009, only 13 states currently required alignment for social studies according to the National Center for Special Education Research's report (Cameto et al., 2009).

Print technology and social studies. The research literature is sparse regarding teaching social studies content standards for students with low incidence disabilities. Yet with 25% of states making social studies content a priority for state alternate assessment and alternate achievement standards (AA-AAS), more states may take notice and be in need of effective instructional strategies for supporting students with low incidence disabilities in acquiring greater functional community knowledge. In addition to being exposed to age appropriate literature, mathematics, and science content, it is important for students with low incidence disabilities to also be taught the foundational tenets of social studies (e.g., geographic locations, people, historical events, civics, governance, and economics) and how these concepts relate to their daily lives and can promote better health, safety, and independent living.

Consistent with the age appropriate, grade-aligned work cited previously (Browder et al., 2007; Browder et al., 2012), Schenning et al. (2012) conducted a multiple probe across participants design study and incorporated print technology adapted social studies stories (e.g., French Revolution, Ancient Rome, the Middle Ages, the Bubonic Plague) with picture supported text and graphic organizers to assess comprehension and generalization of "real-world" problem solving with three middle school students with low incidence disabilities (IQ scores ranged from 33-55). The purpose of the study was to use a structured inquiry format (e.g., "What do you see?" What is the problem? What is a possible solution?") with print technology, picture supported vocabulary and a graphic organizer to aid student comprehension and to organize abstract historical concepts. The print technology picture supports provided participants with a visual means to generate responses to recall questions and to sequence historical events using the graphic organizer prompts. Results indicated that using symbol supported text coupled with graphic organizers and explicit instructional procedures (e.g., model-lead-test) produced higher levels of comprehension and accurate responding for all three students.

Similarly, Zakas et al. (2013) conducted a study with three middle school students with autism and mild to moderate intellectual disability (IQ scores ranged from 61-76) to successfully use print technology picture supports and graphic organizers to answer comprehension questions regarding United States History and to create expository text using a single case, multiple probe across participants design. Using a nine-cell graphic organizer, participants used the print technology picture supports to identify salient social studies content to answer questions concerning events, people, location, time, the sequence of events, and outcomes from adapted social studies passages. The passages were adapted and aligned to a 3rd grade Lexile Framework for Reading (2011) level to decrease the cognitive difficulty associated with expository text content prevalent in social studies material for students with intellectual disabilities. Results revealed a functional relation between the print technology graphic organizer intervention and the ability of the three participants to correctly answer grade aligned social studies comprehension questions. Participants in this study differed in their cognitive abilities from the students in the previous studies mentioned; although they benefitted from the print technology supports, these participants were able to write their responses in the graphic organizers to answer the comprehension question prompts rather than pointing to the print technology picture supports. Additionally, all participants were able to generalize these skills using print technology supports to untrained social studies passages.

The following digital technology interventions illustrate the efficacy of translating common print based instructional tools (i.e., flashcards for teaching sight words) into easily editable technological resources. Embedding digital technology into effective instructional lessons allows special educators to augment their instruction by providing students with repeated trials with consistent prompting and the ease of modifying instructional materials over time to meet students’ changing educational needs and learning goals.

Digital Technology in Academic Content

The following studies exemplify the successful push to promote higher expectations and academic outcomes for students with disabilities using digital technology strategies (CAI and TAI). Lussier-Desrochers et al. (2017) discussed the current technological era as being one of unlimited access to information and entertainment for digital media and discuss the positive impact digital technology presents for individuals with intellectual disabilities (ID) when digital access considerations are properly mitigated to promote inclusion rather than exclusion. Wilkinson and Henning (2007) defined digital, high technology aided AAC devices as those involving electronic, computer technology that allow individuals to interact with the devices (e.g., computers, laptops, iPods, iPads, interactive whiteboards) to produce a communicative response. By definition, VOCA are also included under the digital technology classification. Wilkins and Ratajczak (2009) discussed the benefits of using speech generating devices (SGD) which are digital technology AAC devices to help students gain valuable literacy skills as deemed instrumental by the National Reading Panel which include: (a) phonics, (b) phonemic awareness, (c) vocabulary development, (d) reading comprehension, and (e) content area reading comprehension. The authors stated, digital "high-technology AAC takes these students to the next level of communication and allows them to be functional communication partners with peers and adults" (p. 169).

Pennington (2010) provided a review of the literature from 1997 to 2008 involving digital technology CAI to teach academic skills to students with ASD and found 15 studies that met inclusion criteria for his investigation. Pennington discovered students with ASD showed an increased interest in the multimedia (e.g., animation, voice, and video) presentation of stimuli CAI offers. Initially, CAI was used to help students with ASD by providing immediate feedback; lessons could be repeated with consistency for multiple trials and students could pace themselves through the material. CAI was not found to be an evidence-based practice by Horner et al. (2005) standards due to limited experimental control in the majority of studies. Pennington's findings extended the literature base for teaching by showing CAI as a promising means of teaching students with ASD general education academic content. All 52 participants across the 15 studies met their targeted academic skills when CAI was used as the intervention during instruction. Significantly, each study using CAI found it more efficient than teacher only instruction.

Kim et al. (2006) suggested comprehension is the most difficult aspect of reading to measure for students with disabilities. Kim et al. conducted a comparison study using CAI to teach 24 middle school students with learning disabilities (LD) to read and comprehend modified grade level text using the Computer-Assisted Collaborative Strategic Reading (CACSR; Kim, 2002) while the comparison group used peer read-alouds to increase reading fluency and comprehension. The high technology CACSR program provided participants reading level options individualized to their learning rates, immediate corrective feedback, progress monitoring, and simplified text with picture supports. Students watched video models of how to locate and "chunk" pertinent information in text passages and specific steps for developing comprehension of the passage material. Statistical analysis revealed students in the CACSR intervention group significantly improved on reading comprehension measures through standardized mean difference (SMD) over their peers in the control group. SMD effect sizes = .50-1.18 which supported positive outcomes of the CACSR, a high technology CAI intervention for teaching grade aligned reading, for students with LD.

Demonstrating the effective use of embedding explicit instruction using high technology CAI across content areas, B. R. Smith et al. (2013) examined the effects of

CAI to teach science terms to three middle school students with ASD and intellectual disability (IQ scores ranged from 59-69). Researchers used a multiple probe across participants research design to assess participants' ability to learn challenging grade level science terms (e.g., mitosis and homeostasis) using CAI. Content specific terms were displayed on an iPad 2® showing a photograph and a simplified definition beside it in a slideshow presentation format. The CAI intervention included a model-lead-test procedure, the iPad 2® read the terms aloud, and provided corrective feedback using time delay and highlighting correct responses, touching the correct response on the screen progressed the slideshow to the next item. Results revealed a functional relation between CAI instruction and students' accurate responses. This study added to the literature base substantiating CAI as an effective high technology instructional strategy when coupled with evidence-based teaching practices for students with disabilities. As established in the discussion regarding print technology supports for aligning standards-based curriculum for students with disabilities in the area of social studies, few research studies have incorporated digital technology AAC instructional practices toward meeting grade level alignment in the area of social studies.

Digital technology and social studies. In an effort to gauge the educational gaps between general education students and their peers with disabilities at the secondary level in the areas of English, mathematics, science and social studies, Scruggs, Mastropieri, Berkeley, and Graetz (2010) conducted a meta-analysis from 1984 to 2006 involving 2,403 students with disabilities and found 24 out of 70 intervention studies were targeted at social studies skills. Studies using CAI (n= 7) for students with disabilities resulted in moderate effect sizes ($M = 0.63$) and cited multimedia learning (e.g., using a computerized map rather than an atlas to teach geography) was beneficial for this population. For students with intellectual disability, having access to appropriate instructional tools is critical. Especially with disjointed and abstract content prevalent in social studies curricula, students with intellectual disability require instructional supports that scaffold and organize pertinent information if they are to be successful (Pennington, 2010).

Moving towards more complex, higher-order thinking skills, Okolo et al. (2007) describe the Virtual History Museum (VHM), a web-based interactive learning site, for helping students with disabilities access grade aligned, interactive social studies content using videos, graphic organizers, writing prompts, and repeated trials. For instance, middle school age students have access to detailed information about the Underground Railroad and Frederick Douglas that is modified to meet students' unique learning needs. Authors suggest that using digital technology instructional resources such as VHM helps "level the playing field, enabling students with disabilities to learn as much as honors students over the course of the instructional unit" (p. 9). Yet, the abstract historical content may not be as appropriate to teach students with low incidence disabilities who would benefit from instruction to help them communicate and comprehend issues which directly affect their daily lives.

Later, using a qualitative research design, Bouck, Flanagan, Heutsche, Okolo, and Englert (2011) explored teacher perceptions regarding using high technology "instructional assistive technology" via the VHM to teach students with disabilities grade aligned social studies curriculum content. In total, 13 teachers participated in the study. Teachers reported the VHM tool benefitted students' learning yet took considerable teacher time to become adept with the use of the high technology AT. Benefits for students with disabilities reported by teachers included differentiated instruction, screen reading programs, access to material in novel formats, and the ability to augment visuals and videos not present in standard textbooks that serve to deepen student understanding.

Building upon this premise, McKissick et al. (2013) used CAI to teach three elementary age students with ASD and intellectual disability how to read maps using the legend (social studies) thereby transferring the map reading skills to locating preferred stores in a mall. The research team used a multiple probe across participants design and evaluated the efficacy of using a digital technology CAI intervention package on a laptop to teach participants locations on a map. Multiple map exemplars were presented (i.e., school, mall) and were presented using animated prompts on a 24-slide PowerPoint™ presentation. Participants were provided verbal cues embedded into the CAI package using a model-test format (i.e., "My turn. Click exit on map. Your turn. Click exit on map.") and were assessed for accuracy of correctly identifying map legend symbols. Although results were not robust, a functional relation was established between the high technology CAI intervention package and students' correct responses. Although not defined as such, the McKissick et al. (2013) study could fall under the functional community knowledge umbrella as navigating to familiar places in the community is a common functional skill of daily living. One of the implications stated in support of using digital technology CAI is the consistency, efficiency, and ease of modifying instructional materials over time. Print technology, paper based, AAC materials are often lost and need to be recreated. Additionally, print technology AAC is not presented in the same instructional sequence nor timing as digital technology instruction. These drawbacks can be minimized when programming digital technology CAI instructional materials.

In keeping with technological advances, another form of digital technology is interactive whiteboard (IWB) technology. According to the National Education Association, IWB technologies were created in 1991, yet mainstream use in classrooms across the United States did not become widely apparent until 2006 when 16% of classrooms had whiteboard technology in place. H. J. Smith et al. (2005) define IWB as large, touch-sensitive boards directly connected to a laptop computer and a digital projector which allow participants to use gross motor movements to access content on the screen via touch. Students can 'write' with a fingertip or whole hand rather than needing the fine motor dexterity required to operate a mouse or isolate a letter on a keyboard, thereby mitigating the effects for students with physical impairments. Further, the large screen presentation format of IWB inherently provides enlarged viewing access for students with visual impairments. Anything that can be displayed on a small, personal computer screen, laptop, or iPad® (e.g., videos, animations, audio) can be displayed and engaged interactively with the touch of a hand on an IWB.

Digital technology and interactive whiteboards. Likely prompted by accountability mandates from IDEA 2004, when educators began to shift the teaching focus and educational expectations for students with moderate to severe intellectual disability from functional skills and teaching discrete sight word instruction (Browder et al., 2006) to more complex, grade aligned academic content, the research and evidence base had not been established yet for IWB, however studies are emerging. Similarly, the field of special education is beginning to investigate the implications of large IWB on students' learning grade aligned content and the effects on student motivation and engagement.

Conducting a literature review regarding the educational impact of IWB on instructional practices, H. J. Smith et al. (2005) found two themes emerged in support of IWB (a) IWB enhance teaching practices and (b) IWB technology is a powerful tool to support student learning. Note, H. J. Smith et al. did not mention how many studies were included in their review. However, important discussion points are worth mentioning. H. J. Smith et al. (2005) discuss the advantageous nature of IWB as a teaching tool for both general and special education students: (a) flexibility and versatility, (b) multimedia/multimodal presentation, (c) efficiency, (d) supports planning and resource development, (e) modeling and observational learning, and (f) interactivity and participation. The multimedia ability allows teachers to take "students into the trenches of World War I and give them a 360° panoramic view" (p. 93). Efficiency is maximized as teachers can flow seamlessly from pre-prepared video and instructional activities without losing student attention. Simultaneously, access is enhanced for students with visual and/or gross motor impairments. Student motivation to interact physically with the IWB through touch manipulations also has shown to increase. As H. J. Smith et al. (2005) state, "student eagerness to come up and write on the board has been quite overwhelming" (p. 94).

Mechling, Gast, and Thompson (2008) successfully used digital technology, interactive SMART Boards, which are a brand version of IWB, to teach three students with moderate intellectual disabilities (IQ scores ranged from 52-54) to read functional sight words. Researchers used an adapted alternating treatment design to assess the effectiveness of high technology IWB instruction versus light technology flash cards to teach 122 grocery item words. Both instructional strategies were shown to be effective in teaching the targeted responses. Additionally, social validity measures revealed participants preferred the high technology, IWB lessons because the larger format was easier to see and provided "observational learning" while their peers were working. Student motivation to participate and engage with the IWB was also preferred by participants over the traditional print based flash card presentation method.

Similarly, Campbell and Mechling (2009) used digital technology CAI on an interactive SMART Board to teach letter sounds to three elementary age students with learning disabilities using constant time delay (3s) in a small group format. A multiple probe across three letter sets and across three students was used to investigate the effectiveness of CAI with a high technology IWB. Students learned target and non-target information by observing their peers work on the large IWB. This study supports the initial efficacy of using high technology IWB as an instructional tool and adds to the research literature.

Comparison of Print and Digital Technology Use for Academic Content

Two studies were located specifically investigating the comparative effects of print versus digital technology instruction for students with low incidence disabilities. Mechling et al. (2008) assessed participants' abilities to acquire functional sight word vocabulary (i.e., grocery store terms: spices, charcoal, deli) during observational learning using traditional print based flash cards and a digital SMART Board to present the instructional material to three participants with moderate to severe disabilities ages 19-21. The research revealed higher rates of accuracy during the digital SMART Board trials versus the traditional print based flash card trials. The digital condition did not incorporate interactive features such as touch screen sensitivity to select a response, drag and drop, or electronic corrective feedback. Future research was recommended in these areas, as well as examining teaching additional skills (i.e., writing) via interactive whiteboard technology during small group instruction. The authors note the engaging and motivating features of digital technology may outweigh traditional print based instruction.

Jameson et al. (2012) employed a multiple preference assessment with a single-subject adapted alternating treatment design to compare print technology (e.g., flash cards) and digital technology (e.g., iTouch) presentation formats for learning vocabulary words linked to general curriculum core standards preferences among four students (ages 14-21) with significant cognitive disability (IQ scores ranged from 51-54). Instructional targets included health education words and science core standard terms for eighth grade students (i.e., senses, muscles, calcium, seismic, geysers). Constant time delay was embedded within both presentation formats. Both formats were found to be effective in teaching the instructional targets to criterion, however; students tolerated more trials using the digital technology format and higher error rates were associated with the print technology instructional presentation. These student preference results indicated increased willingness and motivation to engage with the digital technology iTouch device. These findings reveal promising data for special educators when planning instructional lessons aligned with grade level content standards and how teachers may enhance student learning outcomes using digital technology instructional supports.

A study by Rivera et al. (2012) most closely parallels the current study in terms of participant descriptions (e.g., intellectual functioning, cultural backgrounds, receiving special education services in a separate setting), research design, instructional strategy (model-lead-test), and the use of digital technology to deliver instruction. Rivera et al. used a single-case alternating treatments research design to compare the effect of teaching vocabulary word acquisition in English and Spanish using a model-lead-test procedure with three elementary school (ages 8 to10) Mexican American students with moderate intellectual disabilities. All three students were described as ELL. The intervention consisted of 13 Microsoft® PowerPoint™ slides per session with vocabulary words paired with a photograph (e.g., caterpillar). An introductory slide was followed by five review slides, then five Spanish preview slides, five model-lead-test slides (i.e., the intervention), and one "checkout" slide with five randomly ordered vocabulary words. Participants were queried in English and in Spanish for the "checkout" slide (e.g., "What is this?" or "¿Que es esto?") depending upon which treatment they were receiving (e.g., instruction in English or Spanish). The primary dependent variable was the number of correct responses during each treatment condition when participants were asked to identify the vocabulary words in response to the prompt "What is this?" The second dependent variable was the number of correct English words students were able to identify verbally during the generalization probes. The results were mixed; two students performed better during the Spanish mode-lead-test vocabulary interventions (19 correct in Spanish *vs.* 6 correct in English; and 43 correct in Spanish *vs.* 32 in English). The third participant scored equally well during both instructional trials (21 correct in Spanish and 20 correct in English). The authors caution similar results may not be a likely outcome (e.g., higher scores in during Spanish trials) without a teacher who is fluent in Spanish to understand students' comments during sessions. The inherent enticement of embedding technology during instruction was noted as a motivating factor to promote student engagement. Future research utilizing interactive whiteboard technology was recommended. One limitation of the Rivera et al. study in comparison with the current study, despite similarities in IQ levels and intellectual functioning, were participants' verbal abilities; the students in the current study were aided AAC users in addition to having low incidence disabilities and IQ levels below 55.

Implications for practice and unanticipated effects in support of digital technology and IWB use consistently mentioned increases in student motivation, active engagement, and time on task while simultaneously noting decreases in off-task, challenging behaviors. In the field of low incidence disabilities, these are important findings.

Digital Technology Use and Student Motivation

H. J. Smith et al. (2005) conducted a literature review highlighting IWB use with students with moderate to severe intellectual disabilities. The authors noted an increase in student motivation to participate in academic lessons was positively correlated with improved student attention and decreases in off-task behavior when using IWB technology. The added appeal of large, interactive whiteboard technology (e.g., SMART Board, Promethean, Mimio, BenQ) allows typical instructional content, normally accessed on a standard desktop or laptop computer, to be viewed and accessed by the touch of a hand rather than a mouse or keyboard. For students with disabilities, the implications for practice expand the typical classroom options in promising ways. Students with visual impairments have naturally enlarged content on the whiteboard, whereas students with physical motor impairments can use their whole hand to activate an icon on the screen as opposed to an isolated fingertip stroke on a keyboard; in both situations, there is improved access to the academic material.

Khek, Lim, and Zhong (2006) conducted a mixed method research study to determine the effect of alternate learning technologies (ALT), a phrase used to describe modified keyboards, touch screen computers, graphic organizing software, and voice recognition computer capabilities that allow individuals with disabilities to access learning material their nondisabled peers use. Results of the mixed method study found that students with disabilities who use ALT have increased feelings of “academic competence” and greater academic performance. Academic competence was described as student perception linked with social competency which paired together equate to feelings of improved academic success. Use of ALT additionally helped students access the material interactively with their nondisabled peers thus positively impacting greater quality of life and social engagement.

Results from a survey research study (Shane & Albert, 2008) has shown that students with ASD prefer CAI over light technology options. The authors found students with ASD prefer electronic screen media over any other leisure activity. Motivation to interact with digital technology screen devices are enhanced for students with ASD. This form of presentation “excites children with ASD… and research literature shows improved skill acquisition and learning” (p. 1507) using digital technology instructional tools (e.g., video modeling).

In addition to preferences, Soares, Vannest, and Harrison (2009) used an alternating treatment (ABAB) design and found that using CAI during academic instruction with one student with ASD effectively produced decreased rates of self-injurious problem behavior while increasing rates of student engagement. Specifically, the participant demonstrated high rates of academic engagement and task completion equaling increased academic productivity and while decreasing tantrum behavior and self-injury.

Mechling and Bishop (2011) conducted two studies involving computer-based stimuli for three male students, ages 8-9, with profound multiple disabilities and found that the participants preferred personally created interactive videos over commercially available software programs and additionally the participants showed a preference for academic stimuli being presented on the large interactive whiteboard screens. Student preference and motivation to engage in grade aligned, academic activities are noteworthy findings. Naturally, when students are eager to participate in classroom activities, rates of problem behavior decrease while active engagement increases.

Summary of Using Print and Digital Technology to Teach Academic Content

Browder, Wakeman, et al. (2007) clarified that adapted, grade aligned instruction for students with significant cognitive disabilities must be meaningful and motivational for students. Research embedding IWB technology shows promising results in this regard. Extending the research base to investigate the differential effects of print *vs.* digital technology on the comprehension of substantially modified social studies content in the form of functional community knowledge concepts for students with low incidence disabilities while simultaneously assessing the impact of these technologies on student behavior is therefore warranted.

As with learning any new curricular program, print or digital technology, a learning curve exists in which students and teachers increasingly become proficient over time with repeated practice. Coupled with the technological options for presenting engaging, motivating, meaningful, and personal relevant academic content aligned to general curriculum standards across content areas, it is imperative that researchers and special educators keep pace with the quickly evolving technological options that can enhance student learning and outcomes. In the area of moderate to severe intellectual disability, few research studies have been found in the research literature empirically investigating print *vs.* digital technology presentation formats for modified social studies content. Despite the fact that 13 of the 50 United States currently have made social studies a priority content area for Alternate Assessment on Alternate Achievement Standards (AA-AAS), more states may take notice and be in need of effective instructional strategies for supporting students with low incidence disabilities. The research base targeting students with low incidence disabilities and digital technology instruction is limited. Studies involving students with ASD and mild to moderate intellectual disability were included to provide a tenuous framework to base an argument for further examination addressing the needs of students with low incidence disabilities. Examining the differential effects of these instructional strategies on the comprehension of adapted, grade-aligned social studies content for students with low incidence disabilities is worth investigating. Additionally, this study tracked students' on-task behavior as measured by the percent of time spent on-task during print and digital technology lessons focused on functional community knowledge concepts intended to positively impact participants' post-school lives in the areas of health and safety.

The Role of Verbal Behavior on Developing Comprehension

Students with low incidence disabilities and complex communication needs are more likely to display off-task, challenging behavior due to deficits in communication which may impede their abilities to appropriately interact with others. One evidence-based practice, founded on the principles of applied behavior analysis, recommended to address challenging behavior is functional communication training (FCT). Carr and Durand (1985) defined FCT as an antecedent based intervention (e.g., communication) taught as a functionally equivalent replacement behavior for challenging behaviors. Increased rates of off-task behavior are liable to occur when students lack a reliable means of communication. Conducting a functional analysis to determine the function or reason why a behavior is occurring is the cornerstone of FCT. Challenging behavior tends to fall into one of four broad categories: (a) escape behavior to avoid aversive stimuli, (b) attention seeking behavior, (c) access to tangible items or activities (i.e., food or computer games), and (d) automatic reinforcement behaviors which would occur even when an individual is alone (e.g., self-injury or rocking). Once a functional analysis has been conducted to determine the function of a behavior, a socially appropriate and meaningful replacement behavior can be taught to the student using FCT which serves the same function as the off-task behavior. Typically, students demonstrating challenging behavior are taught basic manding skills to make requests or express their needs (e.g., "I want a break" when work tasks are too challenging) to appropriately replace problem behaviors in socially significant ways. FCT provides the gateway for students to learn to extend purposeful communication beyond basic wants and needs. Skinner's (1957) six types of verbal behavior include: (a) mand, (b) tact, (c) echoic, (d) intraverbal, (e) textual, and (f) transcription. In Skinner's hierarchy, the ability to mand (request or protest) is the first form of verbal behavior most typically developing children learn to evoke intentional control over their environment and receive immediate reinforcement for the things they desire. Ample research over the past 30 years has demonstrated the effectiveness of FCT (Dawson, Matson, & Cherry, 1998; Durand & Carr, 1985; Durand & Merges, 1998; Fee & Matson, 1992; Gardener & Cole, 1990; Kurtz, Boetler, Jarmolowicz, Chin, & Hagopian, 2011; Mirenda, 2009; Olive, Lang, & Davis, 2007) as an empirically validated treatment approach to address challenging behavior especially among students with low incidence disabilities and complex communication needs. Once individuals learn to mand to meet their basic wants and needs, the verbal operants Skinner described involving tacts, echoics, and intraverbal skills further help individuals expand their verbal repertoires while simultaneously decreasing rates of off-task behaviors. The Rivera et al. (2012) study, although not stipulated as such, described tact training (naming or identifying vocabulary words) and proceeded to assess language acquisition using intraverbal (question and answer) responses to determine whether instruction in English or Spanish had a stronger effect for ELL students.

To highlight the proposed correlation between Skinner's tenets of verbal behavior and well established evidence-based practices (EBP) in special education, Browder, Ahlgrim-Delzell, Spooner, et al. (2009) conducted a literature review for articles published between 1975 and 2007 specifically evaluating time delay as an EBP. Of the 30 viable studies the authors analyzed, 22 met all seven quality indicators stipulated by the Horner et al. (2005) criteria to be deemed an EBP. The practice of time delay is typically used to teach discrete skill tasks such as sight word reading, or in the case of aided AAC users, touching a SGD button to read a word. Using Skinner's verbal behavior model, using a time delay procedure to read a word would be a tact. Although Browder et al. (2009) did not explicitly correlate the use of time delay to teach tact training for students with complex communication needs who require AAC, as that was not the focus of the review, the premise is viable. Browder et al. (2009) stated that there is a clear evidence base for employing time delay procedures to teach early literacy skills particularly for students with severe developmental disabilities. Additionally, the authors stated time delay can be used "with confidence" to teach symbol recognition for students with developmental disabilities (p. 359).

Increasing Intraverbal Behavior

Intraverbal behavior is a more advanced verbal operant in Skinner's hierarchy. Intraverbal behavior can be described as a dialogue between a speaker and a listener in which one may ask a question and the other responds. In applied behavior analytic terms, this can occur when a speaker's "verbal discriminative stimulus evokes a verbal response from the listener that does not have point-to-point correspondence" (Cooper et al., 2007, p. 531). The verbal operants of mands (requesting or protesting), tacts (labeling or naming), and echoics (repeating) can be viewed as prerequisite skills to build upon for developing intraverbal skills involving question and answer responses (i.e., WH questions). Goldsmith, LeBlanc, and Sautter (2007) describe the prevalence of mand and tact training for students with ASD and the lack of intraverbal skills training for students with intellectual disabilities. Students with intellectual disabilities may struggle with processing and understanding abstract information; targeted verbal operants can be taught using systematic and direct instruction to improve comprehension among these students.

Miguel, Petursdottir, and Carr (2005) investigated the effects of teaching six typically developing preschool children using multiple-tact training (MTT), receptive-discrimination training (RDT), and intraverbal training (IVT) to assess rates of intraverbal responding using a multiple baseline across categories design. The primary dependent variable was the number of correct intraverbal responses provided related to thematic categories (e.g., musical instruments, kitchen items, tools). MTT involved using color photographs to teach children to tact (name) items and then categorize the group the item belongs in by theme. When participants gave an incorrect tact, the experimenter provided an echoic prompt for error correction. RDT tasks involved auditory-visual matching-to-sample tasks which were in effect comprehension questions or comprehension intraverbals. The children were asked to identify either the item or the item category from an array of three pictures when verbally prompted to "point to the ___." Experimenters used gestural prompts (i.e., pointing to the picture) to repair incorrect responses. During the IVT phase, children were asked direct questions which required intraverbal responses rather than picture supports to transfer stimulus control from the photographs to verbal responses (e.g., "What are some tools? Tell me as many as you can."). Tact prompts with photographs from the training sets were used to correct response errors. Miguel et al. found that neither MTT nor RDT training had significant effects on intraverbal behavior. Only the IVT training involving a transfer of stimulus control procedure produced substantial increases in intraverbal behavior when directly taught to these typically developing preschoolers. Miguel et al. suggest future research should focus on students with developmental disabilities to further assess the efficacy of intraverbal training to improve comprehension skills.

The ability to comprehend what people say and answer questions are vital aspects of daily living; these skills are considered intraverbal behaviors. Sundberg and Sundberg (2011) note intraverbal behavior skills have received the least empirical research attention of Skinner's six verbal behavior operants in the last 54 years or more. Specifically, students with ASD often demonstrate strong mand, tact, and echoic skills yet weak intraverbal skills which adversely affect academic, social, and functional communication outcomes. Interestingly, Sundberg and Sundberg conducted a descriptive analysis involving 110 students (e.g., 39 typically developing two to five-year old children and 79 three to fifteen-year old students with ASD) to determine factors associated with intraverbal behavior development. All participants were given an 80-item Intraverbal Assessment Subtest to evaluate the progression of developing increasingly complex intraverbal skills and the differences between typically developing children and children with ASD in acquiring these skills. The most notable finding revealed typically developing children and children with ASD made the same types of errors; for instance, "What shape are wheels?" A typically developing child error response was "triangles" while a child with ASD replied "cars." The incorrect responses depicted intraverbal stimulus control errors. The authors recommend teaching simple noun and verb verbal discriminations prior to WH questions to improve comprehension. Embedding motivation as an added antecedent variable is also recommended. Noting individuals, with and without disabilities, demonstrate strong intraverbal behavior regarding topics of high interest and weak intraverbal behavior for less preferable topics.

Using Skinner's analysis of verbal behavior and specifically mand and tact behavior, Lorah, Parnell, and Speight (2014) used a multiple baseline across participants design to evaluate the effects of using a handheld iPad^{TM} and the ProLoqu2Go app as a high technology digital AAC speech generating device (SGD) on acquisition of tacting two sentence frames (e.g., , "I have…" and "I see…") and discriminating between the two sentences frames for three preschool children with ASD and developmental disabilities. Dependent variables included the number of correct tact responses selected on the iPad ^{TM} depicting the stimuli picture options when tangible objects of the same stimuli were seen (during "I see…" condition) or held in the non-dominant hand (during "I have…" condition). A 5s time delay and full physical prompt were used for error correction procedures. Results indicated the iPad ^{TM} was an effective high technology/digital SGD for all three participants in acquiring tact repertoires. The study was conducted in an unused occupational therapy office and was noted as a limitation of the study. Providing instruction in more natural teaching environments was recommended (i.e., in the classroom) to promote greater generalization. A further limitation, not listed by the authors, is the interpretation of tact training. During the "I see…" and "I have…" conditions, participants were provided the verbal stimulus prompts either "What do you see?" or "What do you have?" These verbal stimulus prompts can be argued to be intraverbal prompts to evoke high technology/digital response prompts on the iPad ^{TM} device lacking point-to-point similarity. By definition, "a tact is a verbal operant under the functional control of a **nonverbal** (emphasis added) discriminative stimulus" while an "intraverbal operant occurs when a **verbal** discriminative stimulus evokes a verbal response" (Cooper et al., 2007, pp. 530-531). In this case SGD aided AAC equates to a verbal response. Despite distinctions between definitions, this study lends credence to the efficacy of incorporating digital AAC devices to promote intraverbal skills among students with complex communication needs to thereby improve comprehension skills by answering simple WH questions.

Overall, despite decade's worth of research supporting Skinner's analysis of verbal behavior, limited research investigating the promotion of intraverbal behavior and comprehension for AAC users and students with low incidence disabilities were found, specifically research involving digital SGD devices for secondary students. Much of the research in this area discuss intervention studies involving preschool and elementary age participants. Teaching students how to answer a variety of functional questions (e.g., "What do you want to eat?" or "Where do you feel hurt?") has the potential to positively impact students' daily lives and post-school outcomes among AAC users with low incidence disabilities. Research investigations need to focus on improving intraverbal behaviors among students with low incidence disabilities toward this goal.

Summary of Verbal Behavior on Promoting Comprehension

Given the importance of communication for all individuals, Skinner's analysis of verbal behavior provides a rich platform to base language acquisition skill development for students with low incidence disabilities who use aided AAC to meet their complex communication needs. Teaching mand behaviors to request or protest wants and needs and thereby reduce challenging behaviors when used as part of a FCT plan have a strong evidence-base (Dawson et al., 1998; Durand & Carr, 1985; Durand & Merges, 1998; Fee & Matson, 1992; Gardener & Cole, 1990; Kurtz et al., 2011; Mirenda, 2009; Olive et al., 2007) for students with a variety of disabilities. Tact training (Miguel et al., 2005) to name or label items observed, heard, or felt in the environment is a foundational aspect of language development and the expansion of vocabulary for all individuals. Tacting also is an important dimension in gaining joint attention between a speaker and a listener (i.e., a dog is seen in a park and a child points and says "dog"). Echoic behavior in which a listener repeats what a speaker has said verbatim is said to have point-to-point correspondence with the verbal stimulus initially heard. Mands, tacts, and echoics provide a strong language foundation for developing more complex intraverbal skills in order to answer questions, share thoughts and opinions, and generally engage in conversational exchanges with others. Recent research has shown one way digital SGDs (e.g., iPad ™) can be used to teach intraverbal skills and question answering for students with low incidence disabilities (Lorah et al., 2014). More research needs to be done to systematically combine what is known about verbal behavior and language acquisition, using EBPs to teach students with low incidence disabilities, and simultaneously addressing students' unique complex communication needs through aided print and/or digital technology AAC to improve communication, comprehension and post-school outcomes.

Instructional and Visual Supports

> Wong et al. (2014) noted visual supports met EBP criteria and are defined as "any visual display that supports the learner engaging in a desired behavior or skills independent of prompts. Examples of visual supports include pictures, written words, objects within the environment, arrangement of the environment or visual boundaries, schedules, maps, labels, organization systems, and timelines" (p. 22).

Wong et al. discuss the benefits of visual supports in reference to students with ASD yet visual supports are also effective supports for students with a range of disabilities. Given the definition, shared stories (with picture supports) and color coded graphic organizers with picture supported text can also fall under the umbrella category of instructional supports to help modify and organize abstract information for students with intellectual disability and ASD. As previously mentioned, instructional and visual supports coupled with systematic instruction have been used to effectively teach students with disabilities (Browder & Spooner, 2014; Brown, McDonnell, & Snell, 2015) a variety of functional and academic skills including literacy (Browder, Trela, & Jimenez, 2007); mathematics (Browder, Spooner, Ahlgrim-Delzell, Harris, & Wakeman, 2008; Courtade, Lingo, Karp, & Whitney, 2013; Root, Browder, Saunders, & Lo, 2017; Spooner, Root, Saunders, & Browder, 2017); science (Browder et al., 2012; Spooner, Knight, Browder, Jimenez, & DiBiase, 2011); social studies (Schenning et al., 2012; Zakas et al., 2012); and functional life skills (McKissick et al., 2013).

Shared Stories

One strategy that helps promote emerging literacy skills among all students is shared stories. Shared stories, also referred to as read-alouds, provide access to literacy activities for students with a range of disabilities and allow students to interact with the text. Teachers read aloud and often include abbreviated text passages and picture symbols that highlight salient vocabulary from adapted, grade-aligned literature to make the content easier to comprehend for students with intellectual disabilities and ASD. Shared stories met the moderate level criteria for being deemed an evidence-based practice (Hudson & Test, 2011) as a means for teaching early literacy skills for students with intellectual disabilities. A text that exemplifies the power of shared story reading of age appropriate and grade-aligned texts (K-12) for students with low incidence disabilities is titled *Literacy beyond picture books: Teaching secondary students with moderate to severe disabilities* (D. D. Smith, DeMarco, & Worley, 2009). D. D. Smith et al. (2009) thoroughly outline a replicable framework special educators can use to teach students K-12 students with low incidence disabilities using a cross curricular approach. Using a similar premise, a study conducted by Mims et al. (2012) investigated the efficacy of using a modified system of least prompts to evaluate listening comprehension skills for text-dependent students using a multiple probe across participants design. During the course of the study, researchers adapted and provided shared stories of five grade aligned biographies (e.g., *John Brown*, *Gary Paulsen*, *Harriet Tubman*, *Matthew Henson*, and *Amelia Earhart*) to four middle school students, ages 12 to 14, with intellectual disabilities and ASD. Prior to the study, three of the four participants could read some sight words while the fourth could not. Students were measured on their number of correct responses to 11 comprehension questions (e.g., eight WH questions and three story sequence questions) for each biography shared story and were provided picture paired text response cards and graphic organizers to respond. Additionally, the paper based supports can be viewed as aided print technology AAC. Results indicated a functional relation between the intervention and each of the four participants' abilities to answer unprompted comprehension questions correctly during shared stories of the adapted biographies.

Another study incorporated shared stories and digital AAC to teach early reading skills to four elementary age nonverbal students with ASD (Spooner, Ahlgrim-Delzell, Kemp-Inman, & Wood, 2014). The study used a multiple probe across participants research design and utilized an iPad2® with a GoTalk Now© aided AAC device installed paired with systematic instruction (e.g., time delay, the system of least prompts, and a task analysis) to examine the effects of shared story reading on early reading skills. Participants ranged in age from eight to twelve with IQs varying from 49-61. The researchers modified four grade aligned books to include picture symbols for target vocabulary words yet left the original text unaltered. Repeated storylines were recorded on to the iPad2® allowing students to engage interactively with the material and text buttons that were sequenced word for word enabling students to read the story verbatim. Prediction and comprehension statements were also provided. Participant performance was measured across two dependent variables: the number of independent correct responses on a 10-step task analysis and the number of correct independent responses to story specific comprehension questions. Results demonstrated a functional relation for participants independently following the task analysis steps for shared story reading yet indicated modest gains for two of the four participants for answering listening comprehension questions correctly.

Color-Coded Graphic Organizational Vocabulary Systems

Given the importance of building communicative competence for AAC users, one approach for helping AAC users gain proficiency and fluency utilizing their print or digital devices is to organize aided symbols into predictable categories according to grammar and syntax. Ebbels (2016) conducted a study using explicit instruction (e.g., modeling) a pre-test post-test design with three school age students, ages 11-14, with specific language impairments (SLI) including severe receptive and expressive language delays yet normal visual perceptual skills. Ebbels designed a visual coding organizational system, 'Shape Coding,' which combined shapes, colors, and arrows to indicate nouns, verbs, and adjectives to impact students' understanding of parts of speech to promote improvements in comprehension and answering WH questions. Ebbels used colors to delineate parts of speech, shapes to code phrases in sentence structures, and arrows to indicate verb morphology. All three students demonstrated significant progress on post-test assessment of comprehension of comparative questions and comprehension of prepositional forms. One limitation included the cumbersome and visually distracting nature of the shapes surrounding words; multiple competing stimuli which could confuse rather than clarify syntactical rules for students with SLI.

Another form of color coding words by categories involves a graphic organizational system called the Fitzgerald Key Format (1954). Parts of speech are arranged using a predictable color key (e.g., people=yellow, action words=green, objects=orange, places=purple, descriptors =blue). Fitzgerald created the color coding system to aid children who were deaf to construct semantic and syntactically correct sentences. At one point, 75% of schools for the deaf in the US were using the Fitzgerald Key Format in their schools to teach writing. This color-coding format is still used both in aided print technology and dynamic display aided digital technology AAC devices such as Tobii Dynavox®. Since words are organized by color in predictable locations, students are able to locate words to communicate much in the same way we locate letters organized on QWERTY keyboards. With repetition and frequency of use, fluency and generalization are likely outcomes.

Thistle and Wilkinson (2009) investigated the effects of color cueing (with and without color) on the speed of locating pictures of fruit on a page for 30 typically developing preschoolers. The preschoolers were more readily able to locate print-based

AAC icons on a page from an array of 12 more quickly using color-cueing, as opposed to black and white line drawings, to scan and select their choices. Promising results have been discussed (Bruno & Trembeth, 2006) using the Fitzgerald Key Format in both print and digital conditions during a week-long pre-test, post-test pilot study at a children's summer camp for students with a range of severe disabilities (e.g., 1p36 chromosome deletion, Down syndrome, schizencephaly, apraxia, athetoid cerebral palsy). Nine children ages four to fourteen with complex communication needs participated and used their own digital SGDs (e.g., DynaVox, E-Talk, Pathfinder, DynaMyte) or print AAC communication boards designed by researchers to participate. Both print and digital AAC systems used the Fitzgerald Key Format. The print and digital technology pages used a semantic-syntactic schema to organize vocabulary words. Researchers initially modeled two-word sentence structures (e.g., noun + verb) then increased complexity by moving to three-word sentences (e.g., noun + verb + noun). Results indicate participants were able to increase sentence length and complexity during the one-week intervention. Performance results were mixed between print and digital technology outcomes; some participants performed better using the aided print technology AAC in which all word options were visible on one communication board as opposed to the aided digital technology SGDs which opened new pages each time a different color category was selected. Despite promising findings, formal statistical analyses were not conducted due to the small group size. Additionally, the week-long pilot study can be viewed as a limitation of the study as confounding variables (e.g., maturation and prior experience using the Fitzgerald system) may have been factors as participants' AAC histories were not described. A paucity of research has been conducted to specifically investigate the effects of the Fitzgerald Key Format on writing and understanding parts of speech to improve comprehension skills for students with low incidence disabilities. For this reason, the proposed study aims to embed the Fitzgerald system and evaluate the comparative effects of print *vs.* digital AAC use to create simple three-word sentences and assess comprehension rates after shared story readings for high school students with low incidence disabilities.

Summary of Color Coded Organizational Vocabulary Systems

Few studies have investigated the efficacy of using color coding organizational systems (e.g., Fitzgerald Key Format, 1954) to teach grammar, syntax, and parts of speech for print or digital aided AAC users with low incidence disabilities to promote sentence creation and comprehension. Yet, a quick Internet search reveals leading dynamic digital AAC manufacturers (e.g., Tobii Dynavox) embed color coding organizational systems into the array of devices they sell. Limited research involving color coding organizational systems (Ebbels, 2007; to support students with low incidence disabilities who are AAC users to comprehend text were located; this represents a gap in the research literature. Specifically, research studies investigating the effects of print *vs.* digital instruction embedding the instructional supports of: (a) adapted shared stories with (b) color coding organizational systems, and (c) direct and systematic instruction identifying vocabulary words (e.g., tact training) and creating simple sentences to promote comprehension skills using WH questions (e.g., intraverbal communication) for students with low incidence disabilities with complex communication needs are lacking in the research literature.

Summary of Chapter Two

Communication is a vital human need for all individuals; Beukelman and Mirenda (2013) noted over 4 million people with complex communication needs rely on AAC to interact with others. Building communicative competence for AAC users with low incidence disabilities through systematic instruction using print and digital teaching strategies has a strong evidence-base across curricular domains (Browder, Trela, Courtade et al., 2010; Browder, Trela, & Jimenez, 2007; McKissick et al., 2013). Embedding principles of Skinner's verbal behavior (e.g., mands) for students with disabilities who demonstrate challenging behavior is well documented in the research literature (Durand & Carr, 1985). Proponents of applied behavior analysis recommend functional communication training to teach individuals appropriate replacement behaviors, using mands (e.g., requesting or protesting), to extinguish the occurrence of challenging behaviors. Teaching mand behavior can be viewed as a foundational communication skill to build upon to teach other, more complex, communicative behaviors (e.g., tacts, echoics, and intraverbal skills) for students with low incidence disabilities who rely on AAC. Once students have strong tact (labeling) skills for identifying visual referents vocally or through AAC, the likelihood of developing intraverbal skills, answering comprehension questions and engaging in question and answer dialogues, is improved. Visual supports, in the form of adapted shared stories (with picture supported text), color coded vocabulary organizational systems (e.g., Fitzgerald Key Format) and graphic organizers (for sentence creation using print or digital AAC), further assist students with low incidence disabilities to process abstract information and comprehend functional and academic content. The current study combined these strategies and compared the effects of print *vs.* digital instruction to determine the accuracy rates of answering comprehension questions aligned to functional community knowledge concepts (e.g., health and safety) and time on-task for high school students with low incidence disabilities who are nonverbal or minimally verbal.

CHAPTER 3: METHOD

Overview

In this study, a single-case alternating treatments design was used to compare the effects of print *vs.* digital AAC technology instruction on the accuracy of answering comprehension questions regarding functional community knowledge concepts (e.g., health, safety, and daily living) for high school students with low incidence disabilities and complex communication needs. Additionally, the current study compared participants' engagement as measured by students' percentage of time spent on-task during both print and digital instructional conditions. The sections to follow describe the participants, setting, measurement, procedures, data analysis, and potential threats to validity.

Participants

Student participants. Students were selected through teacher nomination and knowledge of their eligibility and diagnoses from their IEPs. The following inclusion criteria were used: (a) participants were identified as students with moderate to severe intellectual disabilities and/or autism (e.g., low incidence disabilities; significant cognitive disabilities with IQs below 55, as defined by the state guidelines for Exceptional Children with current IEPs; (b) participants received daily special education services within the regular educational placement; (c) participants had annual goals on their IEPs to address needs in the area of comprehension and adapted, grade-aligned instruction; (d) students were non-verbal to minimally verbal who had complex communication needs; (e) students with challenging behavioral needs as identified by parent/teacher report and/or Behavior Intervention Plans (BIPs were not required) which addressed off-task, challenging behavior were preferred; (f) participants had normal hearing and vision; and (g) participants returned both signed parental and student consent forms. Four high school students (17-19 years of age) with moderate to severe intellectual disabilities and/or autism who receive their primary instruction within a self-contained classroom participated in the study; the classroom was comprised of only four students. Two males and two females (ages 17-19) participated in the study. See Table 1 for demographics.

Table 1

Participant Demographics

Student	Age	Gender	Race	Grade	IQ	Disability	Primary Mode of Communication
Chandler	17	Male	Hispanic	10	***41	Autism	Verbal with frequent echolalia of rote phrases. "Multi-sensory approach" – Visuals, picture symbols, and concrete objects to reinforce concepts.
Joey	17	Male	Hispanic	10	*42	Autism	Non-verbal. Uses low technology aided picture symbols, minimal unaided ASL signs, gestures (i.e., pointing), and yes/no to communicate.
Rachel	19	Female	African American	12	*44	Autism	Limited verbal ("soft, unintelligible verbal speech"). Primarily uses

Phoebe	18	Female	Asian	12	**50	Autism	eye contact, gestures, and pointing to communicate. Non-verbal. Uses low technology aided picture symbols, gestures (i.e., pointing), and circling answers to communicate.

Note. IQ scores obtained from: *Stanford Benet Intelligence Scales, 5th Ed., **Loiter International Performance Scale - Revised, ***Universal Nonverbal Intelligence Test (UNIT; Bracken & McCallum, 1998).

Setting

The study took place within a rural high school within the Southeastern United States which includes students from diverse backgrounds and socioeconomic statuses. The school population was 1,655 and served 129 students with active IEPs. The free and reduced lunch percentage rate was 43.4% for the county in which the school is located. The study occurred within the participants' self-contained classroom setting during their regularly scheduled social studies and language arts time periods. The study was conducted during small group lessons with all four students. The experimenter/interventionist provided the instruction.

Experimenter, Interventionist, and Primary Data Collector

The experimenter, interventionist, and primary data collector for the study was a doctoral student with 16-years of teaching experience in urban and rural elementary schools, eight years specifically working with students with low incidence disabilities. The experimenter was certified in Special Education – Severe Disabilities and the Adapted Curriculum (K-12) and is National Board Certified in Special Education – as an

Exceptional Needs Specialist (birth-22). The experimenter was the primary interventionist teaching the print and digital technology lessons, as well as the primary data collector for recording the students' on-task behaviors. Comprehension data was recorded automatically within the Boardmaker® Professional Online program and stored securely online and within a Microsoft Excel file to graph the data collected.

Materials

Functional community knowledge stories were created and aligned directly to the North Carolina Extended Standards for high school students with disabilities in the areas of Health, Safety, and Independent Living (https://ec.ncpublicschools.gov/disability-resources/significant-cognitive-disabilities/nc-extended-content-standards/copy_of_HealthSafetyIndependentLivingProposed0817.pdf) to promote positive post-school outcomes. Materials included: (a) 20 non-fiction health and safety themed, teacher made adapted stories (e.g., functional community knowledge stories about doctors, police, and fire fighters) ranging from 420-820L according to the Common Core State Standards Lexile® recommendations; (b) the 20 stories were created using print and digital technology formats with color-coded FKF adapted symbol supported text highlighting eight salient vocabulary words per story; (c) digital technology stories were displayed and taught using a Touch Accessible Platform Interactive Technology device (TAPit®, model number TMC-4-US: had a 42 inch multi-touch screen with unintentional touch recognition with military-grade shatter-resistant safety glass. The base height was 7.5 inches from the ground and extended up to 54 inches off the ground and had an adjustable tilt from 0 – 90 degrees. The unit was also tip-resistant. See Appendix L.) during small group instructional lessons; (d) a designated desktop computer was used to provide three WH question (who, what, where) check-out quizzes for each participant after each print and digital technology session; (e) 20 check-out quizzes were created by the experimenter using Boardmaker© Professional and included an array of three response options (i.e., one correct answer and two distractors); (f) behavioral data collection sheets were used for each participant to record the percentage of on-task behaviors observed during print and digital technology instructional conditions (see Appendix D) using a whole interval recording system; and (g) color-coded FKF (i.e., yellow=people, green=action/verb, orange=what, purple=where, blue=descriptors; see Appendix B) writing template graphic organizers in both print and digital technology formats for participants to create two, three-word sentences (e.g., doctors [yellow/who] prescribe [green/verb] medicine [orange/what]; nurses [yellow/who], work [green/verb], hospital [purple/where]) per story using their vocabulary sheets prior to conducting their individual check-out quizzes to promote comprehension were used.

Data collection

Dependent variables. The primary dependent variable was the accuracy of answering WH (i.e., who, what, where) comprehension questions after being taught a functional community knowledge adapted story in either a print or digital format. Each participant took a three question WH check-out quiz on a dedicated desktop computer. The comprehension quizzes consisted of three questions related to each adapted story. The Boardmaker® Online Professional program had an interactive quiz template with a choice of three array (one correct answer and two distractors). The program shuffled the order of each question and the location of the possible responses so participants could not memorize or predict when or where the choices appeared. Participant responses were recorded within the program. Electronic response feedback was provided to the participant in terms of praise and error correction for correct and incorrect responses (e.g., sound, animation, and grey scaling of incorrect responses).

The second dependent variable was the percentage of participants' on-task behaviors during both print and digital technology instructional sessions. Instructional sessions lasted for a minimum of 12 minutes. The experimenter recorded a "X" if the objective and measurable on-task behavior was observed at any point during the 20s instructional interval. On-task behavior was defined as: looking at work materials; looking at the instructor; manipulating the work materials (i.e., pointing to images, circling vocabulary words; moving print or digital images to write sentences); remaining in the designated work space (i.e., sitting during print instruction and sitting while instructor or peer was interacting with the TAPit® or standing during individual turn with the TAPit®. Note: for idiosyncratic stereotypic behavior common among individuals with ASD and unique to the individual participants (i.e., squinting to the side or at fingernails), these behaviors will not be counted with a "0" for off-task, unless they persist continuously for more than 5s (i.e., for looking away). Other stereotypic behavior (i.e., rocking and/or flailing arms) were still considered on-task if the participant was facing forward toward the instructor or the work materials. Each instructional session was video recorded to capture all four participants' observable behaviors to ensure reliability and validity of the data recorded was accurate.

Independent variable package. The experimenter created 20 non-fiction adapted stories into print-based technology (e.g., Boardmaker® picture symbol supported text) and digital technology (e.g., Boardmaker® Professional Online picture symbol supported text with sound and touch sensitivity) adapted stories (see Appendix A) with the FKF color-coding of eight pertinent core vocabulary per story highlighted regarding functional community knowledge concepts (i.e., dental and physical health; who to call in the event of a fire) to instruct participants in order to promote comprehension skills. The percentage of on-task behaviors during print and digital technology lessons was also collected. The independent variable package (color-coded, picture supported, adapted stories, presented via aided print and digital technology, using the TAPit®) had not been taught to the participants in this format previously. Additionally, this was the first time these students were systematically taught how to use the color-coded FKF system to categorize vocabulary words by parts of speech in order to create three-word sentences to promote comprehension of abstract information. During print and digital technology conditions, participants were given two color-coded graphic organizers aligned to the FKF to create three-word sentences to summarize main points of each adapted story (i.e., doctors=yellow, prescribe=green, medicine=orange). The experimenter used explicit instruction and a model-lead-test format to teach participants how to use the three-word sentence graphic organizers. This embedded tact training used aided print and digital technology AAC (e.g., show me/point to "doctor" on your vocabulary page) to promote receptive identification skills (Carbone et al., 2006) needed to build reciprocal intraverbal skills necessary for answering comprehension questions and to assess student learning.

Interobserver Agreement

Explicit determinations of definitions regarding "answering questions" and what constituted "on-task" were operationally defined. For instance, touching a single symbol on a page given a choice of three counted as answering if the participant was minimally verbal and the student pointed, but the direction of the point was unclear to the interventionist, the prompt, “show me again,” was given. Similarly, if a student touched the digital technology and the touch was too light to activate the response, a prompt was given to “try again” or “touch it until you hear a click.” On-task behavior included observable behavior such as visually attending to the instructional material and/or pointing to or touching a vocabulary icon on a print technology page or digital technology using the TAPit®. Explicit definitions were written to include examples and non-examples of the defined behavior. Inter-observer agreement (IOA) was scored by a second observer (a special education teacher with five years of teaching experience and a M.Ed. degree in the Adapted Curriculum) for 30% of the intervention sessions. IOA was measured by viewing the Boardmaker© Professional Online data automatically recorded for the first independent variable regarding accuracy of answering comprehension questions and the interval-by-interval comparison method for on-task behavior per participant (second dependent variable, see Appendix E) and was calculated by the number of agreements divided by the number of agreements plus disagreements and multiplied by 100.

Experimental design

A single-case, alternating treatment design (Barlow & Hayes, 1979; Gast & Ledford, 2014; Ulman & Sulzer-Azaroff, 1975) was used randomly changing from print to digital technology instruction to compare the experimental effects (i.e., accuracy and time on-task) between conditions. According to Cooper et al. (2007) “each successive data point provides a basis for prediction, verification, and replication of that treatment… to demonstrate experimental control & increase confidence in a functional relation” (p.

189). The alternating treatment design does not require baseline steady state responding, the rapid change between alternating treatments (i.e., print based technology and digital technology) were measured independently (i.e., accuracy in answering comprehension questions and the number of on-task behaviors). Further, the design is based upon the behavioral principle of stimulus discrimination (p. 188), in this case, print or digital instruction, allowing for a direct comparison of the two treatments. In an alternating treatment design, each data point reflects prediction of future performance, potential verification of similar responding given each treatment condition, and the possibility of consistent replication effects during each treatment condition. Further, external validity of the intervention package was strengthened across conditions for each participant and were further strengthened through replication of effects across participants.

To control for internal threats to validity and to limit practice effects, participants were taught using print or digital technology instruction in a randomized order. The sequence for determining which condition was used for instruction was randomized by having four print or digital technology adapted story titles (two print and two digital) written on a card and assigned a number one through four, student participants rolled dice to randomize and determine which adapted story was taught next. A decision rule was in place stipulating that no more than two stories in one condition could be taught consecutively (i.e., print=P, digital=D: PD, DP, DD, PP). Additionally, participants were randomized in the order in which they were selected to take the check-out comprehension quizzes at the desktop computer following instruction using the same dice rolling procedure. Participant names were assigned a different number one through four for each day of the study; the numbers were written on clip board next to the four adapted story titles and participants took turns rolling the die to determine who went first, next, and last for each instructional condition.

Visual analysis of graphic data was used to determine the level, trend, stability or variability in the data, immediacy of effect of the intervention, consistency of data across similar phases, and potential overlap of data across treatment conditions. Visual analysis of graphic data is the most common strategy used in single-case research designs to analyze data patterns (Gast & Ledford, 2014; Johnston & Pennypacker, 1993) among individuals or small groups. Data reflecting participants' comprehension scores was collected and displayed cumulatively to show a clear data path in comparison to ultimate (perfect) performance. A steeper slope represented a higher response rate. Cumulative recording allows for a visual comparison between one slope and another (Cooper et al., 2007) in relation to optimal performance. Cumulative recording allowed for visual analysis of growth over time. Data among the four participants are depicted in relation to the aim line of optimal performance if every question was answered correctly across every session. Event recording using a non-cumulative measure, such as the number of correct comprehension questions answered per session, could have also been used. A cumulative measure was selected because of the small number (three) of comprehension questions per check-out quiz across sessions; cumulative recording allowed minute individual nuances to be observed among participants in the visual data more accurately as compared to optimal performance to indicate progress made over time.

Similarly, the data for percentage of on-task behavior was recorded and visually inspected on separate graphs to determine the difference between print and digital technology conditions on the percentage of operationally defined on-task behaviors. On-task behavior was recorded using a whole interval sampling procedure. Occurrences of target on-task behavior were recorded at the end of brief intervals, 20s, during print and digital technology instructional sessions. Whole interval recording (Cooper, 1981; Eaton, 1978; Hall, Hawkins, & Axelrod, 1975) was a good measure to use since the behaviors across the four participants were recorded continuously during instruction. Observation periods were divided into 20s equal intervals for a total of 36 intervals per 12 minute instructional sessions. At the end of each instructional session (print and digital), the number of "on-task" behavioral observations were counted and divided by the total number of observation intervals (36). Data was reported as a percentage of the observation intervals for each participant during each condition. Every print and digital technology session was video recorded using a GoPro HERO™. Whole interval recording data was scored after instruction by viewing the recordings and pausing at each 20s interval to mark whether participants were on-task during each interval or not.

General Procedures

Print and digital technology conditions were conducted the same way each time. A brief adapted story was read to students either in print or digital technology format (see Appendix A for an example) based upon the results of the randomization dice roll. Student participants had access to the print technology color-coded vocabulary pages during direct instruction with the interventionist. The experimenter/interventionist created: (a) color-coded FKF print technology vocabulary pages for each adapted story with eight high priority core words aligned to the story; (b) the same print color-coded vocabulary pages were translated to digital technology status (i.e., sound, movable buttons, electronic corrective feedback); and (c) each participant individually took a check-out comprehension quiz (see Appendix C) after the print and digital technology lessons, quizzes were made using Boardmaker© Online Professional quiz template software with a choice of three format. The experimenter modeled how to utilize the color-coded FKF using a model-lead-test procedure (i.e., I do, we do, you do) during instruction to identify pertinent vocabulary (e.g., tact training to label words heard in the story) and to create two, three words sentences using the FKF within a graphic organizer to help promote comprehension of the text. The experimenter showed the classroom teacher, who collected IOA data, how to score student data using the print and digital technology systems and how to recognize the topography and operational definitions of on-task behavior in objective rather than subjective terms.

Print procedures. Each participant received a paper-based FKF color-coded vocabulary sheet to identify the eight key vocabulary from the adapted stories (see Appendix B) and how to use the picture supported vocabulary words during print technology lessons using explicit instruction (Archer & Hughes, 2011) to create simple three-word sentences using a model/lead/test strategy. The paper-based FKF color-coded graphic organizer was provided for participants to “write” two, three-word sentences using the vocabulary page provided (i.e., yellow=person, green=action, orange=what; doctor prescribes medicine). Archer and Hughes recommended scaffolding instruction by guiding students through the learning process by breaking skills into small steps which are demonstrated to model how to perform the skill. Students were given multiple opportunities to perform and immediate corrective feedback to minimize responses errors.

Digital procedures. Similarly, the same supports, color-coded vocabulary and three-word sentence graphic organizer using FKF were in place in digital technology format during the digital condition sessions and were interactive (vocabulary word "buttons" were movable and "spoke" the button labels when touched). Participants were able to drag and drop the color-coded vocabulary words into the graphic organizer to write their three-word sentence using the digital technology vocabulary template provided. Students were presented the functional community knowledge concepts using color coded (Fitzgerald Key Format) vocabulary pages identifying the salient aspects of the lesson (i.e., main people/characters, actions, events) using Boardmaker® picture symbols.

Procedural fidelity. The experimenter's print and digital lessons were assessed across 30% of the sessions for all participants. Billingsley, White, and Munson (1980) noted the importance of correctly presenting the steps involved in delivering the independent variable package across conditions to ensure instruction is consistent. All lessons were video recorded to ensure reliability and accuracy of data collection. A second observer assessed procedural fidelity using an instructional fidelity checklist. Procedural fidelity was calculated by dividing the number of steps correct by the total number of steps and multiplying by 100 to yield a percentage.

Social validity. Wolf (1978) advocated for researchers to consider three levels of social validity for participants: goals, procedures, and effects as a means to collect feedback regarding the social significance of the intervention similar to a "customer satisfaction" survey. Teaching staff were provided an opinion questionnaire to evaluate the efficacy of using print and digital technology instruction including the color-coded

FKF vocabulary system to teach/scaffold parts of speech to promote comprehension for students with low incidence disabilities (see Appendix H). Similarly, student participants were provided two familiar picture symbols to choose from (yes and no) to indicate their preferences between print and digital technology instructional formats and under which condition they felt they learned best (see Appendix I).

CHAPTER 4: RESULTS

Interobserver Reliability

A second observer, a special education classroom teacher with five years of teaching experience and a master's degree in Special Education in Adapted Curriculum who specializes in working with students with ASD, evaluated interobserver agreement (IOA) data across all four participants during both print and digital technology treatment conditions including data collection of the first two dependent variables. The first dependent variable consisted of a check-out quiz at a designated desktop computer which assessed participants' accuracy in responding to three WH comprehension questions (who, what, where) regarding the content of the functional community knowledge adapted stories that were taught. IOA data were collected for 30% of print and digital technology instructional sessions (three for print technology and three for digital technology for a total of six out of the 20 sessions). IOA during print and digital technology instruction was a mean of 100%.

For whole interval recording of the second dependent variable for determining the percentage of time on-task for each participant during 12 minute lessons, print and digital technology instruction, intervals were divided into 20s segments equaling 36 intervals per instructional session. The total number of intervals recorded as on-task, as opposed to off-task, were divided by 36 to provide a percentage of time on-task. The second observer also reviewed the video recordings of 30% of the print and digital technology intervention sessions (three print and three digital) and scored IOA data for the second dependent variable for the percentage of time spent on-task across the four participants during the small group instructional sessions. Interobserver agreement ranged from 85%

to 100% (overall *M*=92.5%). IOA was calculated by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100. Agreements and disagreements for scoring on-task behavior were discussed. After initial discrepancies across observers for collecting IOA data, the interventionist/experimenter re-defined on-task behavior to include and allow for five continuous seconds within each 20s interval of idiosyncratic stereotypic behavior unique to each participant if the participant was forward facing toward the instructor and/or instructional materials. Stereotypic behavior (squinting to the side) that persisted for more than five seconds within an interval was recorded as off-task. The interventionist/experimenter re-trained the second observer while simultaneously reviewing the intervention videos to ensure consistency and reliability of the IOA data for measuring on-task behavior under the expanded definition.

Procedural Fidelity

The second observer additionally recorded the procedural fidelity data. Procedural fidelity data were collected for 30% of the print and digital technology intervention sessions (three during print technology and three during digital technology). The data resulted in a mean of 100% fidelity across treatment conditions.

Results for Research Question 1: What are the comparative effects of using print *vs*. digital technology to teach functional community knowledge content on the accuracy of WH (who, what, where) comprehension questions for students with low incidence disabilities?

Figure 1 displays the pre-test and post-test comprehension scores for all four participants and the total number of questions answered correctly. Twenty adapted, functional community knowledge tests based on health, safety, and independent living concepts (10 print and 10 digital) consisted of three WH questions each for a total of 60 questions. The Figure 1 represents the cumulative number of pre-test and post-test comprehension questions answered correctly by participant. Participants' pre-test scores ranged from 19-31 correct out of 60, with an overall average of 25.5% correct, prior to intervention. Participants post-test scores ranged from 34-55 correct out of 60, with an average of 42% correct, after intervention. Figure 1 shows the overall average increase in comprehension scores of 16% across all four participants and indicates the effectiveness of the print and digital technology intervention package.

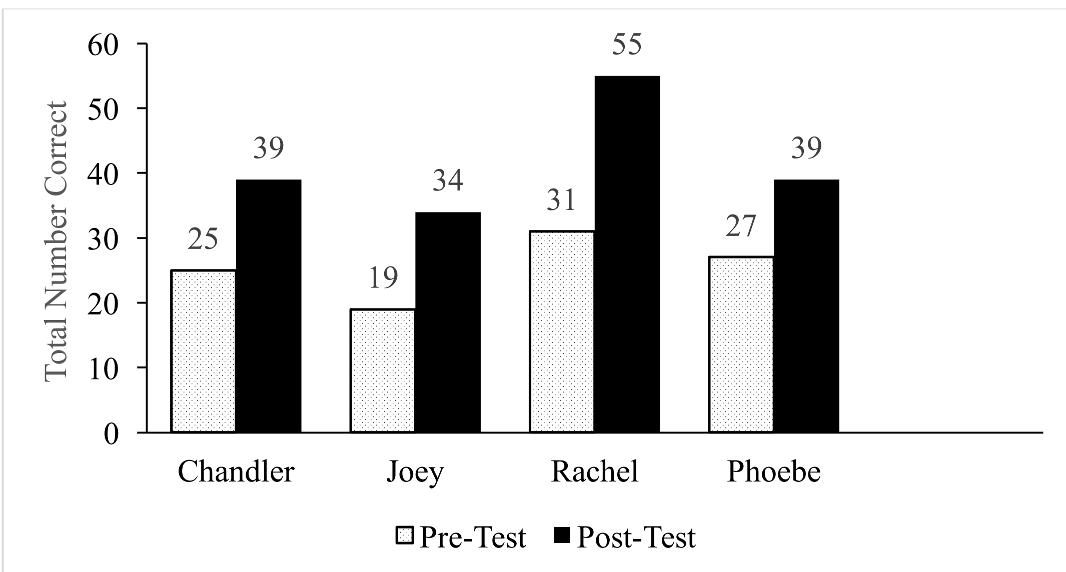

Figure 1. Cumulative pre-test and post-test comprehension scores across participants.

Table 2 illustrates the comparison of each participants' pre-test and post-test scores. All four participants demonstrated progress during print technology instruction relative to their pre-test comprehension scores. Three out of four participants revealed progress on comprehension accuracy after receiving digital technology instruction in relation to their pre-test scores.

Table 2

Print vs. Digital Technology Progress Compared to Pre-Test Comprehension Accuracy

	Pre-Test	Print Technology % of Cumulative Correct	Digital Technology % of Cumulative Correct
Chandler	25/60 = 42%	57% = ↑15%	63% = ↑21%
Joey	19/60 = 32%	47% = ↑15%	30% = ↓2%
Rachel	31/60 = 52%	93% = ↑41%	100% = ↑48%
Phoebe	27/60 = 45%	70% = ↑25%	73% = ↑28%

Note: The 2% “loss” for Joey during digital instruction is not an actual loss as each intervention condition was measured separately and cumulatively; it is displayed to demonstrate growth across conditions relative to the pre-test scores.

Figures 2 through 5 depict the individual cumulative recording data per participant during print and digital technology small group instruction. Results varied across participants. One participant demonstrated marginally higher performance accuracy answering WH comprehension questions during digital technology instruction; the second participant revealed higher accuracy during print technology instruction; the third participant displayed virtually no difference in answering WH comprehension questions across conditions; and the fourth participant showed higher accuracy initially during print technology instruction then leveled equally with digital technology instruction as the study progressed.

Chandler. Figure 2 shows Chandler’s cumulative recording data. Chandler’s print and digital technology comprehension scores were nearly equal through session 9.

During sessions 10-20, Chandler's comprehension scores showed a slight increasing trend in favor of digital technology instruction. The optimal number correct in both conditions was 30 (10 adapted stories in each treatment x 3 questions each = 30 questions total). For Chandler, the difference between conditions was 16 cumulative correct for print technology instruction and 19 cumulative correct for digital technology WH questions. Results from the graph display a higher slope in favor of the digital technology instructional intervention on comprehension.

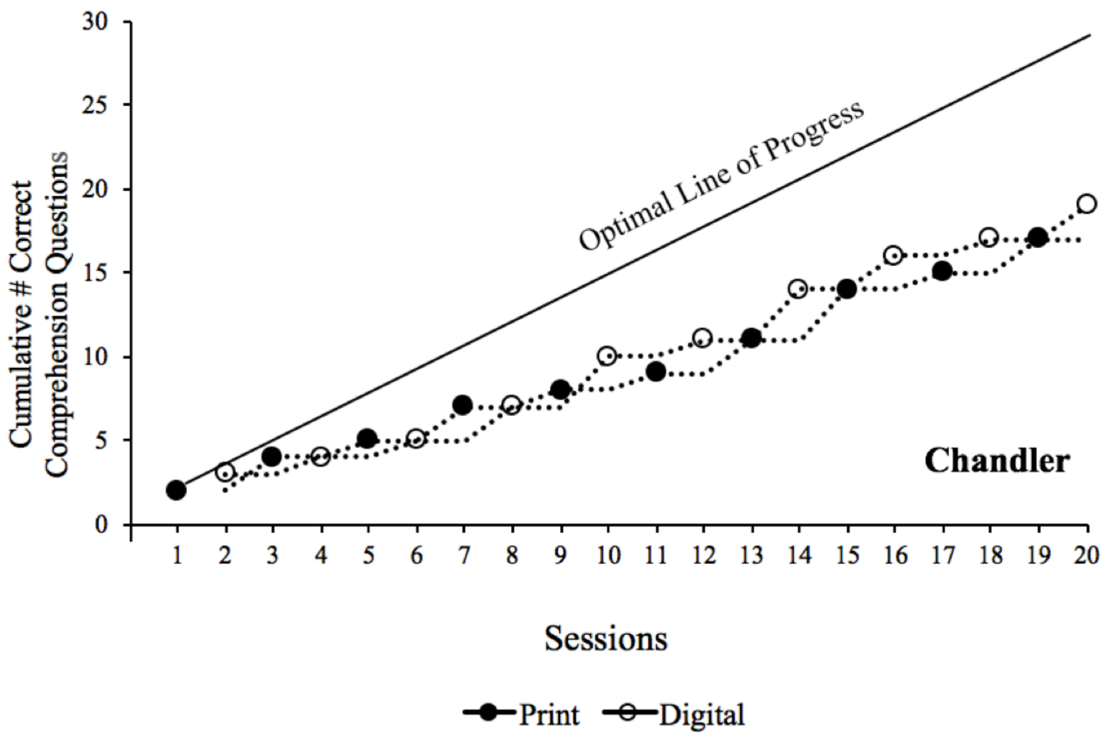

Figure 2. Chandler's Print *vs*. Digital Cumulative Number Correct on Comprehension.

Joey. Figure 3 shows Joey's cumulative recording data. Joey's print and digital technology comprehension scores illustrated a slow rate of progress under both treatment conditions initially. Joey's cumulative number correct during print technology instruction began to out pace his digital technology performance until sessions 10-11 in which the cumulative scores intersected with six cumulative correct each. Thereafter, a clear separation in the data path was visible demonstrating print technology instruction as being superior to digital technology instruction for Joey. Joey's comprehension scores showed a slight increasing trend in favor of print technology instruction. For Joey, the difference between conditions was 14 cumulative correct for print technology instruction and 10 cumulative correct for digital technology WH questions. Results from the graph displayed a higher slope in favor of the print technology instructional intervention on comprehension.

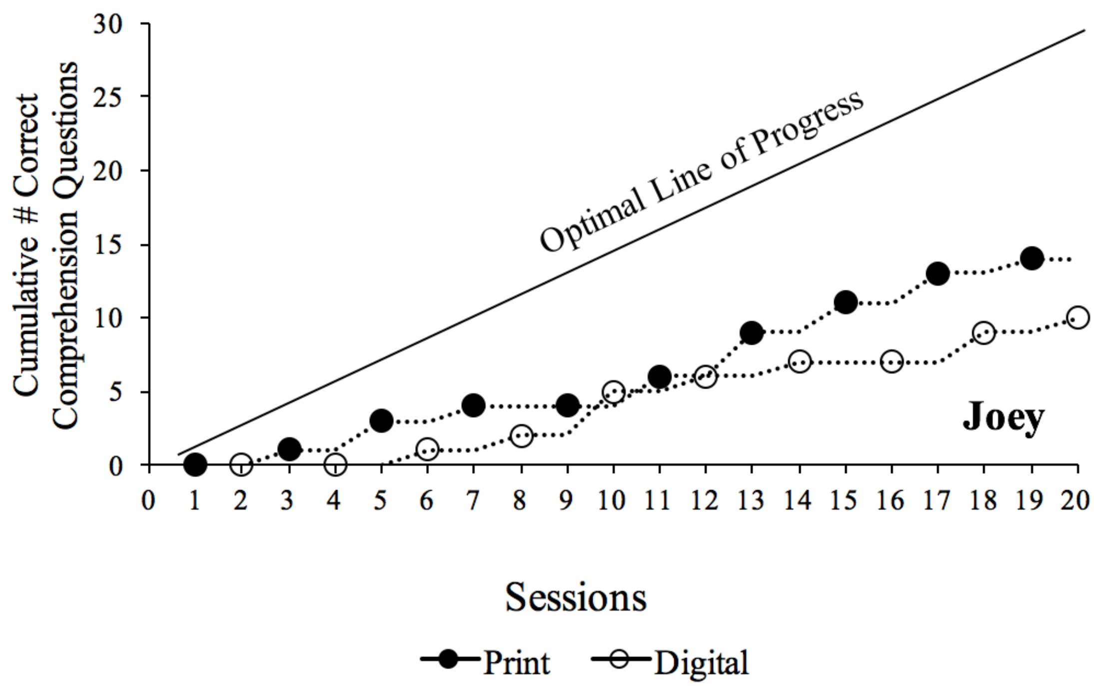

Figure 3. Joey's Print *vs.* Digital Cumulative Number Correct on Comprehension.

Rachel. Figure 4 illustrates Rachel's cumulative recording data. Rachel's cumulative recording data for comprehension during print and digital technology instruction show virtually no difference in effectiveness. Rachel scored 28 out of 30 comprehension questions correct during print technology instruction and a perfect score of 30 out of 30 correct during digital technology instruction which matched the optimal line of progress. When viewed in relation to the pre-test and post-test data graph in Figure 1, Rachel answered 52% of the comprehension questions correctly prior to intervention and immediately demonstrated mastery progress across both treatment conditions, print and digital technology, and maintained mastery along the optimal line of progress throughout the duration of the intervention sessions.

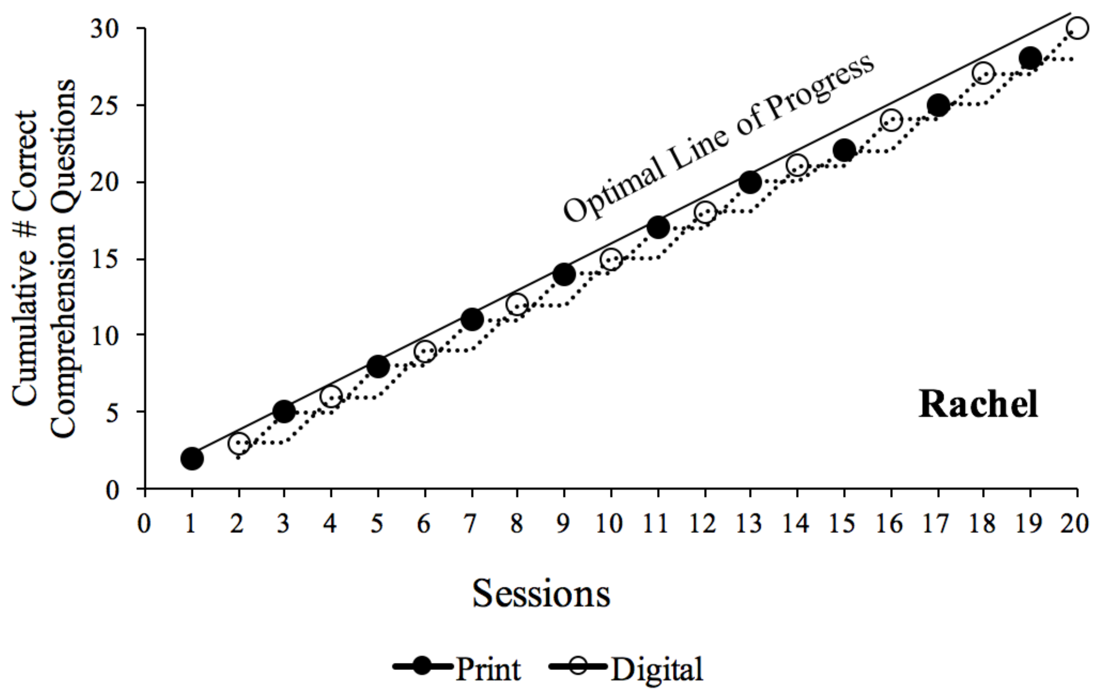

Figure 4. Rachel's Print *vs*. Digital Cumulative Number Correct on Comprehension.

Phoebe. Figure 5 shows Phoebe's cumulative recording data. Phoebe's cumulative number correct on comprehension initially indicate superior effectiveness for print technology instruction in relation to the optimal line of progress for sessions 1-11 while digital technology instruction numbers lagged behind. Then, between sessions 13 and 14, Phoebe's print and digital technology cumulative recording data intersected and maintained no difference for the remainder of the print and digital technology instructional sessions.

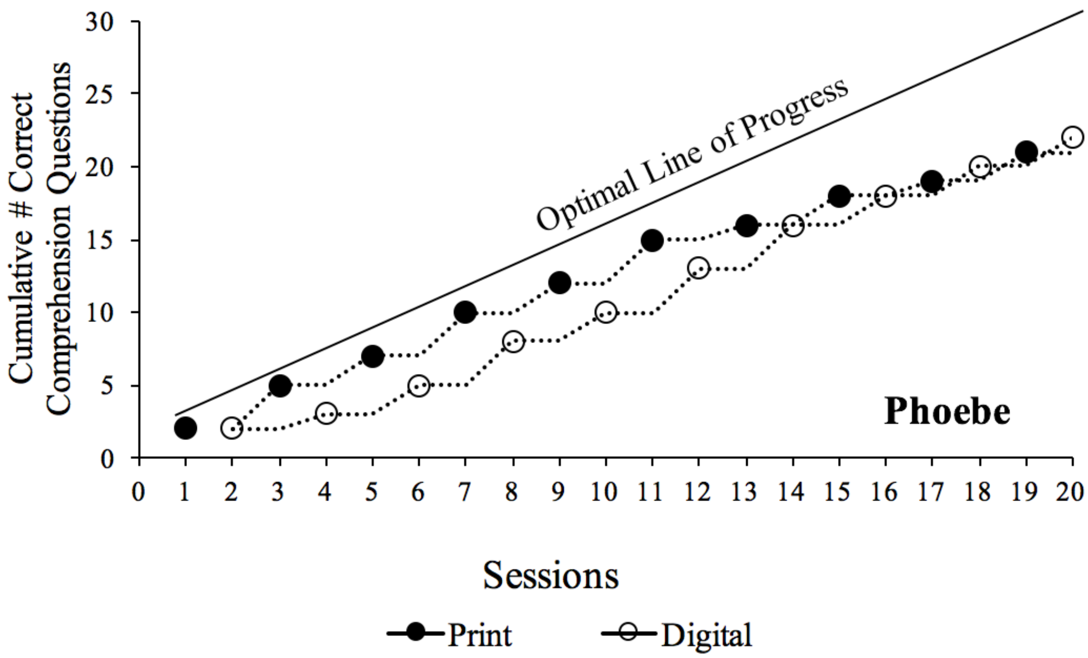

Figure 5. Phoebe's Print *vs.* Digital Cumulative Number Correct on Comprehension.

Results for Question 2: What are the comparative effects of using print *vs.* digital technology instruction on the percentage of on-task behavior among students with low incidence disabilities?

All four participants demonstrated higher percentages of on-task behavior during print technology instructional sessions as opposed to digital technology. For students with low incidence disabilities including ASD and complex communication needs, the following percentages of time on-task were higher across print as compared to digital technology treatment conditions and are therefore, worthy of mention.

Chandler. Chandler's percentage of time on-task was notably higher during print technology instruction throughout the study. During print technology instruction, Chandler's time on-task ranged from 40-70%, with a mean average of 55% for on-task behavior. During digital technology instruction, Chandler's time on-task ranged between 17-49%, with a mean average of 30% for on-task behavior. Higher rates of stereotypic behavior (i.e., arm flailing and rocking) were evident across both treatment conditions during video analysis, however, during print technology treatment conditions, Chandler had continual access to tangible print materials to manipulate and thus, stereotypic behaviors mentioned were minimized in comparison to the latter digital technology treatment conditions.

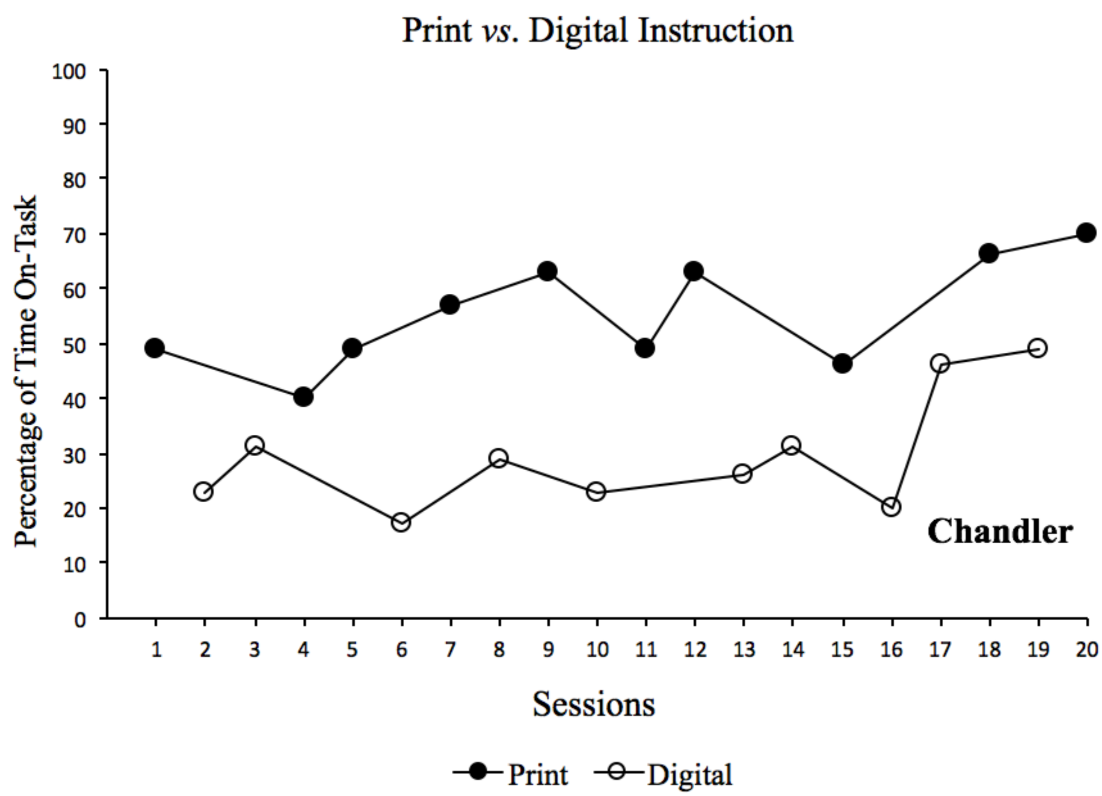

Figure 6. Chandler's Percentage of Time On-Task during Print *vs*. Digital Instruction.

Joey. Joey's percentage of time on-task was markedly higher during the print technology treatment conditions as compared to the digital technology treatment conditions. During print technology instruction, Joey's time on-task ranged from 54-97%, with a mean average of 77% for on-task behavior. During digital technology instruction, Joey's time on-task ranged between 29-66%, with a mean average of 44% for on-task behavior. Similarly, during video analysis of the alternating treatment conditions, Joey demonstrated more intervals on-task (tacting, circling, and pointing to print materials) likely due to the increased opportunities to perform having had continual access to the instructional materials as opposed to the digital treatment technology conditions when opportunities to perform were limited to when individual participants volunteered or were called up to interact using the large TAPit® digital technology computer.

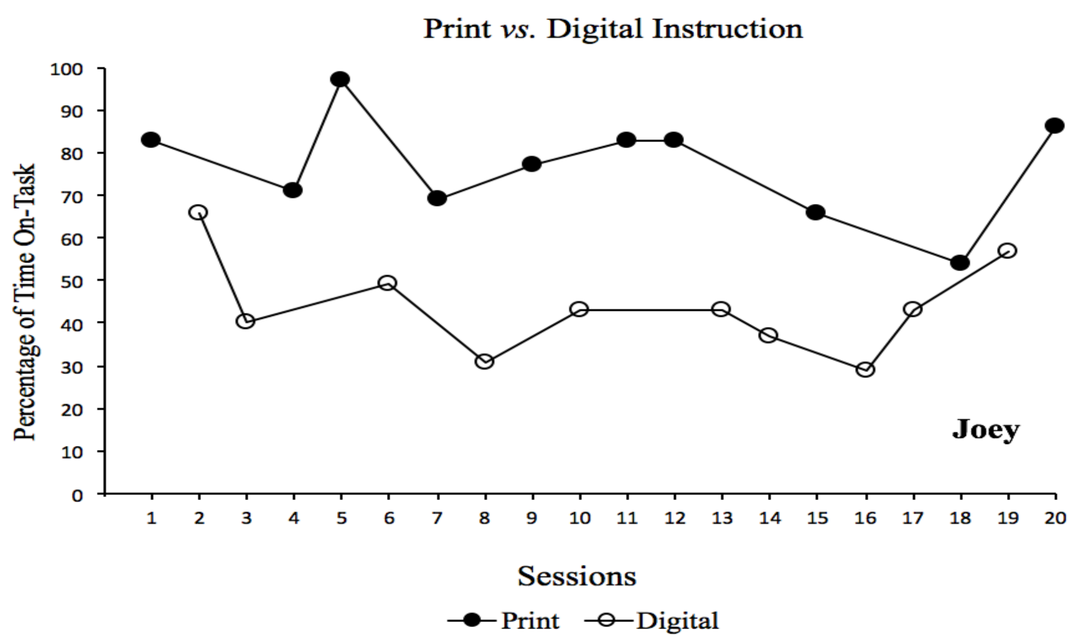

Figure 7. Joey's Percentage of Time On-Task during Print *vs*. Digital Instruction.

Rachel. Overall, Rachel engaged in a higher percentage of on-task behavior during print technology instruction. During sessions 6-11, Rachel's percentage of time on-task was nearly equivalent across treatment conditions. During print technology instruction, Rachel's time on-task ranged from 31-86%, with a mean average of 66% for on-task behavior. During digital technology instruction, Rachel's time on-task ranged between 29-51%, with a mean average of 41% for on-task behavior.

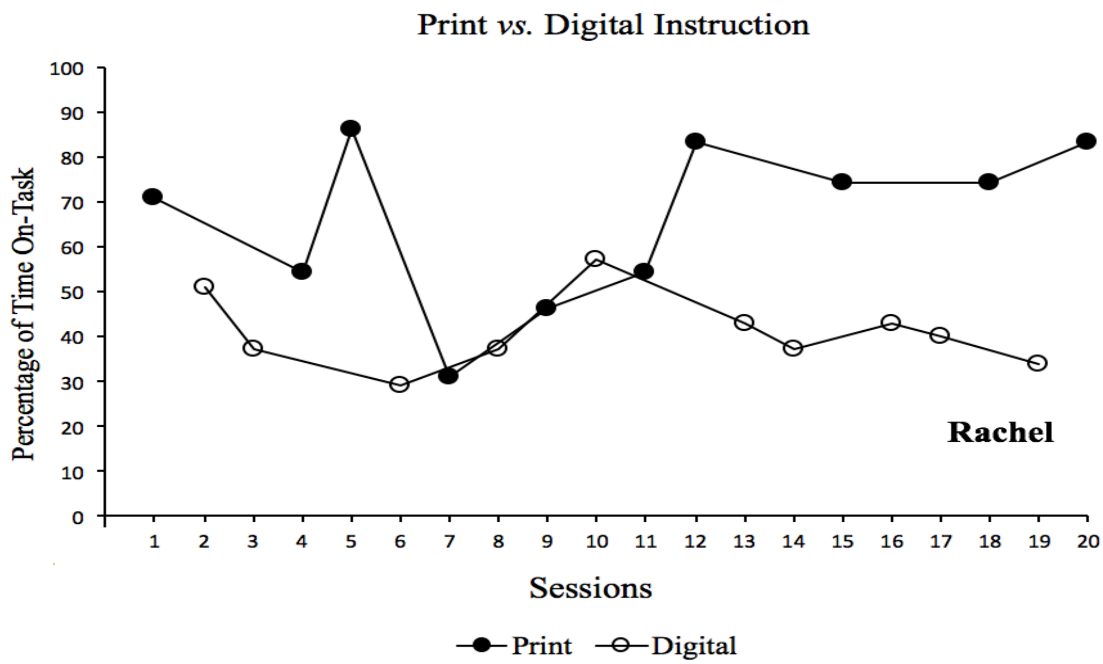

Figure 8. Rachel's Percentage of Time On-Task during Print *vs*. Digital Instruction.

Phoebe. Phoebe demonstrated consistent idiosyncratic stereotypic behaviors (i.e., laughing and squinting out of one eye at her fingernails) across treatment conditions. Phoebe displayed higher percentages of time on-task during print technology sessions as compared to digital technology instructional sessions. During print technology instruction, Phoebe's time on-task was variable and ranged from 49-92%, with a mean average of 65% for on-task behavior. During digital technology instruction, Phoebe's time on-task ranged between 20-46%, with a mean average of 40% for on-task behavior.

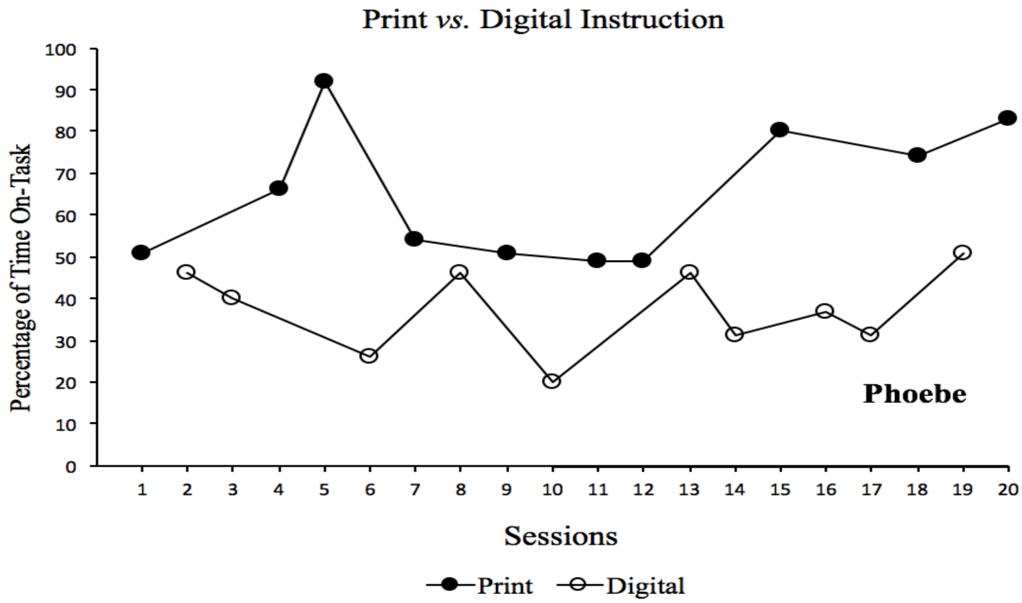

Figure 9. Phoebe's Percentage of Time On-Task during Print *vs*. Digital Instruction.

Results for Question 3: What are the opinions of teaching staff regarding the use of print and digital technology instruction to teach students with low incidence disabilities? Table 3 represents the social validity responses to an open-ended opinion questionnaire (see Appendix H) of the primary special education classroom teacher and the teaching assistant who both work full-time in the classroom where the research intervention took place.

Table 3

Social Validity: Teaching staff opinions

Question	Teaching Staff	Response
What are your opinions about using the large, interactive computer device (i.e., TAPit®) to teach your students?	Special Education Teacher	It appeared that the use of the large interactive computer device increases student engagement. Students enjoyed using the device to

		complete their instruction.
	Teaching Assistant	The students were engaged and really seemed to like the device.
What are your opinions about using the Fitzgerald Key Format to teach your students to create basic (three word: subject/verb/subject) sentences using print or digital technology?	Special Education Teacher	Using the system increased students' understanding of words and sentences. I have never seen or used this system but I would like to implement it through all subject areas.
	Teaching Assistant	It is a great tool to teach students how to put sentences together.
Do you feel the color coded Fitzgerald Key Format helped your students comprehend the shared story elements better? Why or why not?	Special Education Teacher	Yes, because students were able to visually associate vocabulary words with parts of speech. These skills can be used across all subject areas.
	Teaching Assistant	When told to select a certain color, they were able to create their own sentences using the color codes.
Which format, print or digital technology, do you feel was more effective for teaching your students?	Special Education Teacher	I feel print was more effective because students had materials in close proximity and were not required to look at materials (on the large computer

		screen) further away from them.
	Teaching Assistant	Print is the better way because they are able to manipulate it from their seats; hands on with print is better.
Do you feel as though one format, print or digital technology, was more motivating and engaging for your students? If so, which one?	Special Education Teacher	Digital was more motivating for the students.
	Teaching Assistant	Watching the process, I felt the kids liked the print better. They have a whiteboard, so they already work on an interactive board bigger than the TAPit®.

Results for Question 4: How do students with low incidence disabilities rate the use of print and digital technology instruction? Table 4 displays the results of the four student participants' responses to the yes/no social validity questionnaire (see Appendix I). The participants unanimously indicated their preferences for using the Fitzgerald Key Format for creating sentences at school, home, and after school (in the community). The majority, three out of four, indicated their preferences for using the large, interactive whiteboard to learn.

Table 4

Social Validity: Participants' Responses

Question	Yes	No
Did you like using the color coded vocabulary words to write sentences?	4	0
Did you like using the big computer to learn and to write sentences?	3	1
Would you like your teacher to use the big computer more during class to teach?	3	1
Were the big computer lessons fun?	3	1
Would you like to use the colored vocabulary words to write sentences at home?	4	0
Would you like to use the colored vocabulary words to write sentences after school?	4	0

CHAPTER 5: DISCUSSION

The purpose of this study was to examine the comparative effects of print *vs.* digital technology instruction on participants' cumulative accuracy of answering WH (who, what, where) functional community knowledge comprehension questions and to measure the percentage of participants' on-task behavior during print and digital technology instructional sessions with four high school aged students with low incidence disabilities. Using a single-case research, alternating treatments design (Barlow & Hayes, 1979; Cooper et al., 2007; Ulman & Sulzer-Azaroff, 1975), students received instruction using a model-lead-test instructional procedure with color coded vocabulary words, graphic organizers, and adapted stories following the FKF under both print and digital technology instructional sessions. Participants were explicitly taught, using model-lead-test, how to create three-word sentences using color coded core vocabulary words from each adapted story and graphic organizers following the FKF to delineate parts of speech in order to promote comprehension. The findings for each research question are presented, followed by a discussion of the study's contributions, limitations, recommendations for future research, and implications for practice.

Research Question 1: What are the comparative effects of using print *vs.* digital technology to teach functional community knowledge content on the accuracy of WH (who, what, where) comprehension questions for students with low incidence disabilities?

Because there were only three WH comprehension questions asked after each print and digital technology instructional session, the cumulative number of correct responses were recorded. The upward slope in the graphs revealed the cumulative progress over sessions in relation to the optimal line of progress (30 correct for each condition). Based on the study's results, the cumulative comparative data revealed in the visual displays depict virtually no difference between print and digital technology instruction on the accuracy of answering WH comprehension questions across all four participants.

Notably, Rachel's comprehension accuracy as compared to the other three participants, represented the most drastic improvement reflected in both her post-test score, an increase of 40% above her pre-test score, and during the intervention across both treatment conditions. Visual inspection of the cumulative graph for Rachel displayed a steeper slope of responding in perfect alignment with the optimal line of progress for answering WH comprehension questions correctly as compared to her peers. After digital technology instruction, Rachel scored with 100% accuracy in each of the 10 check-out quizzes and with 93% accuracy (28 out of 30 questions correct) after print technology instruction. After the pre-test data was collected, Rachel's performance indicated an immediacy of effect after the intervention treatment package was introduced under both print and digital technology instructional conditions. These results are consistent with research supporting the use of systematic instruction and the model-lead-test procedure to promote skill acquisition for students with disabilities (Archer & Hughes, 2011; Azrin & Foxx, 1971; Bechtolt, McLaughlin, Derby, & Blecher, 2014; McKissick et al., 2013; Rivera et al., 2012; B. R. Smith et al., 2013; Snell, 1978).

Chandler's cumulative comprehension data resulted in nearly equal performance across both treatment conditions and demonstrated virtually no difference in the effectiveness of either treatment. Chandler's data performance also may have been impacted by the topography of his perseverative self-stimulatory behaviors (i.e., frequent flailing of arms, rocking of his body, parroting of words recently heard) associated with stereotypy common among some individuals with autism which may have affected his cognition and the ability to process new information (Heflin & Alaimo, 2007). Joey and Phoebe initially demonstrated higher accuracy when answering comprehension questions following print technology instruction. The variance in scores between print and digital technology instruction for these two participants, as well as time spent on-task discussed next, may have been impacted by the greater number of opportunities to perform and manipulate the tangible instructional materials available during print technology instruction. This hypothesis coincides with recommendations from Horner, Williams, and Knobbe (1985) who suggested increased opportunities to perform acquired skills leads to better skill maintenance. As the research study progressed, participants became increasingly familiar with the model-lead-test procedure during both treatment conditions. Anecdotal observational information noted increased fluency in responding to instructional prompts during both treatment conditions which may explain why all participants except Joey demonstrated closely paralleled cumulative performance across conditions as the instructional demands became familiar and routine.

The sequence presentation of response options may have been a factor which contributed to Joey's comprehension scores. The three WH question check-out quizzes were presented on a designated desktop computer. Each of the three response options were read aloud from left to right and Joey had a predictable tendency to select the last response option presented without waiting to discriminate between the three answer choices. Fortunately, the multiple choice quiz template within Boardmaker© Professional Online automatically shuffled the order of the answer choices each time the quiz was administered. Since Joey consistently selected the last option presented; it is possible, based on the shuffling of the answer choices in the software program, to answer 33% of the questions correctly without discrimination if the correct answers were shuffled electronically into the far right position.

The importance of conveying negative results in the research literature.

When a single-case research design (SCRD) study provides results lacking a strong effect in response to the intervention, experimental control is questioned. SCRD relies upon experimental control to account for internal threats to validity to determine, with a degree of certainty, if an independent variable produced a clear and reliable effect on participants' behavior. SCRD researchers utilize visual analysis of graphic data to gauge the efficacy of an intervention and the causal relationship between the effects. Tincani and Travers (2018) discussed the importance of sharing research failing to produce robust outcomes in order to prevent publication bias in the field of special education. The current study did not produce strong treatment distinctions between print and digital technology interventions despite adherence to using quality indicator guidelines throughout the implementation of the study.

Kittleman et al., (2018) and Boorman, Foster, Laast, and Francke (2015) proposed the need for including research findings which yield negative results to the larger research community. The authors described the conveyance of negative results as useful for informing other researchers in the field. When research results fail to produce anticipated outcomes and strong effects between the independent and dependent variables

(DV), the intervention itself may still be viable and worthy yet suffer from one of several confounding issues (i.e., poor treatment integrity; inadequate measurement systems for assessing the DV). In the case of the current study, there may have been too many components packaged into two treatment conditions to adequately measure which component (i.e., color coding of core vocabulary, adapted text, graphic organizers) was reliably responsible for the comprehension growth captured for the first DV across participants.

Research Question 2: What are the comparative effects of using print *vs.* digital technology instruction on the percentage of on-task behavior among students with low incidence disabilities?

In the present study, participants' time on-task during print and digital technology treatment conditions were assessed using a whole interval recording (Cooper, 1981; Eaton, 1978; Hall et al., 1975) procedure to measure continuous behavioral data during small group instruction, simultaneously, for each participant. Visual analysis of the alternating treatment design graphs indicated participants spent a greater percentage of time on-task during print technology instructional sessions as compared to digital technology instruction. As mentioned previously, participants had more natural opportunities to perform (Horner et al., 1985) and interact with print technology instructional materials. During print technology instructional sessions, participants had: (a) individual copies of the adapted story being taught, (b) a color-coded FKF vocabulary page highlighting the core vocabulary of the story (n=8), dry eraser makers to circle or identify (defined here as tacting or labeling) key vocabulary as it was mentioned in the adapted text, and (c) a color-coded FKF graphic organizer to create three-word sentences using Velcro™ backed vocabulary words (see Appendix C). During digital technology instructional sessions, participants did not have constant access to instructional materials to manipulate until each participant took a turn interacting with the digital media (i.e., tacting vocabulary words found in the adapted text and dragging and dropping digital, with sound and embedded error correction, vocabulary words into a color-coded FKF graphic organizer for creating three-word sentences) on the TAPit® device screen; opportunities to perform during digital instructional sessions were limited by the nature of the digital media and design of the intervention. Additionally, for students with low incidence disability, observational learning (Farmer, Gast, Wolery, & Winterling, 1991) by watching peers take turns at the TAPit® tacting adapted story vocabulary words and creating three-word sentences was observed to be less engaging for participants when it was not their turn at the TAPit® board.

The data evident in the graphs depict the variable nature of participants' time on-task across conditions. All participants demonstrated higher percentages of time on-task throughout the duration of the study during print technology instruction. Joey, in particular, was more engaged (i.e., circling and tacting vocabulary words) when he had constant access to tangible curriculum materials.

One question arose during the current study involving measurement of on-task behavior for students with ASD. The question revolved around whether students with ASD who engage in high rates of repetitive, stereotypic behavior can simultaneously be counted as on-task while facing forward toward the instructor and/or work materials. Can behaviors such as rhythmic body rocking which cause the participants' eye gaze to not be consistently forward facing or the repetitive visual gaze of an individual at their own fingernails while forward facing be marked as on-task? These occurrences precipitated the need for a refined operational definition of on-task to be developed so that IOA would be consistent in measuring the same observable behavior.

Stereotypic behavior and measuring on-task behavior for students with ASD. Engagement in stereotypic behavior is a common hallmark of individuals with ASD. The *Diagnostic and Statistical Manual*, 5th edition (*DSM-5*) include repetitive, stereotyped patterns of behavior as part of the diagnostic criteria for determining ASD. Additionally, the *DSM-V* indicate the presence of restricted, repetitive behaviors "markedly interfere with functioning" in all areas. Some examples of stereotypic behaviors include rhythmic body rocking, flailing of hands and arms, mouthing of non-food objects, visual fascination with lights and patterns (i.e., moving fingers in front of the eye), and vocalizations. These behaviors are considered self-stimulatory and do not serve a clear function in relation to external stimuli in the environment (Azrin & Foxx, 1971; Berkson, 1967). For individuals with ASD who frequently engage in stereotypic behavior, the pervasive assumption in current research (Edelson, 2013; May, Kennedy, & Bruzek, 2012) and seminal literature (Foxx & Azrin, 1973) mention how the occurrence of continual stereotyped behavior interfere with the individual's ability to learn. King and Krishnamoorthy (1998) referred to repetitive, stereotyped behavior as "seemingly driven and non-functional motor behavior… that markedly interfere with normal activities." The general consensus indicated when individuals with ASD engage in repetitive, stereotyped behavior, they were unable to attend well to external stimuli in the environment, namely instruction.

Decreasing the occurrence of repetitive, stereotyped behavior was not a targeted focus of the current study. Despite participants' frequent engagement in stereotyped behavior, participants in this study demonstrated the ability to attend to the instructional content during both print and digital technology instructional conditions as evidenced by consistent gains made in comprehension for all participants. In this case, engagement in stereotypic behavior did not interfere with learning. When measuring on-task behavior for students with ASD, it is important to adjust the sensitivity of the operational definition to encompass a range of stereotypic behavior.

Research Question 3: What are the opinions of teaching staff regarding the use of print and digital technology instruction to teach students with low incidence disabilities?

The special education teacher and the teaching assistant were both present in the classroom for 100% of the research study sessions. Both staff members viewed the implementation of the print technology and digital TAPit® technology interventions positively for providing systematic instruction for students with low incidence disabilities. Teaching staff noted the immediate increase in engagement and motivation during students' turns tacting and creating digital three-word sentences using the color coded FKF on the TAPit® device. Noted increases in student engagement and motivation during CAI are consistent with the research literature (Mechling & Bishop, 2011; Mechling et al., 2008; Soares et al., 2009) particularly among students with autism (Shane & Albert, 2008). The teaching staff felt that the students learned the best through print technology instruction; however, the teaching staff believed students were more motivated to participate in the digital technology instructional sessions.

Results from the social validity questionnaire also indicated the intention of teaching staff to continue to utilize the color coded FKF for teaching other content areas in the future during print and/or digital technology lessons to reinforce the structural organization for explicitly teaching students to categorize words by part of speech to increase understanding of abstract concepts. The lead special education teacher stated she "had never seen a system like that (color coding by part of speech)." Teaching staff liked the consistency and saw an improvement in students' abilities to create intelligible three-word sentences beyond indicating basic wants and preferences using the format to demonstrate comprehension of main ideas in the adapted functional community knowledge stories.

Research Question 4: How do students with low incidence disabilities rate the use of print and digital technology instruction?

All four participants indicated "yes" the color coded FKF helped them to learn how to write three-word sentences. Also, the student participants expressed the desire for their teacher to use the color coded FKF in more of their lessons. Positive responses also indicated the desire to use the color coding format to communicate at home as well as out in their communities.

Contributions of the Study to the Research Community

The NLTS2 (2011) data and research literature revealed poor post-school outcomes for aided ACC users (Bouck & Flanagan, 2016; Ganz et al., 2011; Lund & Light, 2006) in the areas of health, safety, and independent living. Three broad themes were systematically combined to address these issues in the current study: (a) using aided print and digital technology (typically referred to as low and high tech AAC) and EBPs to access the general curriculum, (b) targeting tenets of Skinner's (1957) verbal behavior for language acquisition and reinterpreting the word "verbal" as it pertains to aided AAC users, and (c) embedding visual and instructional supports to promote comprehension for students with low incidence disabilities who require aided AAC to communicate. See Appendix J for the Conceptual Framework which guided this research.

Using print and digital technology and EBPs to access the general curriculum. EBPs of using systematic instruction, visual supports, and CAI previously found to be effective for teaching academic and functional skills for students with mild to moderate intellectual disabilities and autism (Browder, Trela, Courtade, et al., 2012; Browder, Trela, & Jimenez, 2007; Rivera et al., 2012; Schenning et al., 2013; Zakas et al., 2013) also were found to be effective in teaching students with low incidence disabilities when coupled with print and digital technologies. The current study effectively embedded a combination of EBPs to teach functional community knowledge concepts using both print and digital technology instruction coupled with color coding using FKF of salient vocabulary to promote comprehension for students with low incidence disabilities.

This study contributes to the existing research literature (Jameson et al., 2012; McKissick et al., 2013; Mechling et al., 2008; Miguel et al., 2005; Shane & Albert, 2008; B. R. Smith et al., 2013) by demonstrating another means to utilize print technology and interactive digital technology to teach students with low incidence disabilities. Learning to identify core vocabulary (tacting) to increase executive functioning necessary to answer comprehension questions (intraverbal skills) using color coding of core vocabulary is an important skill to teach students with low incidence disabilities and ASD.

Although not robust, the comparative effects of print and digital technology on comprehension accuracy did not demonstrate a difference across conditions, however, this data can be promising for special educators. The variation in scores across conditions indicates the viability of using both print and digital technology for instructional purposes.

Embedding visual and instructional supports to promote comprehension. The results of this study extend the sparse research (Bruno & Trembeth, 2006; Ebbels, 2016; Thistle & Wilkinson, 2009) work in the area of color coding, specifically utilizing the FKF to promote comprehension by teaching aided AAC users how to determine parts of speech. Further, this study adds to the body of research (Browder, Ahlgrim-Delzell, et al., 2008; Browder, Trela, Courtade, et al., 2012; Zakas et al., 2013) involving adapted stories, shared stories, graphic organizers, and the power of visual supports to modify abstract curricular content to meet the learning needs of students with low incidence disabilities.

Limitations of the Study

Every study has limitations. This study is no different. Designing a research study with digital technology as a central feature resulted in routine challenges. There were numerous technological limitations and set-backs that occurred during the study.

During four of the randomized digital technology lessons, the interactivity between the TAPit® and the laptop with a disc drive (to run the interactive Boardmaker© sentence writing lessons) connected to the TAPit® through a Video Graphics Adapter

(VGA) cable (a High Definition Multimedia Interface (HDMI) was also an option) froze or caused animation glitches and interruptions during instruction.

Also, the Boardmaker© Professional online software used for the multiple choice check-out quizzes encountered a security breach online and all 20 adapted stories and corresponding quizzes were lost, could not be recovered, and cost the experimenter/interventionist excessive time to recreate. Additionally, the Boardmaker© picture icons are not consistent across platforms (online versus CD) which may be confusing for students and may negatively impact comprehension performance. To mitigate this issue, the experimenter/interventionist decided to use only Boardmaker© picture symbols from the Mayer-Johnson© 6.0 Speaking Dynamically Pro CD and uploaded every adapted story and interactive sentence writing templates into the Boardmaker© Professional Online system to maintain consistency across technological platforms. This instructional decision required the use of a laptop with a disc drive to run the Mayer-Johnson© 6.0 Speaking Dynamically Pro CD hooked to the TAPit® device. Technological issues of this nature are consistent with previous research literature representing potential limitations when embedding CAI (B. R. Smith et al., 2013; McKissick et al., 2013).

The GoPro HERO™ used to videotape each session for measurement of the second dependent variable, time on-task, cropped some of the instructional sessions to 11:49 minutes as opposed to a minimum of 12 minutes. Whole interval recording for all sessions were subsequently divided by a total 35 intervals instead of 36 intervals lasting 20s each. Involuntarily decreasing the divisor by one interval was a limitation because the number of intervals slightly inflated the data.

Recommendations for Future Research

Prior to discussing future digital technology research involving teaching students with low incidence disabilities and ASD, the importance of adequately defining on-task behavior is important. Investigating time spent on-task as a predictor of student engagement and ultimately learning (Fredericks, Blumenfeld, & Paris, 2004) is common among general and special education researchers. On-task behavior typically includes eye contact and/or looking at instructional materials or the instructor as a component of defining students' attention to instruction. For students with ASD, a hallmark indicator of ASD in the DSM-V is typified by the lack of eye contact (Heflin & Alaimo, 2007; Worley & Matson, 2012). Attempts to sensitively and accurately measure on-task behavior involving eye contact for students with ASD appear incongruous. In the current study, operationally defining on-task behavior with replicable precision and accuracy for IOA measurement created a challenge. Training the second observer using examples and non-examples during simultaneous video analysis was necessary. When on-task behavior for the current study was compared to the comprehension data for the first dependent variable, a clear correlation between on-task behavior (i.e., eye contact) and gains in comprehension were not found. Eye contact or looking at the instructor or educational material did not account for listening and hearing. Future research should consider alternate measures of on-task behavior for students with ASD accounting for idiosyncratic stereotyped behavior unique to each individual.

Future research recommendations include teacher training in digital technology lesson creation, systematic instruction using digital technology, and further investigation for the use of the color coding FKF to improve comprehension and sentence creation using the format across content areas, including academic and functional language skills. Future research could embed the use of IWB (i.e., SMART Board) for students with low incidence disabilities to investigate access, especially for those with gross motor and/or visual impairments, since the larger format provides greater physical and visual input.

The decision to use IWB technology in the form of the TAPit® for students with low incidence disabilities was to provide a large and engaging form of interactive digital media to provide instruction. Large IWB has the innate advantage of providing access both visually and physically for students with low incidence disabilities who may present challenges in these areas. The TAPit® specifically is a movable IWB device on wheels. The screen can raise and lower on a hydraulic lift down to seven inches off the ground and up and to five feet high. The screen can be adjusted to lay flat like a tabletop and has touch point sensitivity built in so a student with a physical impairment can lean on the screen for support without disrupting screen navigation with their dominant hand. Future research could shape the digital technology presentation down from IWB to handheld digital technology, such as iPads for each participant during small group instruction, to address the issue discovered in this study involving limited opportunities to perform. Individual iPads could be programmed with the adapted stories, digital “drag and drop” color coded vocabulary using the FKF, and color coded graphic organizers for sentence construction with built in error correction and prompting. In this way, regardless of whether a student performed better using print or digital technology, students would have a functional form of communication to use in their post-school lives that is handheld and portable. According to Burkhart and Porter (2012) the ultimate goal of aided AAC, is to provide a means for individuals to communicate what they want to say, to whoever they want to say it to, whenever and wherever they want to say it.

Additionally, future research should consider adapted stories containing more than eight core vocabulary words to tact and utilize for sentence construction for students with low incidence disabilities. Eight core vocabulary words per adapted story limited the complexity of participants' sentences possible to create given the graphic organizer and corresponding color code using the FKF (see Appendix B).

Implications for Practice

Digital technology has been shown to be an effective means to provide CAI especially in the form of video modeling and video self-modeling for students with ASD (Bereznak, Ayres, Mechling, & Alexander, 2012; Campbell & Mechling, 2009; Mechling & Bishop, 2011; Mechling, Gast, & Krupa, 2007). This study demonstrates another means to provide instruction via digital technology using an IWB in the form of the TAPit® for students with low incidence disabilities. The current study's intervention package could be adopted by special education classroom teachers from K-12 to provide small group instruction across content areas which make the intervention tools practical for daily teaching. Especially when educators prepare instructional lessons using digital technology, the content can be saved, edited, shared with collaborative colleagues, and re-used over time to meet individual student needs. A benefit of digital technology instruction is the ease of editing content based upon student need each time a lesson is taught in the future.

Another benefit is the efficient use of teacher time; a teacher can work one-on-one with a student in need while a teaching assistant can teach the rest of the students using digital technology or *vice versa*. Special educators would need to be technologically savvy beyond basic programming and familiar with these software platforms to make these instructional decisions as needed.

For special educators, the results indicate the need for more opportunities to perform during small group instruction when using digital technology to maintain on-task behavior for students. Closely aligning instructional materials on individual digital technology devices (i.e., iPads) to maintain instructional momentum and increase natural opportunities for engagement across students would be one way to level the playing field between print and digital technology when teaching.

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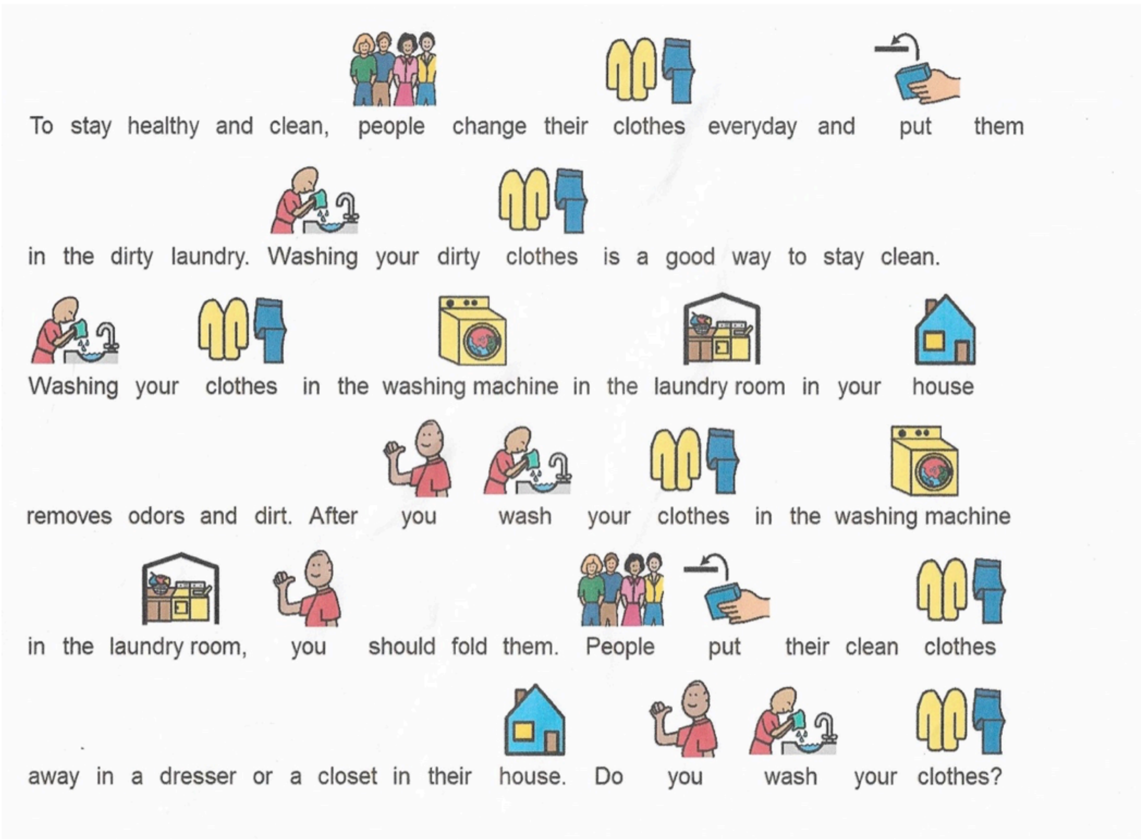
Appendix A

Example of adapted text using picture symbol feature of pertinent vocabulary which was used in both print and digital technology formats.



Appendix B

Example of color-coded Fitzgerald Key Format for adapted text vocabulary using a graphic organizer for both print and digital instructional conditions.

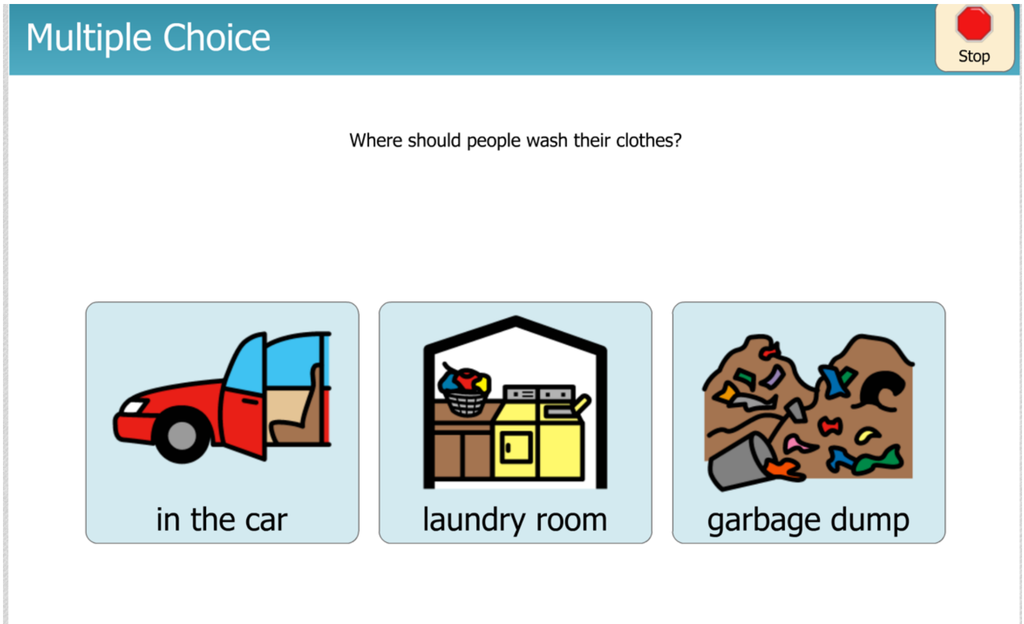
Color code key: people/characters=yellow, action words/verbs=green, objects=orange, places=purple

Appendix C

Fitzgerald Key Format and three word, color coded graphic organizer for writing noun, verb, noun sentences to promote comprehension.

Appendix D

Example of a choice of three multiple choice question using Boardmaker® Professional Online quiz templates.



Appendix E

Whole Interval Recording Form for Measuring the Percentage of Time On-task

Definition of "on-task" behavior: **Participant:** ______________________

Participant is counted as on-task during each interval as evidenced by any of the following behaviors: looking at work materials; looking at the instructor; manipulating the work materials (i.e., pointing to images, circling vocabulary words, moving print or digital images to write sentences); remaining in the designated work space (i.e., sitting during print instruction and sitting while instructor or peer is interacting with IWT or standing during individual turn with IWT). **Note**: for stereotypic behaviors common among individuals with autism spectrum disorder and unique to the individual participants (i.e., squinting to the side or at fingernails), these behaviors will not be counted with a **0**, for off-task, unless they persist for more than 3s (for looking away). Other stereotypic behaviors (i.e., rocking and/or flailing arms) will still be considered on-task if the participant is looking forward at the instructor or at the work materials.

Procedure: Whole Interval Recording -

- Observe the participant for the entire duration of each interval (20s) x 36 intervals = 12 minutes.
- Record the interval with an **X** if the desired on-task behavior occurred during the entire duration of the interval.
- Record the interval with a **O** if the desired on-task behavior did NOT occur for the entire duration of the interval.
- Percentage is scored by totaling the number of **X** on-task intervals per session divided by the total number of intervals (36).

Session	.2	.4	1	1.2	1.4	2	2.2	2.4	3	3.2	3.4	4	4.2	4.4	5	5.2	5.4	6	6.2	6.4	7	7.2	7.4	8	8.2	8.4	9	9.2	9.4	10	10.2	10.4	11	11.2	11.4	12	Total
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Appendix F

Procedural Fidelity Checklist Date: ___________ Overall Percentage: _______

Print

		Codes: + (correct) - (incorrect) n/a not applicable	
Material Set-Up	1. Each student receives a color-coded vocabulary page		
	2. Each student receives a paper copy of the adapted text with picture symbol supports		
	3. Each student receives a color-coded graphic organizer to write their two summary sentences.		
	4. Deliver instructional cue: **“Today we’re going to read a story, write two sentences each, and answer some questions on the computer.”**		
Instruction	5. Experimenter secures student attention (e.g., students are sitting in their seats and their eyes are looking at the experimenter)		
	6. Provides instructional cue, **“Remember, listen to the story.”**		
	7. Experimenter reads the adapted story.		
	8. Experimenter points to the picture symbol supported vocabulary words as they appear in the text.		
	9. Experimenter points to the color-coded picture symbol supported		

	vocabulary words heard in the text on the individual Fitzgerald Key Format vocabulary page.		
	10. Experimenter prompts participants to locate vocabulary words by name & color (part of speech). For instance, "point to 'police officer' – it's a yellow word."		
Model vocabulary identification (tact)	11. Experimenter models pointing to vocabulary words heard in the text on the vocabulary page, "**Watch me. This is the -------- (e.g., police officer**). **'Who' words are in yellow."**		
Lead	12. Experimenter prompts participants to locate vocabulary words together by name & color (part of speech). For instance, "**We'll do it together. Let's point to 'police officer' – 'who' is a yellow word**."		
Test	13. Experimenter cues participants, "**Now it's your turn. Point to ------ (e.g., police officer)**. **It's a yellow word."**		
	14. Experimenter provides immediate error correction with a more supportive prompt (e.g., gestural, model, physical) if the participant points to the incorrect vocabulary word. "**Try again. Point to the yellow word----- (e.g., police officer)**."		
Sentence creation **Model**	15. "**Now we're going to write a 3-word sentence about our story using our graphic organizers. Watch me first**."		
(yellow word = who goes 1st)	**16. "First I need a yellow word from my vocabulary page; yellow words describe who/people."** Model selecting and placing the 1st word in the graphic organizer and read the word aloud.		

(green word = what/action word goes 2nd)	17. **“Next I need a green word from my vocabulary page; green words describe what/action.”** Model selecting and placing the 2nd word in the graphic organizer and read the word aloud.		
(purple word = where/location goes 3rd)	18. **“Last, I need a purple word from my vocabulary page; purple words describe where/places.”** Model selecting and placing the 3rd word in the graphic organizer and read the word aloud.		
	19. Experimenter reads the 3-word sentence and points to the picture supported text in each color-coded graphic organizer cell (e.g., doctor works [in a] hospital).		
Lead	20. “Let’s write a sentence together. **First, let’s find a yellow word from our vocabulary page; yellow words describe who/people.”** Lead selecting and placing the 1st word in the graphic and read the word aloud.		
	20. **“Next, let’s find a green word from our vocabulary page; green words describe what/action.”** Lead selecting and placing the 2nd word in the graphic organizer and read the word aloud.		
	21. **“Last, let’s find a purple word from our vocabulary page; purple words describe where/places.”** Model selecting and placing the 3rd word in the graphic organizer and read the word aloud.		
	22. Experimenter reads the 3-word sentence and points to the picture supported text in each color-coded graphic organizer cell (e.g., doctor works [in a] hospital) with the participant.		
Test	23. **“Now it’s your turn to write your own sentence. First you need a**		

	yellow word from your vocabulary page; yellow words describe who/people." Test – participant selects (points to) a yellow word from the vocabulary page.		
Error correction procedure if needed Score n/a if not applicable	24. * If the participant selects a different color-coded word, the experimenter covers up the other non-yellow vocabulary word options and cues the participant to point to a yellow word.		
	25. "Next you need a green word from your vocabulary page; green words describe what/action." Test – participant selects a green word from the vocabulary page.		
Error correction procedure if needed Score n/a if not applicable	26. * If the participant selects a different color-coded word, the experimenter covers up the other non-green vocabulary word options and cues the participant to point to a green word.		
	27. **"Last, you need a purple word from your vocabulary page; purple words describe where/places."** Test – participant selects a purple word from the vocabulary page.		
Error correction procedure if needed Score n/a if not applicable	28. * If the participant selects a different color-coded word, the experimenter covers up the other non-purple vocabulary word		

	options and cues the participant to point to a purple word.		
	28. Experimenter reads each participant's 3-word sentence and points to the picture supported text in each color-coded graphic organizer cell (e.g., doctor works [in a] hospital) to the group.		
	29. Experimenter collects the materials (e.g., adapted stories, vocabulary pages, & graphic organizers), concludes the small group lesson, and reminds each participant that they will be taking a brief 3 question quiz at the desktop computer.		
Comprehension assessment	30. At the desktop computer, the experimenter has Boardmaker® Professional Online quiz already loaded and minimized on the screen.		
Participant #1	31. Once the participant is seated and ready, the experimenter cues the participant. **"You're going to take a brief 3 question, multiple choice quiz. There will be 3 answer choices on the screen. Touch the picture to mark your answer choice. Do your best."**		
	32. Question #1 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	33. Question #2 (computer randomizes order of questions and shuffles response options).		

	* Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	34. Question #3 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	35. Experimenter thanks the participant & checks to make sure the quiz data is scored in the Boardmaker® Professional Online system under the participant's pseudonym. **"Great job, I like the way you worked so hard to answer each question!"** (high five)		
Participant #2	36. Once the participant is seated and ready, the experimenter cues the participant. **"You're going to take a brief 3 question, multiple choice quiz. There will be 3 answer choices on the screen. Touch the picture to mark your answer choice. Do your best."**		
	37. Question #1 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	38. Question #2 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not		

	record the response choice and automatically move to the next question.		
	39. Question #3 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	40. Experimenter thanks the participant & checks to make sure the quiz data is scored in the Boardmaker® Professional Online system under the participant's pseudonym. **"Great job, I like the way you worked so hard to answer each question!"** (high five)		
Participant #3	41. Once the participant is seated and ready, the experimenter cues the participant. **"You're going to take a brief 3 question, multiple choice quiz. There will be 3 answer choices on the screen. Touch the picture to mark your answer choice. Do your best."**		
	42.. Question #1 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	43.. Question #2 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		

	44. Question #3 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	45. Experimenter thanks the participant & checks to make sure the quiz data is scored in the Boardmaker® Professional Online system under the participant's pseudonym. **"Great job, I like the way you worked so hard to answer each question!"** (high five)		
Participant #4	46. Once the participant is seated and ready, the experimenter cues the participant. **"You're going to take a brief 3 question, multiple choice quiz. There will be 3 answer choices on the screen. Touch the picture to mark your answer choice. Do your best."**		
	47. Question #1 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	48. Question #2 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	49. Question #3 (computer randomizes order of questions and shuffles response options).		

	* Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	50. Experimenter thanks the participant & checks to make sure the quiz data is scored in the Boardmaker® Professional Online system under the participant's pseudonym. **"Great job, I like the way you worked so hard to answer each question!"** (high five)		
	• 47 steps if error correction is NOT needed • up to 48-50 steps if error correction is needed Procedural Fidelity Checklist **Steps Performed Correctly/Opportunities**	/	
	Fidelity %		

Appendix G

Procedural Fidelity Checklist Date: ___________ Overall Percentage: _______

Digital

		Codes: + (correct) - (incorrect) n/a not applicable	
Material Set-Up	1. Experimenter opens the Interactive whiteboard technology (IWB) to the Boardmaker® Professional Online page where the adapted story is located		
	2. Deliver instructional cue: **"Today we're going to read a story, write one sentence each using our color-coded graphic organizer, and answer some questions on the desktop computer."**		
Instruction	3. Experimenter secures student attention (e.g., students are sitting in their seats and their eyes are looking at the IWB)		
	4. Provides instructional cue, **"Remember, listen to the story."**		
	5. Experimenter touches the IWB and it reads the adapted story. Experimenter re-reads the adapted story (at a slower pace than the speech generated voice).		
	6. Experimenter touches the picture symbol supported vocabulary words as they appear in the text.		

	7. Experimenter points to the color-coded picture symbol supported vocabulary words heard in the text on the Fitzgerald Key Format vocabulary template shown on the bottom of the screen		
	8. Experimenter prompts participants to come up to the IWB to locate vocabulary words by name & color (part of speech). For instance, "touch the word 'police officer' – it's a yellow word."		
Model vocabulary identification (tact)	9. Experimenter models touching the vocabulary words heard in the text on the vocabulary template on the IWB, "**Watch me. This is the -------- (e.g., police officer**). **'Who' words are in yellow."**		
Lead	10. Experimenter prompts participants to come up to the IWB to locate vocabulary words together by name & color (part of speech). For instance, "**We'll do it together. Let's point to 'police officer' – 'who' is a yellow word**."		
Test	11. Experimenter cues participants, "**Now it's your turn. Touch the word ------ (e.g., police officer)**. **It's a yellow word."**		
	12. Experimenter provides immediate error correction with a more supportive prompt (e.g., gestural, model, physical) if the participant touches the incorrect vocabulary word. "**Try again. Touch the yellow word----- (e.g., police officer)**."		
Sentence creation **Model**	13. "**Now we're going to write a 3-word sentence about our story**		

	using our graphic organizers. Watch me first.”		
(yellow word = who goes 1st)	**14. “First I need a yellow word from the vocabulary template; yellow words describe who/people.”** Model touching and dragging & dropping a cloned image of the 1st word in the graphic organizer. The IWB reads the word aloud when touched.		
(green word = what/action word goes 2nd)	15. **“Next I need a green word from my vocabulary page; green words describe what/action.”** Model touching, and dragging & dropping the 2nd word in the graphic organizer and the IWB reads the word aloud when touched.		
(purple word = where/location goes 3rd)	16. **“Last, I need a purple word from my vocabulary page; purple words describe where/places.”** Model touching and dragging & dropping the 3rd word in the graphic organizer and IWB reads the word aloud when touched.		
	17. Experimenter touches each vocabulary word in the 3-word graphic organizer (e.g., doctor works [in a] hospital) and the IWB speaks each word aloud.		
Lead	18. “Let’s write a sentence together. **First, let’s find a yellow word from our vocabulary template; yellow words describe who/people.”** Lead touching and dragging & dropping the 1st word in the graphic while the IWB reads the word aloud.		

	19. **"Next, let's find a green word from our vocabulary template; green words describe what/action."** Lead touching and dragging & dropping the 2nd word in the graphic organizer and IWB reads the word aloud.		
	20. **"Last, let's find a purple word from our vocabulary template; purple words describe where/places."** Model touching and dragging & dropping the 3rd word in the graphic organizer and IWB reads the word aloud.		
	21. Experimenter prompts the participant to touch each vocabulary word in the 3-word graphic organizer with her (e.g., doctor works [in a] hospital) while the IWB speaks each word aloud.		
Test **Note**: Error correction is embedded into the IWB program designed for this activity. Incorrect color choices will "snap back" to the vocabulary template. The experimenter can prompt the participant to "try again, find a **yellow** word."	22. **"Now it's your turn to write your own sentence. First you need a yellow word from your vocabulary template; yellow words describe who/people."** Test – participant touches a yellow word from the vocabulary template and drags & drops it into the graphic organizer.		
Note: Error correction is embedded into	**23. "Next you need a green word from your vocabulary page; green words describe**		

the IWB program designed for this activity. Incorrect color choices will "snap back" to the vocabulary template. The experimenter can prompt the participant to "try again, find a **green** word."	**what/action."** Test – participant touches a green word from the vocabulary template and drags & drops it into the color-coded graphic organizer.		
Note: Error correction is embedded into the IWB program designed for this activity. Incorrect color choices will "snap back" to the vocabulary template. The experimenter can prompt the participant to "try again, find a **purple** word."	24. **"Last, you need a purple word from your vocabulary page; purple words describe where/places."** Test – participant touches a purple word from the vocabulary template and drags & drops it into the color-coded graphic organizer.		
	25. Experimenter touches the IWB and has it read each participant's 3-word sentence in the color-coded graphic organizer (e.g., doctor works [in a] hospital) to the group.		
	26. Experimenter concludes the small group lesson, closes the IWB down, and reminds each participant that they will be taking a brief 3 question quiz at the desktop computer.		
Comprehension assessment	27. At the desktop computer, the experimenter has Boardmaker®		

	Professional Online quiz already loaded and minimized on the screen.		
Participant #1	28. Once the participant is seated and ready, the experimenter cues the participant. **"You're going to take a brief 3 question, multiple choice quiz. There will be 3 answer choices on the screen. Touch the picture to mark your answer choice. Do your best."**		
	29. Question #1 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		

	30. Question #2 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	31. Question #3 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		

	32. Experimenter thanks the participant & checks to make sure the quiz data is scored in the Boardmaker® Professional Online system under the participant's pseudonym. **"Great job, I like the way you worked so hard to answer each question!"** (high five)		
Participant #2	33. Once the participant is seated and ready, the experimenter cues the participant. **"You're going to take a brief 3 question, multiple choice quiz. There will be 3 answer choices on the screen. Touch the picture to mark your answer choice. Do your best."**		
	34. Question #1 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	35. Question #2 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	36. Question #3 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	37. Experimenter thanks the participant & checks to make sure the quiz data is scored in the Boardmaker®		

	Professional Online system under the participant's pseudonym. **"Great job, I like the way you worked so hard to answer each question!"** (high five)		
Participant #3	38. Once the participant is seated and ready, the experimenter cues the participant. **"You're going to take a brief 3 question, multiple choice quiz. There will be 3 answer choices on the screen. Touch the picture to mark your answer choice. Do your best."**		
	39. Question #1 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	40. Question #2 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	41. Question #3 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	42. Experimenter thanks the participant & checks to make sure the quiz data is scored in the Boardmaker® Professional Online system under the participant's pseudonym. **"Great job, I like the way you worked so**		

	hard to answer each question!" (high five)		
Participant #4	43. Once the participant is seated and ready, the experimenter cues the participant. **"You're going to take a brief 3 question, multiple choice quiz. There will be 3 answer choices on the screen. Touch the picture to mark your answer choice. Do your best."**		
	44. Question #1 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	45. Question #2 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	46. Question #3 (computer randomizes order of questions and shuffles response options). * Experimenter can prompt participant to **try again/touch the screen harder** if the computer does not record the response choice and automatically move to the next question.		
	47. Experimenter thanks the participant & checks to make sure the quiz data is scored in the Boardmaker® Professional Online system under the participant's pseudonym. **"Great job, I like the way you worked so hard to answer each question!"** (high five)		

	Procedural Fidelity Checklist **Steps Performed Correctly/Opportunities**	**/47**	
	Fidelity %		

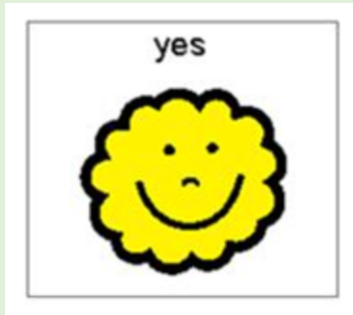
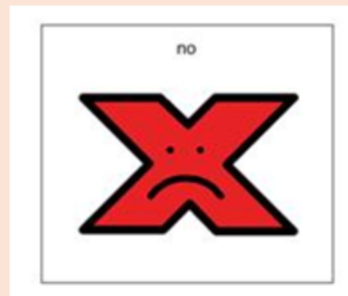
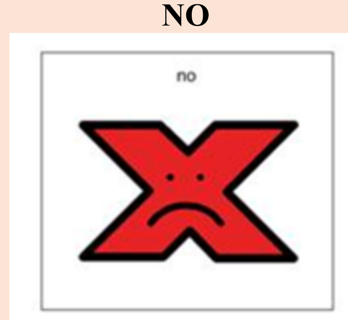
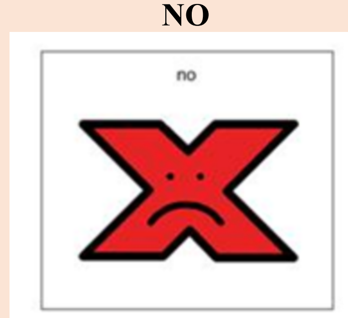
Appendix H

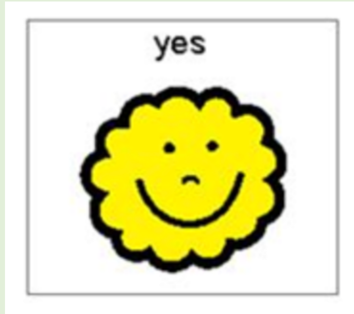
Teaching Staff: Social Validity Questionnaire

What are your opinions about using the TAPit® to teach your students?	
What are your opinions about using the color coded Fitzgerald Key Format to teach your students to create basic sentences (three word: noun, verb, noun; who, what, where) using print or digital technology?	
Do you feel the color coded Fitzgerald Key Format helped your students comprehend the shared story elements better? Why or why not?	
Which format, print or digital technology, was more effective for teaching your students?	
Do you feel as though one format, print or digital, was more motivating and engaging for your students? If so, which one?	

Appendix I

Participant: Social Validity Questionnaire

Did you like using the colored coded vocabulary words to write sentences?	**YES** 	**NO** 
Did you like using the big computer to learn and write sentences?	**YES** 	**NO** 
Would you like your teacher to use the big computer more during class to teach?	**YES** 	**NO** 
Were the big computer lessons fun?	**YES** 	**NO** 

Would you like to use the colored vocabulary words to write sentences at home?	**YES** 	**NO** 
Would you like to use the colored vocabulary words to write sentences after school?	**YES** 	**NO** 

Appendix J

TAP·it®

Touch Accessible Platform
Interactive Technology

Revolutionize learning with the TAP·it® platform's intended touch technology

The TAP·it platform is the first interactive learning station designed to provide accessibility to all students. This technology recognizes the difference between an arm resting upon the screen and a finger or assistive device intentionally "tapping" or selecting an image. Providing an optimal interface for teaching students with special educational needs at their own pace, the TAP·it platform reinforces skills that can be transferred to other computer-based learning applications utilizing the Internet, educational software, or communication devices.

Accessible to students or adults with significant physical or learning disabilities

The TAP·it platform is within reach for students or adults using wheelchairs, walkers or other mobility devices, providing full access to the screen with easy adjustments that adapt to individualized needs. Worries about navigation are eliminated as users can maneuver up to the workstation and have full reach capabilities.

Motorized adjustments provide easy accommodations

Raise the TAP·it platform's screen anywhere to a height of 137 cm or lower it to within 19 cm from the floor with the touch of a button. The 42" interactive, touch-sensitive LCD panel can be tilted from 0 - 90 degrees. This flexibility makes the TAP·it platform infinitely more accessible to physically challenged students and their instructors than stationary, wall-mounted boards.

The TAP·it platform has been independently tested for safety and durability

Resistant to dust, grit, grime and other contaminants, the commercial grade LCD panel is made of shatter-resistant safety glass. Repurposed exclusively for the TAP·it platform, this low-glare screen technology is used by the military and resists marks and scratches. The field-tested platform is counter-balanced, so even if a student or adult leans his full body weight against it, the TAP·it platform will not tip.

Easily move the TAP·it platform where you need it

Mobility is essential for educators who may use the TAP·it platform in multiple environments, from the classroom to therapy settings. Roll the TAP·it platform to the desired location; commercial grade locking casters keep the workstation stable.

TheTAP·it® Platform: Creating a Custom Fit for Success

Finding assistive technology that serves the needs of multiple individuals with a variety of special needs is challenging. Meet Bre, a bright and witty 11-year-old with congenital limb deficiencies and an extraordinary sense of courage and determination. Whether she is using her motorized wheelchair or modeling her new prosthetic legs, the Touch Accessible Platform for Interactive Technology (TAP·it) accommodates her individual needs with its wide base, tilt angles, and height adjustment capabilities.

The TAP·it platform uses intended touch technology, which means it recognizes the difference between purposeful and accidental interactions with the screen. Any software used on a computer can easily be used on this touch-sensitive platform.

The TAP·it platform interactive workstation responds to a variety of styluses, including:

- Pointers
- Head Pointers
- Balls
- Mouth Sticks
- Switches/Scanners
- On-Screen Keyboards

Serving a wide range of students' special needs, the TAP·it platform provides multiple modes of learning to accommodate tactile, visual and auditory learners, as well as those with:

- Traumatic Brain Injury
- Down Syndrome
- Intellectual Disabilities
- Autism Spectrum Disorder
- Cerebral Palsy
- Spinal Cord Injuries
- ADD & ADHD
- Learning Disabilities
- Vision & Hearing Disabilities
- Sensory Processing Disorder
- Muscular Dystrophy

The TAP·it platform truly helps lay the groundwork for success. The customizable design allows students like Bre to focus on what matters most: their education.

Fine Motor Delays – Students can operate the screen using a finger, assistive device, or reach stick. Larger icons help them select the correct target to make their choices. The work area is designed to ensure that the majority of students are able to reach the entire surface.

Involuntary Arm Movements – Students can use the interface to interact with applications on the LCD panel. This helps to accommodate their lack of precision and accuracy in directing the mouse pointer.

Visually Impaired – The TAP·it platform works with any software on your computer allowing teachers, students and parents to resize text and graphics, adjust brightness or contrast controls, and enlarge images or change background colors within seconds. The low-glare, matte finish display is shadow-free, providing optimal viewing for low-vision users.

Hearing Impaired – Finger-touch input keeps hands free of pen tools that interfere with signing. Interactive media keeps students engaged. They can read from the board and sign at the same time, increasing opportunities for communication between teachers and students.

Developmental Delays – The TAP·it platform offers ongoing visual reinforcement to complement lessons and improve functional capabilities. While their eye movement increases, students with ASD, ADD, etc., can track content with greater ease. The physical interaction and visual stimulus offers an additional sensory channel to help process information.

Applications – Any software, switch or website you currently use works with the TAP·it platform. Use what is currently working with the students for activities. Keep the students in their routines and minimize additional preparation for the teachers. Occupational therapists can practice cause and effect, eye tracking, and extended reach capabilities with gaming software and websites. Every teacher has a preference, and if you use it on your computer, you can use it on the TAP·it platform.

Warranty – The TAP·it platform is protected by a three-year parts and labor warranty.

Appendix K

Logic Model for the Study