THE USE OF TECHNOLOGY TO TEACH READING SKILLS TO INDIVIDUALS WITH AUTISM SPECTRUM DISORDER: SYSTEMATIC QUALITY REVIEW, META-ANALYSIS, AND SINGLE-CASE RESEARCH EVALUATION

by

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A Dissertation

Submitted to the Faculty of Purdue University

In Partial Fulfillment of the Requirements for the degree of

Doctor of Philosophy

Department of Educational Studies

West Lafayette, Indiana

May 2020

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To my family who have gave me unconditioned support

ACKNOWLEDGMENTS

This work would not have been possible without the continuous mentorship and support of my dissertation committee members, Drs. Rispoli, Mason, Roberts, and Whitford. It has been an honor for me to work with such an accomplished and insightful group of faculty. I am deeply indebted to Dr. Rispoli, who has provided invaluable guidance over the last three years. As my academic advisor and mentor, she has taught me more than I could ever give her credit for here. I would also like to extend my gratitude to Dr. Brodhead and Jasmine Begeske for their priceless advice and encouragement.

It has been a privilege to collaborate with many outstanding colleagues in the Special Education program. I would like to express my special thanks to Emily Gregori and Catharine Lory, who never wavered in their support not only as incredible colleagues but also as a sincere friends. I also wish to thank my dear friends, Havva Demirkiran and Soojung Kim, who always filled my graduate student life with joy.

I would also like to acknowledge and thank my community partners at the Wabash Center. I am particularly grateful to Stacia, MJ, Jessica, and Doria for their assistance in conducting my research study. It was a great pleasure for me to meet and work with three passionate students every week and witness their progress. I would also like to express my deepest appreciation to those students and their family.

No one has been more important to me in the pursuit of this work than my family. I would like to thank my parents, whose love and guidance are with me whatever I pursue. I am extremely grateful to my grandmother, who never stopped praying for me until the end of her life. Although she is not here with me, I believe that she can look at the completion of this work in heaven. I also want to thank my sister for her unwavering encouragement. I would like to extend my sincere thanks to my parents and sister in law, who have been always supportive of my personal career. Most importantly, I wish to thank my husband, Soonam Lee. I truly appreciate the unconditioned love and support he has gave me since we first met at Purdue.

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ABSTRACT

Although technology has been commonly used to teach reading skills to students with autism spectrum disorder (ASD), the overall quality and evidence base of research supporting this practice has not yet been fully investigated. The purpose of this dissertation was to examine the effects of technology-based reading interventions for students with ASD through a systematic quality review, meta-analysis, and single-case experimental study.

In Study 1, articles that incorporated technology into reading interventions for students with ASD were systematically aggregated ($N = 31$), and the methodological rigor of both group design ($n = 4$) and single-case design studies ($n = 27$) were evaluated based on the What Works Clearinghouse (WWC) quality indicators. A total of 16 studies (52%) met the WWC standards without or with reservations. Study characteristics related to participant, setting, interventionist, technology usage, intervention components, and targeted reading or nonreading outcomes were coded and synthesized for these 16 studies with high-quality research evidence. Results indicated that two types of technology (i.e., computer, tablet) were used for developing materials, supporting interventionist-directed reading instruction, and delivering reading instruction without interventionist-directed reading instruction.

The purpose of Study 2 was to quantify the magnitude of effect of technology-based reading interventions for students with ASD and determine if participant and intervention characteristics moderate intervention effects. A total of 13 single-case studies that met the WWC quality indicators were included in the meta-analysis, and these studies yielded 50 separate effect sizes with 13 participants. The Tau-U effect size without baseline control was calculated to quantify the effects of technology-based reading interventions, and statistically significant tests were conducted to analyze categorical variables. Results of this meta-analysis found a medium

overall effect of .89 (95% CI [.83, .96]) for technology-based reading interventions and variables associated with the use of time delay moderated reading outcomes.

In Study 3, the effects of adapted science eBooks within shared reading on reading comprehension and task engagement of high school students with ASD were investigated using a single-case multiple-probe design. For the reading materials, one grade-level science textbook was selected based on its alignment with secondary science standards and participants' interests and daily living activities. The selected textbook was converted to an eBook format that included various auditory and visual features (e.g., text-to-speech, highlighted keywords, summarized sentences, pictures) using Microsoft PowerPoint and Google Cloud Text-to-Speech and was presented on an iPad screen. The shared reading intervention included before, during, and after reading strategies (i.e., pre-teaching a key vocabulary word, reading and sharing information, retelling). The results of this study indicated that all three participants demonstrated noticeable improvements in reading comprehension. Despite the longer duration of intervention sessions, participants exhibited similar or better task engagement with intervention as compared to baseline sessions.

Taken together, these findings provide additional support for the efficacy of technology to teach reading skills to students with ASD. Major findings, implications for research and practice, limitations, and directions for future research are discussed.

CHAPTER I: GENERAL INTRODUCTION

Students with ASD have comprised an increasing proportion of students receiving special education services. Based on recent estimates (Centers for Disease Control and Prevention, 2018), the prevalence of ASD has increased from 1 in 68 children to 1 in 59 children within two years. Given that most students with ASD are educated in regular schools and more than half of them spend at least 40% of the time in general education classrooms (U.S. Department of Education, National Center for Education Statistics, 2016), teachers are required to select and provide effective interventions to successfully support students with ASD to be successful in classroom. Moreover, educational policies (e.g., Every Student Succeeds Act, 2015; Individuals with Disabilities Education Improvement Act, 2004; No Child Left Behind, 2001) emphasized that all students, including students with ASD, should be provided evidence-based practice to work toward the general education curriculum. As academic expectations for students with ASD have been increased, there is an increased need to identify effective practices for teaching academic skills to students with ASD (e.g., Fleury et al., 2014; Ledbetter-Cho, O’Reilly, Lang, Watkins, & Lim, 2018; King, Lemons, & Davidson, 2016).

Although there is a general assumption that students with ASD have a relative strength in academic subject areas (Nation, Clarke, Wright, & Williams, 2006), unique challenges that are driven from the disorder (e.g., social-communication deficits, restrictive and repetitive behavior) may contribute to difficulties with achieving academic outcomes. Students with ASD can have a wide range of reading skills, but they are more likely to be placed at high risk for literacy failure due to delayed language development (e.g., Bishop & Snowling, 2004; Nation et al., 2006). Students with ASD may demonstrate a lower level of reading skills than IQ-matched controls (Minshew, Goldstein, Taylor, & Siegel, 2004) and exhibit poor comprehension, as opposed to well-developed decoding skills (Nation et al., 2006; O’Conner & Klein, 2004). In addition to difficulties learning to read, minimal appropriate task engagement and lack of motivation of students with ASD during classroom activities are often considered as critical factors of poor academic outcomes (Fleury et al., 2014; Koegel et al., 2010).

Reading in content areas, such as science, may exacerbate the existing reading challenges some students already have (Gajria, Jitendra, Sood, & Sacks, 2007). O’Connor and Klein (2004) suggested that students with ASD may have difficulties comprehending content due to limited ability to integrate information, understand anaphoric references, and monitor comprehension. Given that comprehending science contents requires extensive vocabulary and background knowledge (Knight et al., 2015), it might be expected that students with ASD would struggle to comprehend science contents and would not perform as well as their peers in science without individualized explicit instructions.

One increasingly popular option for providing individualized instruction to students with ASD is incorporating technology into academic interventions. Technology devices (e.g., computer, smartboard, iPad) are widely available and have various features that make them potentially desirable for use in educational settings with students with ASD (Ledbetter-Cho et al., 2018). Students with ASD have a relative strength in the ability to engage with visual stimuli (Dawson, 1996; Fleury et al., 2014; Mesibov & Shea, 2010; Stringfield, Luscre, & Gast, 2011). Students with ASD may prefer electronic devices over other forms of presentation (Shane & Albert, 2008) and may take advantage of capitalizing on visual supports through technology (Mayes & Calhoun, 2003). Given that using technology enables teachers to easily embed various types of stimuli (e.g., visual, auditory), technology-based academic interventions can be a particularly appealing option for educators who teach students with ASD.

In this dissertation, the effects of using technology to teach reading skills to students with ASD were investigated. First, the quality of the research literature on technology-based reading interventions for students with ASD was evaluated. Reviewed articles were appraised according to the WWC quality indicators for group design and single-case design studies. Additionally, descriptive analysis was conducted to collect information regarding characteristics of the participants, settings, implementers, targeted reading outcomes, technology, and its results. This quality review aimed to evaluate the quality of extant research evidence on technology-based reading interventions for students with ASD and provide practical information regarding how technology can be incorporated into reading interventions for this population to educators.

Second, a meta-analysis of single-case research on technology-based reading interventions for individuals with ASD was conducted. The purpose of this meta-analysis was to quantify the effects of technology-based reading interventions for students with ASD. Additionally, data were aggregated across relevant variables (i.e., participant characteristics, reading materials, technology, intervention components, targeted reading outcomes) and used to determine the areas in which these interventions were effective.

Third, a single-case research study was conducted to address how technology can be practically applied to teach academic reading skills to students with ASD. The purpose of this single-case study was to determine if there is a functional relationship between adapted science eBooks within shared reading and improvements in comprehension of science content and task engagement of students with ASD. Each participant was given an adapted grade-level science eBook consisting of visual and auditory supports (e.g., text-to-speech, highlighted keywords, summarized sentences, pictures). During shared reading, students were taught intensive comprehension strategies, such as pre-teaching a key vocabulary word before reading, reading and sharing information during reading, and retelling after reading. The effects of using adapted science eBooks within shared reading were evaluated using a single-case multiple-probe design across participants. The participants were expected to demonstrate improved reading comprehension of science content and task engagement during reading. Inter-observer agreement (IOA), treatment fidelity, and social validity data were collected, and implications for practice and future research were discussed.

CHAPTER II: A SYSTEMATIC QUALITY REVIEW

Introduction

The identification of evidence-based practices (EBPs) has become a critical component of the movement for accountability in education (Maggin, Briesch, & Chafouleas, 2013). Students with autism spectrum disorder (ASD) are increasingly educated in general education settings (Cihak, Fahrenkrog, Ayers, & Smith, 2010), and many have potential to achieve at a high level academically and to benefit from the general education curriculum (Zager & Shamow, 2005). Given the increased emphasis on using EBPs and required access to grade-level academic standards (e.g., Every Student Succeeds Act [ESSA], 2015), teachers must provide effective instruction for students with ASD to achieve meaningful academic outcomes in their classrooms. However, the adoption of effective practices requires distinguishing scientifically validated instructional strategies from those lacking sufficient empirical evidence (Slavin, 2006). The relatively limited evidence base on high-quality academic interventions for students with ASD may contribute to teachers' difficulty with adopting EBPs for this group of learners (Finnegan & Mazin, 2016).

Students with ASD often exhibit unique challenges in reading and require individualized reading instruction (Nation, Clarke, Wright, & Williams, 2006). Reading is a complex metacognitive process that demands a variety of skills ranging from decoding each individual word to understanding the intended meaning of a text (Head, Flores, & Shippen, 2018; Nation et al., 2006). Core deficits in social-communication skills in students with ASD may pose barriers to learning to read (Nation et al., 2006). For instance, delayed oral language development may place students with ASD at a high risk of literacy failure (Bishop & Snowling, 2004). Students with ASD may exhibit difficulties using phonological-based strategies to read words (Frith &

Snowling, 1983; Nation et al., 2006) and present with unique discrepancies between well-developed decoding skills and poor comprehension skills (Brown, Oram-Cardy, & Johnson, 2013; Frith & Snowling, 1983; Griswold, Barnhill, Myles, Hagiwara, & Simpson, 2002; Minshew, Goldstein, Taylor, & Siegal, 1994; Nation et al., 2006). Overall reading comprehension may be impacted by additional challenges due to limited skills in integrating information, understanding anaphoric references, and students self-monitoring their reading comprehension (O'Conner & Klein, 2004).

To ameliorate these reading difficulties, interventions that build on strengths and interests of students with ASD may prove to be effective in promoting positive reading outcomes. Researchers have indicated that children with ASD often prefer electronic devices over other forms of presentations (Shane & Albert, 2008). Incorporating technology into academic instruction may leverage this preference and capitalize on the use of visual supports for this population (Mayes & Calhoun, 2003). As an example of technology-based interventions, computer-assisted instruction (CAI) has been applied to literacy instruction for students with ASD (e.g., Armstrong & Hughes, 2012; Bossler & Marssaro, 2003, Grindle, Hughes, Saville, Huxley, & Hastings, 2013). Currently, there are several educational software programs (e.g., Headsprout) developed to teach literacy skills, and research suggests those CAIs yielded positive reading outcomes for students with ASD (Grindle et al., 2013; Whalen et al., 2010). Technology was also successfully incorporated into interventionist-directed interventions to present electronic story maps (e.g., Browder, Root, Wood, & Alison, 2017) or reading materials including visual and audio support (e.g., Alison, Root, Browder, & Wood, 2017; Spooner, Ahlgrim-Delzell, Kemp-Inman, & Wood, 2014; Spooner, Kemp-Inman, Ahlgrim-Delzell, Wood, & Ley Davis, 2015).

There is a growing body of research on technology-based interventions for students with ASD (Kagohara et al., 2013; Knight, McKissick, & Saunders, 2013; Pennington, 2010; Ramdoss et al., 2011; Root, Stevenson, Davis, & Geddes-Hall, 2017). Pennington (2010) reviewed 15 articles that applied CAI to teach academic skills to students with ASD. Findings of this study indicated that CAI was effective for teaching a limited set of academic skills, but functional relations were found in a few of the single-case design studies and none of the group comparison studies. Ramdoss et al. (2011) reviewed CAI interventions implemented to improve literacy skills in students with ASD. After reviewing 12 CAI studies, the authors noted that the effects of CAI on literacy skills were inconsistent and that future studies would be required to determine the efficacy of CAI.

Knight et al. (2013) reviewed 25 articles that used technology to teach academic skills. Findings of this review indicated that using technology would be considered as a promising practice to teach academic skills to students with ASD and had a low to moderate level of evidence. Kagohara et al. (2013) conducted a systematic review of 15 studies that included iPads, iPods, and related devices (e.g., iPhones) in teaching programs for individuals with developmental disabilities. The reviewed studies reported positive outcomes, but only one of the reviewed articles examined the effects on academic outcomes. More recently, Root et al. (2017) evaluated the research evidence of CAI studies based on the National Technical Assistance Center on Transition (NTACT, 2015) quality indicators. Findings of this quality review suggested CAI as an evidence-based practice to teach academic skills to students with ASD.

Previous literature reviews have mostly focused on CAI interventions or investigated effects on improving overall academic skills, but none has been conducted specifically on technology-based reading interventions for students with ASD. In addition, only one of the literature reviews (i.e., Root et al., 2017) controlled for experimental rigor. To increase the likelihood that educators adopt scientifically validated instructional strategies, this literature review synthesized characteristics of technology-based reading interventions with high-quality research evidence.

The purpose of this literature review was to determine the quality of the research on technology-based reading interventions for students with ASD and summarize the study characteristics. Both group design and single-case design studies were systematically aggregated, and the experimental rigor of each article was analyzed based on the quality indicators suggested by What Works Clearinghouse (WWC). Additionally, descriptive information of high-quality research studies was summarized to identify characteristics of technology-based reading interventions for students with ASD.

Research Questions

This study sought to answer the following research questions:

1. What is the quality of the evidence base for technology-based reading interventions for students with ASD according to the WWC standards for group design and single-case design research?
2. What are the study characteristics of technology-based reading interventions for students with ASD that met the WWC standards without and with reservations?

Method

Search Procedures

To systematically retrieve literature on technology-based reading interventions for students with ASD, the following procedures were used. The overall search procedures are displayed in Figure B1.

Electronic search. Four major electronic databases (i.e., *Academic Search Premier*, *Education Source*, *ERIC*, and *PsycINFO*) were searched for relevant articles using the following Boolean phrase: "autis* AND (technolog* OR multimedia* OR computer* OR iPad* OR iPod* OR smart* OR tablet* OR AAC OR etext* OR ebook*) AND (reading* OR academic* OR literacy OR comprehension* OR vocab* OR word*)". The electronic search was limited to scholarly peer-reviewed journals, but there was no restriction on publication date and yield 3815 articles.

Title and abstract review. The title and abstract of each article were reviewed to screen articles that were (a) published in English, (b) empirical (e.g., single-case studies, group design studies), (c) present in educational intervention targeting reading outcomes, and (d) with participants with ASD. If the title and abstract did not specify these variables, the article was kept for the full-text review. Through this title and abstract screening process, 63 articles were identified.

Full-text review. Each of 63 studies identified in the title and abstract review was evaluated to determine if it met the inclusion and exclusion criteria for this review. To be included for this review, articles had to meet all of the following criteria. First, the study was published in an English peer-reviewed scholarly journal. Second, the study applied experimental research design including a group design (e.g., randomized controlled trials [RCTs], quasi-experimental designs [QEDs]) or single-case design (e.g., reversal design, multiple-baseline design, multiple-probe design, alternating treatment design). If group design studies did not include control groups (e.g., pre- and posttest design for one group), these studies were excluded for this review. Qualitative studies, validity studies, perception studies, literature reviews, theoretical articles, dissertations, and these were also excluded. Third, at least one of the participants was diagnosed with ASD. Fourth, one or more of the dependent variables was an outcome related to reading (e.g., comprehension, vocabulary, phonics, phonemic awareness, or fluency). Learning of letters or words was also considered a reading outcome. Picture-sound matching skills without pairing any letters or words were not considered as reading outcomes. Fifth, the study included at least one type of technology (e.g., computer, smart phone, iPad, iPod, tablet PC, smart board) as part of the intervention or as an instructional tool. Studies using high-tech alternative and augmentative communication (AAC) were excluded in the review if the AAC was used only to facilitate communication skills. However, if a study applied the AAC device for an instructional purpose, such as presenting sight words and producing sounds to teach decoding skills, this study was included in this review. After reviewing full-text, 28 articles were identified for inclusion in this review.

Additional literature search. We conducted an ancestral search of the references of 28 articles to find additional relevant studies (*n* = 1134). Through this search, three more studies were identified for inclusion. Further, the list of included studies in this review was compared to the included studies in relevant previous literature reviews (i.e., Kagohara et al., 2013; Knight et al., 2013; Pennington, 2010; Ramdoss et al., 2011; Root et al., 2017; *n* = 87). No additional studies were identified by reviewing included studies in previous reviews. Throughout the systematic article search procedures, a total of 31 articles were identified and reviewed for this study.

Quality Review

Each of the included articles was reviewed based on the quality standards developed by WWC (Version 4.0, Kratochwill et al., 2010/2013). Articles utilizing group design (i.e., RCTs, QEDs) and single-case design (i.e., reversal design, multiple-baseline design, multiple-probe baseline design, alternating treatment design) research were evaluated separately. A study can receive one of the three following ratings: (a) meet the standards without reservations, (b) meet the standards with reservations, and (c) does not meet the standards.

Group design standards. WWC group design standards can only be applied to RCTs and QEDs with control groups. Therefore, QED studies with no control groups were excluded from the full-text review procedures for this review. A total of four group design studies were identified and reviewed based on the WWC group design standards. The WWC also developed separate design standards to review (a) group design studies that assigned individuals (e.g., students) to a condition and (b) studies that assigned clusters (e.g., classroom, schools) to a condition. The WWC standards for individual-level group design studies and cluster-level group design studies are displayed in Figure B2 and Figure B3, respectively.

Individual-level assignment. For group design studies that used individual-level assignment, the WWC standards include three major domains for review: (a) study design, (b) sample attrition, and (c) baseline equivalence (see Figure B2). Group design studies were divided into RCTs and QEDs contingent upon randomized control. Only RCTs with low attrition rates were eligible to meet WWC group design standards without reservations. High-attrition RCTs or QEDs were eligible to meet WWC group design standards if equivalence was established at baseline for the groups in the analytic sample. QEDs or high-attrition RCTs that did not demonstrate the baseline equivalence standard did not meet WWC group design standards, and those studies were excluded from the further narrative synthesis in this review.

Cluster-level assignment. For group design studies that used cluster-level assignment, the WWC design standards included seven criteria (see Figure B3). The WWC standards initially consider the rigorousness of evidence of an intervention's effects on individuals (i.e., Steps 1 to

4). If the effects on individuals were not credibly demonstrated, the evidence of the intervention's effects on clusters were reviewed (i.e., Steps 5 to 7). To receive the highest rating (i.e., to meet WWC standards without reservations), the study should be an RCT. Cluster RCTs that have limited potential bias from changes in the composition of clusters and individuals within clusters after the random assignment were eligible to meet WWC standards without reservations. Cluster RCTs with a high risk of bias and all cluster QEDs were considered to meet WWC standards with reservations if the study satisfied a requirement for the baseline equivalence individuals in the analytic intervention and comparison groups.

Single-case design standards. For this review, the adapted WWC design standards were used to evaluate the rigorousness of single-case research studies. The basic standards of WWC include three major domains to review: (a) systematic manipulation of independent variable (IV), (b) measuring inter-assessor agreement (IAA), and (c) attempts to demonstrate effect overtime and data points per phase. In addition to these three major domains, measures of treatment fidelity were also examined. Treatment fidelity is typically defined as the degree to which an intervention is implemented as planned (Smith, Daunic, & Taylor, 2007). Given that a high level of treatment fidelity (e.g., 80% or above) refers to accurate and consistent dissemination of intervention, measuring treatment fidelity can be considered as a critical factor in determining the quality of research in that without treatment fidelity. Without treatment fidelity, it is difficult to ascertain with confidence whether the study outcomes were caused by the intervention or by factors incidental to the intervention (Bellg et al., 2004). In this review, the treatment fidelity domain was evaluated based on the data the authors provided in the articles. The majority of studies measured treatment fidelity, which could measure differently based on the roles of technology and interventionist of each study. The treatment fidelity was indicated by (a) the proper operation of technology (e.g., computer was set up properly), (b) the participant's or interventionist's adherence to protocol of technology use (e.g., the interventionist monitored the participant's performance and reminded the participant to stay focused on using the technology), and (c) the interventionist's adherence to protocol of instructional delivery (e.g., the interventionist used 3 sec time delay to prompt the participant to read a sight word presented on an iPad screen). The adapted WWC standards for single-case design studies are presented in Table A1, and the coding procedures for each design standard are presented below.

Single-case design standard 1: Independent variable. The first design standard evaluated whether the independent variable was systematically manipulated for minimizing threats to internal validity with the researcher determining when and how the conditions changed. If a study described criteria for introducing intervention and changing phases, this study was considered to meet the standard without reservations.

***Single-case design standard 2: Inter-assessor agreement*.** The *Design Standards 2-1, 2-2,* and *2-3* measure the quality of IAA. To meet this standard, the IAA data should be collected by two or more evaluators over time (i.e., *Standard 2-1),* in each phase and in 20% of data points (i.e., *Standard 2*-2). In addition, the average of collected IAA should be 80% or higher and at least .60 if measured by Cohen's kappa (i.e., *Standard 2-3*).

***Single-case design standard 3: Treatment fidelity*.** The *Design Standard 3* evaluated the quality of treatment fidelity. If a study measured treatment fidelity at least 20% of the intervention sessions across conditions (i.e., *Standard 3-1*) and the average of treatment fidelity data was at or above 80% (i.e., *Standard 3-2*), this study met the *Design Standard 3*.

***Single-case design standard 4: Number of phases and data points*.** The *Design Standard 4* assessed whether the number of phases and data points per phase were sufficient to demonstrate the effects of the intervention. Specific rating criteria for the reversal/withdrawal design, alternating treatment design, and multiple-baseline/probe designs are presented in Table A1. For the multiple-probe design studies, three additional standards were given. Only multiple-probe design studies that met both the basic standard and additional standard were eligible to meet the *Design Standard 4*.

***Single-case final rating*.** Because the *Design Standard 3* (i.e., treatment fidelity) was an additional standard for this review, the rating for the *Standard 3* was not considered for the final ratings but presented in the results section to provide more detailed information. Ratings for three original standards suggested by WWC (i.e., *Design Standards* 1, 2, and 4) were counted for the final ratings. If an article met all the three original design standards without reservation (i.e., all ratings were “Y”), this study was considered *Meets Standards without Reservations*. If the article met one or more of the standards with reservations (i.e., Ratings included both “Y” and “R”), this article was rated as *Meets Standards with Reservations*. The article was considered as *Does Not Meets Standards* if the article did not meet one of the design standards (i.e., one or more “N”).

Narrative Synthesis

After articles with a high quality of research evidence were identified through the quality evaluation, narratives of the identified articles were reviewed to (a) summarize study characteristics of technology-based reading interventions for students with ASD and (b) identify types and roles of technology used for the high-quality research studies.

Study characteristics. The articles that met the WWC standards without and with reservations were coded for the following characteristics: (a) participants, (b) settings, (c) design, (d) technology, (e) intervention, (f) interventionist, (g) outcomes, (h) effects, and (i) results.

Participants. The demographic information of participants was coded in four parts (i.e., the number of participants, the number of male participants, the number of participants with ASD, the age range). The age group of participants were further coded based on the specific age provided by the authors (i.e., pre-K = 3–5 years; elementary = 6–11 years; middle = 1–15 years; high = 16–19 years; adult = above 20 years).

Setting. The setting for intervention was coded based on the description the article provided (e.g., self-contained classroom, home, university laboratory).

Design. The study design was recorded. Because all reviewed articles applied either group design or single-case research design, the study design was specified to one type of group designs (e.g., RCT, QED) or single-subject designs (e.g., alternating treatment, multiple-baseline).

Technology. The use of technology was coded based on the type of hardware (e.g., computer, iPad) and software (e.g., PowerPoint, SMART notebook).

Intervention. The intervention referred to the independent variable of each experimental study. If one study compared effects of two types of interventions, both independent variables were listed. If a reading intervention package included several subcomponents (e.g., time delay, modeling, reinforcement), all of the subcomponents were coded as well.

Interventionist. The person who delivered the intervention to participants was coded as the interventionist (e.g., teacher, researcher, parent). Researchers included all implementers who were specially assigned to execute the research study, such as graduate students, research assistants, and experimenters. In the CAI studies, the computer program delivered reading instruction without any human-delivered instructions. If the article reported that a person delivered an initial direction to start the CAI program or monitored the participants in the same classroom, that person was coded as the interventionist.

***Outcomes*.** The outcomes referred to operationally defined and monitored dependent variables through the experiment. The dependent variables were coded based on the operational definition (e.g., percentage of correct responses) with measurements (e.g., comprehension quiz).

***Effects*.** The effects of intervention on each dependent variable were coded in *strong*, *moderate,* or *weak*. For group design studies, the evidence was coded based on the effect size that the authors provided (e.g., Cohen's d). For single-case studies, the level of evidence was coded based on the causal relationships for each outcome variable as suggested by WWC (Version 4.0, Kratochwill et al., 2010/2013). To provide *strong* evidence, the article was required to include at least three demonstrations of the intervention effects along with no effect. If an article provided three demonstrations but also included at least one demonstration of a no effect, this article was considered to have *moderate* evidence of a causal relationship. If an article did not include three demonstrations of an effect, this article was rated to have *no effect*. For alternating treatment design studies, each participant's data was initially coded for strong or no effect based on the visual analysis and the ratio between strong and no effect was considered for final ratings. For example, if an alternating treatment design study demonstrated strong effects for three participants and no effect for one participant, this study was considered to have moderate overall effects with a 3:1 ratio.

***Results*.** The results of each article were summarized based on the information the authors provided. Interobserver agreement (IOA) and treatment fidelity were also recorded if they were measured in the reviewed article measured those.

Technology usage. After extracting basic characteristics of technology-based reading interventions with high-quality research evidence, the use of technology was further investigated. Technology usage was coded for each of the following variables: (a) hardware, (b) software, (c) key features, (d) primary role, and (e) availability. Within each of these variables, additional coding occurred. The use of technology was grouped based on the types of hardware (e.g., computer, iPad). Software was coded for the program that was installed and run on the hardware (e.g., Classroom Suite, SMART notebook). Key features of the software program were summarized. The general information regarding the software (e.g., AAC application, commercially developed CAI package) and its usage (e.g., presenting words with audio voice) were listed.

The primary role of technology was categorized into one of three areas: (a) If the software program was a tool to develop reading materials or individualized CAI or iPad-assisted instruction (IAI) programs (e.g., Vizard, PowerPoint), the role of technology was coded for *developing materials*; (b) If a CAI or IAI program delivered reading instructions without any other supports provided by an interventionist, the role of technology was coded as *delivering instruction*; and (c) If the use of technology was accompanied by a human implementer's instruction as a part of the intervention (e.g., presenting story map template, providing audio voice), the role of technology was considered as *supporting instruction*.

If a study used technology for two purposes (i.e., developing materials, delivering instruction), only the primary role of the software program was coded. For instance, if a study used PowerPoint to develop an individualized CAI program and used the researcher-developed program to deliver reading instruction, the primary role of the software (i.e., PowerPoint) was considered to be *developing materials*. Finally, the availability of each software program was coded based on the cost for using the program (e.g., monthly service fee, one-time purchase fee for downloads or licenses). This information was retrieved from each manufacturer's official website in January 2019.

Inter-rater Agreement

Inter-rater agreement (IRA) data on article search procedures, quality evaluation, and narrative synthesis were obtained by trained second coders. All second coders (i.e., one undergraduate student, two doctoral students in special education) were trained by the first author until they reached 90% or higher agreement on three consecutive articles. Detailed procedures for training second coders and obtaining IRA are described below.

Article search. Following the training, each coder independently reviewed at least 25% of articles for the title and abstract search (*n* = 154) and 100% of articles for the full-text review (*n* = 15) and ancestral search (*n* = 28). IRA was calculated by dividing the agreed articles by agreed and disagreed articles and multiplying by 100 (Kennedy, 2005). The calculated IRA was 92% for the title and abstract search, 91% for the full-text review, and 100% for the ancestral search. After discussing the disagreements, all coders reached 100% of agreements.

Quality review. Following the training, three doctoral students in special education independently evaluated 100% of the reviewed articles (*N* = 31) based on WWC design standards. IRA was for quality evaluation was calculated using point-by-point agreement (Kazdin, 1982) for each sub-standard. The initial IRA was 100% for the group design studies (*n* = 4) and 93.8% for the single-case design studies (*n* = 27). After discussing all disagreements, 100% of IRA was obtained.

Narrative synthesis. One undergraduate student and one doctoral student in special education also independently reviewed and extracted descriptive information from the articles that met the WWC design standards without and with reservations (*n* = 16). IRA was calculated by using point-by-point agreement (Kazdin, 1982) for each study variable. If both coders extracted the same descriptive information for a study variable, it was considered as the agreement. The IRA for the narrative synthesis was 98%. In instances of disagreement, the article was discussed until the coders reached an agreement.

Results

Quality Review

A total of 31 articles were evaluated based on the WWC design standards. The results of quality evaluation of group design studies (*n* = 4) and single-case design studies (*n* = 27) are presented in Table A2 and Table A3, respectively.

Group design studies. The four group design studies assigned participants to experimental or control group either in an individual-level (*n* = 3, 75%) or a cluster-level (*n* = 1, 25%). The individual-level group design studies and cluster-level group design studies were reviewed using different procedures as described in Figure B2 and Figure B3. Two of the three individual-level group design studies (67%) met the design standards with or without reservations, and the one cluster-level group design study did not meet the standards.

Individual-level assignment. Three group design studies that applied the individual-level assignment included two RCTs (Ahlgrim-Delzell, Browder, & Wood, 2014; Moore & Calvert, 2000) and one QED (Serret, Hun, Thümmler, Pierron, Santos, Bourgeois, & Askenazy, 2017). One of the two RCT studies (Ahlgrim-Delzell et al., 2014) reported a low attrition rate and was eligible to receive the highest rating (i.e., Meets the standards without reservations). Another RCT study (Moore & Calvert, 2000) did not provide sufficient information to determine the attrition level and baseline equivalence, so this study was not able to meet the standards. One

QED study (Serret et al., 2017) reported mean scores and standard deviations on pretest across conditions, and only one dependent variable (i.e., word segmentation) met the baseline equivalence criteria suggested by WWC. This QED study was considered to meet the WWC standard with reservation, and the other dependent variables that did not meet the baseline equivalence were excluded from the narrative synthesis.

Cluster-level assignment. One out of four group design studies (25%) utilized the cluster-level RCT. Due to the high attrition in the experimental group and insufficient information for determining the baseline equivalence, this study did not meet the WWC standards.

Single-case design studies. The 27 single-case designs included (a) reversal/withdrawal design (*n* = 1, 0.4%), (b) alternating treatment design (*n* = 6, 22%), (c) multiple-baseline design (*n* = 6, 22%), and (d) multiple-probe design (*n* = 14, 52%) studies.

Single-case design standard 1: Independent variable. All 27 reviewed articles met the Design Standard 1. All studies systematically manipulated technology-based reading interventions only for the intervention phase and provided sufficient information regarding when and how the independent variable condition changed.

Single-case design standard 2: Inter-assessor agreement. More than half of the reviewed studies (*n* = 15, 55%) met the Design Standard 2 without reservations. Six studies (22%) met this standard with reservations because the IAA data was collected at least 20% of the sessions but the IAA was not measured across conditions or it was not specified. The other six studies (22%) did not meet the IAA standard. Those studies did not report IAA data or collected IAA in less than 20% of the sessions.

Single-case design standard 3: Treatment fidelity. The majority of studies (*n* = 20, 74%) measured treatment fidelity to ensure that the interventionist consistently implemented the intervention as planned. More than 40% of reviewed single-case studies (*n* = 12, 44%) met the *Design Standard 3* without reservations. In the eight studies (30%) that met the *Design Standard 3* with reservations, the treatment fidelity data was collected only during intervention sessions or not specified if it was collected across conditions. Seven studies (26%) did not provide treatment fidelity data.

The treatment fidelity was measured differently based on the roles of technology. In the majority of studies that measured treatment fidelity (*n* = 12, 60%), the use of technology was paired with interventionist-directed instructions (Ahlgrim-Delzell et al., 2014; Alison et al., 2017; Browder et al., 2017; Ganz, Boles, Goodwyn, & Flores, 2014; Hetzroni & Shalem, 2005; Knight, Wood, Spooner, Browder, & O'Brien, 2015; Leytham, Pierce, Baker, Miller, & Tandy, 2015; Mechling, Gast, & Langone, 2002; Spooner et al., 2014; Spooner et al., 2015; van der Meer et al., 2015; Whitcomb, Bass, & Luiselli, 2011). In those studies, the treatment fidelity was measured by ensuring the interventionist's adherence to protocol of instructional delivery. In the other eight studies that measured treatment fidelity (40%), computer- or iPad-based software programs served as interventionists (Coleman-Martin, Heller, Cihak, & Irvine, 2005; Coleman, Hurley, & Cihak, 2012; Coleman, Cherry, Moore, Park, & Cihak., 2015; El Zein, Gevarter, Bryant, Son, Bryant, Kim, & Solis, 2016; Lee & Vail, 2005; McMahon, Cihak, Wright, & Bell, 2016; Saadatzi, Pennington, Welch, Graham, & Scott, 2017; Smith, Spooner, & Wood, 2013). In almost all of those studies (*n* = 7), treatment fidelity was measured by using a checklist to ensure the interventionist's adherence to protocol of technology (e.g., set up a computer, remind student to participate in the activity, provide oral directions for completing the probe). In Saadatzi et al.

(2017), treatment fidelity directly measured proper operation of the CAI program during the intervention sessions.

Single-case design standard 4: Number of phases and data points. Of the reviewed single-case studies, 67% met the *Design Standard 4* without reservations (*n* = 7, 26%) or with reservations (*n* = 11, 41%). The other 33% of the studies did not meet this standard (*n* = 9) due to insufficient demonstrations of effects (e.g., multiple-baseline design across two participants) or data points per phase (e.g., collected two data points for baseline).

All of the six alternating treatment design studies (100%) meet the *Design Standard 4* without reservations (Armstrong & Hughes, 2012; Chen, Wu, Lin, Tasi, & Chen, 2009; Coleman et al., 2012; Coleman et al., 2015; El Zein et al., 2016; Ganz et al., 2014). There were 14 multiple-probe design studies, and only one of the multiple-probe design studies (7%) met the *Design Standard 4* (Spooner et al., 2015). Half of the multiple-probe design studies (*n* = 7, 50%) met the standard with reservations (Ahlgrim-Delzell et al., 2014; Alison et al., 2017; Browder et al., 2017; Hetzroni & Shalem, 2005; Lee & Vail, 2005; Smith et al., 2013; Spooner et al., 2014). These studies included 1 to 2 probes within first 3 sessions across conditions, 1 to 2 probes prior to intervention across conditions, and/or 1 probe after the intervention in some conditions not receiving intervention. The other six multiple-probe design studies (43%) did not meet the *Design Standard 4*. There were no multiple-baseline design studies that received the highest rating for the *Design Standard 4*. Four out of six reviewed multiple-baseline design studies (67%) met the *Design Standard 4* with reservations (Bosseler & Massaro, 2003; Morlock, Reynolds, Fisher, & Comer, 2015; Saadatzi et al., 2017; Yaw, Skinner, Parkhurst, Taylor, Booher, & Chambers, 2011), and two studies (33%) did not meet this standard.

Single-case design final rating. About half of the reviewed single-case design studies (*n* = 14, 52%) met the WWC design standards without reservations (Coleman et al., 2015; El Zein et al., 2016; Ganz et al., 2014; Spooner et al., 2015) or with reservations (Alison et al., 2017; Browder et al., 2017; Coleman et al., 2012; Lee & Vail, 2005; Morlock et al., 2015; Saadatzi et al., 2017; Smith et al., 2013; Spooner et al., 2014; Yaw et al., 2011). The other half of the single-case studies (*n* = 13, 48%) did not meet at least one of the three standards (i.e., *Design Standard 1*, *2*, and *4*), so they could not meet the overall WWC design standards.

Narrative Synthesis

Study narratives of the technology-based reading intervention studies with high research rigor (*n* = 16) were synthesized. The overall study characteristics and the specific technology usage are summarized in Table A4 and Table A5, respectively.

Study characteristics. Descriptive information of 16 articles were summarized based on (a) participants, (b) setting, (c) design, (d) technology, (e) intervention, (f) interventionist, (g) outcomes, (h) effects, and (i) results.

Participants. A total of 102 students participated in the 16 studies with high-quality research evidence. Eighty-two students (80%) were male, and the other 20 students (20%) were female. Seventy-five of them (74%) were students with ASD. The majority of participants (*n* = 79, 77%) were elementary school–aged students (i.e., 6 to 11 years old). Fourteen of the participants (14%) were middle schoolers (i.e., 12 to 15 years old). Only a few participants were high school students (i.e., 16 to 19 years old, *n* = 4, 4%), pre-K aged students (i.e., 3 to 5 years old, *n* = 3, 3%), or adults above 20 years old (*n* = 2, 2%). Ahlgrim-Delzell et al. (2014) included AAC users, and Alison et al. (2017) included English language learners (ELLs) who are using English as a second language.

Setting. The majority of studies (*n* = 14, 88%) were conducted in separated classrooms without typically developing peers, including the self-contained classroom (*n* = 8, 50%), empty classroom in school (*n* = 4, 25%), and university lab (*n* = 1, 6%). Serret et al. (2017) implemented technology-based reading intervention at the participant's home, and Ganz et al. (2014) implemented the intervention at home for one of the participants. Only one study (6%) was implemented in a general education classroom during the students' independent work time (Smith et al., 2013). However, the typically developing peers did not take part in any of the intervention procedures.

Design. Identified technology-based reading intervention studies with high research rigor (*n* = 16) included 2 group design studies (13%) and 14 single-case design studies (88%). Specifically, one RCT study (Ahlgrim-Delzell, Browder, Wood, Stanger, & Preston, 2016) and one QED study (Serret et al., 2017) were included (6%). Six studies (38%) utilized single-case multiple-probe design (Alison et al., 2017; Browder et al., 2017; Lee & Vail, 2005; Smith et al., 2013; Spooner et al., 2014; Spooner et al., 2015). A single-case alternating treatment design was used in five studies (31%), and four of them compared the effects of technology-based interventions with interventionist-directed interventions (Armstrong & Hughes, 2012; Coleman et al., 2012; Coleman et al., 2015; El Zein et al., 2016). One alternating treatment design study (Ganz et al., 2014) compared the effects of iPad-based sessions with the nontreatment condition (i.e., iPad was turned off). Three studies (19%) were single-case multiple-baseline studies (Morlock et al., 2015; Saadatzi et al., 2017; Yaw et al., 2011).

Technology. Two types of technology devices were used in 16 studies. Half of the studies (*n* = 8, 50%) incorporated iPads into reading interventions, and the other half of the studies (*n* = 8, 50%) used computers. GoTalk Now was the most common software program used for technology-based reading intervention (*n* = 4, 25%), and PowerPoint was applied in two studies (13%). Wynn Wizard, SMART notebook, Classroom Suite, Space Voyage, iCommunicate, Word Wizard, GemIIni, Vizard, SEMA-TIC, and Keynote were each utilized in one of the reviewed studies (6% each).

***Intervention*.** Half of reviewed studies (*n* = 8, 50%) delivered reading interventions through CAI or IAI programs (Coleman et al., 2012; Coleman et al., 2015; El Zein et al., 2016; Lee & Vail, 2005; Saadatzi et al., 2017; Serret et al., 2017; Smith et al., 2013, Yaw et al., 2011). In the other half of the studies (*n* = 8, 50%), systematic instruction was paired with technology-based reading interventions. Time delay was used in eight studies (Ahlgrim-Delzell et al., 2016; Alison et al., 2017; Browder et al., 2017; Coleman et al., 2012; Lee & Vail, 2005; Saadatzi et al., 2017; Spooner et al., 2014; Spooner et al, 2015). Seven studies (44%) included systematic prompting strategies as a reading intervention component (Ahlgrim-Delzell, et al., 2016; Alison et al., 2017; Browder et al., 2017; Coleman et al., 2015; Ganz et al., 2014; Spooner et al., 2014; Spooner et al., 2015). Modeling was provided in six studies (Alison et al., 2017; Browder et al., 2017; Coleman et al., 2015; Ganz et al., 2014; Saadatzi et al., 2017; Spooner et al., 2014).

The majority of studies included audio or visual supports. More than half of the reviewed articles (*n* = 10, 63%) embedded audio supports (e.g., text-to-speech) into technology-based reading interventions (Ahlgrim-Delzell et al., 2016; Alison et al., 2017; Browder et al., 2017; Coleman et al., 2015; Lee & Vail, 2005; Saadatzi et al., 2017; Smith et al., 2013; Spooner et al., 2014; Spooner et al., 2015; Yaw et al., 2011). Eight studies (50%) included a form of visual supports, such as graphic organizers (Browder et al., 2017), pictures paired with target words or sentences (Lee & Vail, 2005; Serret et al., 2017; Smith et al., 2013; Spooner et al., 2014), highlighted keywords (Armstrong & Hughes, 2012), or visual script (e.g., Ganz et al., 2014).

In seven studies (41%), planned reinforcement was delivered during or after the reading intervention. Verbal praises or reinforcement slides were delivered by the CAI programs (Coleman et al., 2012; Coleman et al., 2015; Lee & Vail, 2005; Saadatzi et al., 2017) or the interventionist (Spooner et al., 2014). Two studies delivered preplanned reinforcement after the intervention sessions (Browder et al., 2017, El Zein et al., 2016).

Three studies (18%) used shared reading intervention (Alison et al., 2017; Spooner et al., 2014; Spooner et al., 2015). One study (6%) included repeated reading (Armstrong & Hughes, 2012), one included story retelling (Armstrong & Hughes, 2012), and one included text preview strategies (El Zein et al., 2016).

Interventionist. The majority of studies (*n* = 12, 75%) were implemented by researchers. There were three studies (19%) in which either teachers (Ahlgrim-Delzell et al., 2016) or intern teachers (Coleman et al., 2012; Coleman et al., 2015) implemented the interventions. One study (6%) was implemented by caregivers (Serret et al., 2017).

Outcomes. A total of 29 reading and nonreading skills were measured in 16 articles with high research evidence. Eight studies (50%) measured decoding skills as one of the dependent variables (Ahlgrim-Delzell et al., 2016; Coleman et al., 2012; Coleman et al., 2015; Lee & Vail, 2005; Morlock et al., 2015; Saadatzi et al., 2017; Serret et al., 2017; Yaw et al., 2011), and five of them (31%) specifically measured sight word recognition. The next common dependent variable was reading comprehension (*n* = 6), which was targeted in six studies (Alison et al., 2017, Armstrong & Hughes, 2012; Browder et al., 2017; El Zein et al., 2016; Spooner et al., 2014; Spooner et al., 2015). Four studies (25%) measured vocabulary skills (Ahlgrim-Delzell et al., 2016; Browder et al., 2017; Ganz et al., 2014; Smith et al., 2013), and one of them (6%) targeted vocabulary acquisition in the science content area (Smith et al., 2013). Two studies

(13%) measured correct identification of story elements (Alison et al., 2017; Browder et al., 2017). The other types of reading outcomes included story retelling (Armstrong & Hughes, 2012), fluency (Morlock et al., 2015), and total scores obtained from the curriculum-based measurement (Ahlgrim-Delzell et al., 2016).

Four different nonreading outcomes were measured in three studies (18%). Two studies (Spooner et al., 2014; Spooner et al., 2015) measured performances during the intervention (e.g., orienting the book correctly, turning pages). Task refusal (El Zein et al., 2016), average prompt level (Ganz et al., 2014), and spontaneous comments (Ganz et al., 2014) were targeted in one study (6%).

Effects. A total of 29 reading and nonreading outcomes were targeted, and the effects of the intervention on each outcome variable was coded as strong, moderate, or no effect, according to the effect size the authors provided (group designs) or visual analysis suggested by WWC (single-case designs). More than a half of study outcomes indicated strong effects (n = 15, 52%), and three study outcomes indicated moderate effects (n = 3, 10%). The 28% of the outcome variables (n = 8) indicated no effect in seven studies (Ahlgrim-Delzell et al., 2016; Armstrong et al., 2012; Coleman et al., 2012; Coleman et al., 2015; El Zein et al., 2016; Ganz et al., 2014; Morlock et al., 2015). Due to the absence of graphs, three dependent variables (10%) in two single-case studies (Armstrong et al., 2012; Ganz et al., 2014) were not able to be coded. In five out of seven studies that utilized single-case alternating treatment designs, technology-based reading interventions did not lead to better outcomes than the other intervention conditions (Armstrong et al., 2012; Coleman et al., 2012; Coleman et al., 2015; El Zein et al., 2016; Ganz et al., 2014).

Results. Almost all studies reported functional relations between technology-based reading interventions and targeted outcomes for all of the participants (n = 12, 75%) or some of the participants or outcome variables (n = 2, 13%). There were four alternating treatment design studies that compared the effects of teacher-directed interventions (TDI) with the effects of CAI or IAI (Armstrong & Hughes, 2012; Coleman et al., 2012; Coleman et al., 2015; El Zein et al., 2016), and none of those studies demonstrated clear differences between two conditions. All single-case studies (n = 14, 100%) reported above 80% of IAA. The majority single-case studies (29%) reported treatment fidelity, and it was all above 80%.

Technology usage. In addition to overall characteristics of technology-based reading interventions with high-quality research evidence, the type of technology and its primary role during the reading intervention were specified to provide detailed information on the technology usage (see Table A5). Two technology devices (i.e., computer, iPad) and 12 software programs were incorporated into reading interventions (i.e., PowerPoint, Classroom Suite, GemIIni, SEMA-TIC, Vizard, Word Wizard, Wynn Wizard, GoTalk NOW, iCommunicate, Keynote, Space Voyage, SMART Notebook). The usage of technology could be categorized into three alternatives based on its primary role during the intervention sessions: (a) developing materials, (b) delivering instruction without interventionist-directed instruction, and (c) supporting interventionist-directed reading instruction.

Developing materials. In the six of the reviewed studies (38%), technology was used to develop reading materials or individualized CAI/IAI programs for the research purposes. To develop individualized CAI/IAI programs, PowerPoint (Coleman et al., 2012; Yaw et al., 2011), Vizard (Saadatzi et al., 2017), and Keynote (Smith et al., 2013) were used in four studies (25%). These programs included key features of presenting texts with screen with audio voice, presenting verbal direction, and providing feedback or reinforcement. Armstrong and Hughes (2015) utilized Wynn Wizard to develop e-texts including audio voice and highlighted keywords.

Delivering instruction. In five studies (31%), technology was used to deliver reading instruction without extra interventionist-directed instruction. Three CAI programs (i.e., Classroom Suite, SEMA-TIC, Word Wizard) provided reading instructions for learning sight words (Coleman et al., 2015; Lee & Vail, 2005) or overall literacy skills (Serret et al., 2017). An IAI program (i.e., Space Voyage) was implemented in one study (6%) to improve reading comprehension skills (El Zein et al., 2016). GemIIni is a commercially developed website that offers video-modeling materials. Morlock et al. (2015) used this website to deliver instruction to teach word recognition and pronunciation skills.

Supporting instruction. In five studies (31%), the technology was paired with direct instruction provided by interventionists, and the main role of technology was supporting interventionist-directed reading interventions. Only iPad devices were used for this purpose, and the GoTalkNow application was the most common software program (Ahlgrim-Delzell et al., 2016; Alison et al., 2017; Spooner et al., 2014; Spooner et al., 2015). In one study (6%), iCommunicate was used to present target words with audio voice and providing response opportunities (Ganz et al., 2014). In one other study (6%), the SMART Notebook was utilized to provide participants with a touch-based story-map template (Browder et al., 2017). The use of technology was paired with interventionist-directed instructions using constant time delay (Ahlgrim-Delzell et al., 2016; Alison et al., 2017; Browder et al., 2017; Spooner et al., 2014; Spooner et al., 2015), systematic prompts (Ahlgrim-Delzell et al., 2016; Alison et al., 2017; Browder et al., 2017; Ganz et al., 2014; Spooner et al., 2014; Spooner et al., 2015), and modeling (Ganz et al., 2014).

Discussion

This systematic quality review included 31 technology-based reading intervention articles involving participants with ASD. A total of 16 articles met the WWC design standards without or with reservations, and the study characteristics and technology usage in the 16 articles were summarized. Prior to this study, several literature review studies have suggested that technology can be successfully incorporated into interventions for students with ASD and other developmental disabilities (Pennington, 2010; Ramdoss et al., 2011; Knight et al., 2013; Kagohara et al., 2013). However, no reviews were found that specifically investigated technology-based reading interventions for students with ASD, and only a few reviews evaluated the quality of research evidence (Knight et al., 2013). Findings of this study add to the emerging body of research on technology-based reading interventions for students with ASD. In this discussion section, we highlighted some strengths and areas for improvement for future research and suggested how technology can be used to teach reading skills to students with ASD in practice. Lastly, the limitations of this literature review and directions for future research were discussed.

Quality of Research

The overall findings of this systematic quality review indicated that more than half of reviewed group design and single-case design studies were considered to have high-quality research evidence. In the case of group design studies, the majority of group design studies were initially excluded from the further review due to the absence of control groups. To sustain the methodological rigor of group design studies, the WWC design standards suggest researchers to utilize either RCTs or QEDs with control groups. One RCT study with low attrition received the highest rating (Ahlgrim-Delzell et al., 2014), and other reviewed group design studies met the standard with reservations or did not meet the standards due to lack of randomized control (Serret et al., 2017), high attrition rate (Whalen et al., 2010), or insufficient information that is critical to decide quality of research (Moore & Calvert, 2000). Due to the limited number of reviewed group design studies (n = 4), results of this quality evaluation may not be enough to draw a general conclusion on methodological rigor of group design studies on this topic. However, future researchers would need to utilize the design standards suggested by predominant organizations (e.g., WWC) to monitor their own methodological rigor to increase the credibility of research findings.

Strengths of reviewed single-case design studies were evident in three of four WWC design standards. Especially, it is noteworthy that all of the reviewed articles systematically manipulated independent variables. All the single-case studies reported when and how the intervention was implemented and provided a clear distinction between baseline and intervention phases, and the majority of the studies reported above 80% of IAA and treatment fidelity. However, areas for improvements in quality of research were identified as well. In the following section, we will elaborate on these areas for improvements and suggest ways to improve experimental rigor in each area.

First, while majority of studies measured and reported above 80% of IAA and treatment fidelity, in many of those studies, the researchers did not specify if the data were collected across all conditions (e.g., baseline, intervention, maintenance) or were collected only during specific experimental phases (e.g., intervention only). This information would provide critical information to determine whether or not the study effectively controlled some confounding variables across conditions and increase the internal validity of the research study. Future researchers would need to consider collecting reliability and fidelity data at least 20% of the session across participants and across conditions.

Second, though one of the most common intervention components was CAI and IAI, there is no general consensus on how to measure treatment fidelity if the intervention was delivered solely by technology. Six CAI or IAI studies reported treatment fidelity, but only a few studies used sufficient detail when describing how it was measured. In the CAI or IAI studies, treatment fidelity was defined either as the proper operation of computer program or as steps completed by the interventionist (e.g., redirecting students, setting up a computer). Measuring treatment fidelity during the CAI or IAI sessions requires unique considerations in that learning through the software program requires learners' attention to the program. In order to deliver CAI or IAI interventions as intended, the study participants would need to demonstrate high level of engagement throughout the intervention sessions. Participant inattention to the program and different levels of engagement across sessions can be considered as a confounding variable that should be controlled throughout the session, and it would impact the overall validity of the study. Thus, future researchers would need to identify effective ways to measure treatment fidelity of CAI or IAI interventions and monitor engagement during the CAI or IAI sessions. Additionally, the role of the interventionist during the CAI or IAI intervention sessions would need to be described with sufficient details in the future research studies.

Compared with other areas of strengths, a relatively small number of articles (n = 7, 26%) met the *Design Standard 4* (i.e., number of phases and data points) without or with reservations. Although the insufficient number of demonstrations or data points does not necessarily mean that findings of the study are not valuable, it is crucial to determine the quality of research evidence. The WWC standards apply different sub-standards for each of single-case designs (e.g., multiple-probe, alternating treatment). Because obtained academic skills cannot be reversed, the majority of technology-based reading intervention studies utilized either multiple-probe or multiple-baseline designs. However, half of multiple-baseline studies (n = 3, 50%) and more than half of multiple-probe design studies (n = 8, 57%) did not meet the *Design Standard 4*, whereas all alternating treatment studies met this standard without or with reservations. It may not be surprising in that the WWC require multiple-probe design studies to meet a greater number of sub-standards to meet the *Design Standard 4* than alternating treatment designs.

The most commonly missed sub-standards for multiple-probe designs were collecting three probes within the first three sessions, collecting three probes prior to intervention across conditions, and collecting one probe after intervention in all conditions not receiving intervention. Utilizing multiple-probe design to examine the effects of academic interventions could have a practical value in that it does not put the participants in repeated failure situations without supports, but the researchers would be required to collect sufficient probe data for a valid prediction of the participant's future performance. If the number of probe data was insufficient or the obtained data did not show a clear baseline trend, it could influence the overall validity of the study. Thus, to add high-quality research evidence to the field, future researchers would be required to demonstrate at least three times of effects (e.g., across participants, settings, or conditions) with sufficient data points.

Implications for Research

In the area of reading, the National Reading Panel (NRP, 2000) suggested five reading components of reading instruction: (a) phonemic awareness, (b) phonics, (c) vocabulary, (d) comprehension, and (e) fluency. Previous studies have indicated that reading instructions for students with ASD and other developmental disabilities have focused heavily on teaching sight words, especially when they have moderate to severe educational needs (Browder, Wakeman, Ahlgrm-Delzell, & Algozzine, 2006). While teaching sight-words was still one of the most common targeted outcomes in this literature review, it was worth noting that other reading components (e.g., vocabulary, comprehension) were also targeted in many technology-based reading intervention studies (e.g., Alison et al., 2017; Armstrong & Hughes, 2012; Browder et al., 2017; El Zein et al., 2016; Smith et al., 2013; Spooner et al., 2014). However, there is still a lack of research on phonics or fluency instructions for this population, and more high-quality research evidence is required to identify EBPs to teach specific reading skills to students with ASD.

As there has been increased emphasis on accessing to grade-level academic standards (ESSA, 2015), a number of technology-based reading intervention studies aimed at reading age-appropriate storybooks (Alison et al., 2017; Armstrong & Hughes, 2012; Browder et al. 2017; Spooner et al., 2014; Spooner et al., 2015) or science vocabulary acquisition (Smith et al., 2013). However, none of those studies was implemented for a group of students with and without disabilities in a general education classroom. To increase generalizability of technology-based reading interventions for this population, future researchers should investigate how technology can be incorporated into reading interventions within their typical routines rather than pulling the students out to provide one-on-one interventions. Additionally, a fewer number of participants in secondary education (18%) were involved in the reviewed studies. Considering that students with ASD may have different educational needs in reading across age groups, more research should be conducted in secondary education settings.

In this literature review, six alternating treatment design studies compared the effects of technology-based reading interventions with the effects of interventionist-directed interventions.

The majority of the studies concluded that both interventions led to improved reading outcomes compared with baseline, but neither of those interventions lead to better reading outcomes than another. Delivering reading interventions through CAI or IAI programs may have relative strengths in that it typically requires a minimal level of teachers' support (e.g., computer setup, redirecting the student to focus on the activities), and the students can repeat the intervention session whenever it is needed. However, delivering instruction through technology has limitations in teaching in-depth comprehension skills and providing in vivo feedback based on the student's verbal responses. In this literature review, almost all CAI and IAI studies targeted teaching sight-words through embedded visual/audio prompts and reinforcement/error correction slides (Armstrong & Hughes, 2012; Coleman et al., 2012; Coleman et al., 2015; Lee & Vail, 2005; Saadatzi et al., 2017; Yaw et al., 2011). There is little evidence on applying CAI or IAI to teach other NRP reading components (e.g., fluency, phonemic awareness, comprehension). Given the pros and cons of using CAI or IAI programs, future researchers would need to provide guidelines to select the most appropriate modes of reading instructions to address unique needs in students with ASD.

Implications for Practice

Some alternating treatment studies implied that CAI or IAI may have reading outcomes equivalent to interventionist-directed interventions (Armstrong & Hughes, 2012; Coleman et al., 2012; Coleman et al., 2015; El Zein et al., 2016; Lee & Vail, 2005; Saadatzi et al., 2017; Smith et al., 2013). However, current research evidence cannot fully suggest when and how CAI or IAI can be effectively applied for students with various educational needs in reading. Because the majority of the CAI and IAI interventions were designed to teach sight-word reading skills, findings from the research studies may not be generalizable to teach other NRP reading components (e.g., fluency, phonics, comprehension). Depending on the student's educational needs and targeted reading outcomes, educators may want to develop individualized programs, use research-based commercial CAI/IAI programs, or pair the use of CAI/IAI programs with teacher-directed strategies (e.g., least-to-most prompt, modeling, guided questions).

To improve comprehension skills of students with ASD, the educators may want to consider implementing shared story reading intervention (Alison et al., 2017; Spooner et al., 2014; Spooner et al., 2015) or using graphic organizers (Browder et al., 2017). In the reviewed articles, technology devices were used to provide visual cues, text-to-speech, alternative response mode for answering comprehension questions, and additional tools to visually organize obtained information from the text. The shared reading and electronic story-mapping interventions were implemented as a package that involves various intervention components. Omitting or adding some interventional components may allow educators to easily apply the package intervention to practice, but educators may need to continuously monitor the students' progress because similar results may not be guaranteed.

Limitations and Directions for Future Research

This systematic quality review adds to the emerging body of research on technology-based reading interventions for students with ASD, but the following limitations should be considered. First, we interpreted each of the WWC design standards as relevant to the purpose of this review. Our interpretation of the WWC design standards may have resulted in the dismissal of some high-quality research studies.

Second, we evaluated the methodological rigor based on the information the researchers provided. If researchers omitted to report critical information for this review, it may have impacted on our quality ratings. Future researchers should report sufficient information to substantiate the methodological rigor of the studies.

Third, compared with the other quality indicators suggested by other predominant organizations (e.g., Council for Exceptional Children), the WWC design standards put more weight on the rigorous experimental design (e.g., collecting IAA, number of phases and data points) than contextual information (e.g., setting, participants, intervention agent, description of practice). To fill the gap between research and practice, future researchers would need to consider not only designing rigorous experimental studies but also providing detailed information for further replications.

Fourth, our analysis in this literature review was limited only to articles published in peer-reviewed scholarly journals. The exclusion of gray literature (e.g., dissertation, government report, policy statement, conference paper, book chapter) may have led to potential publication bias as studies with null or negative findings are less likely to be published (Gage, Cook, & Reichow, 2017). Given that published studies typically have larger effect sizes than gray literature (Gage et al., 2017; Polanin, Tanner-Smith, & Hennessy, 2016; Rothestein & Hopewell, 2009), publication bias may result in overestimated effect sizes or giving false impression that the intervention is more effective than it actually is (Gage et al., 2017). Future researcher would need to consider including gray literature to systematically represent the current research base or providing valid reason for not including gray literature (Gage et al., 2017).

Fifth, this literature review summarized the effects of technology-based reading interventions based on narrative synthesis. Future research would need to consider measuring magnitudes of effects of technology-based reading interventions and comparing the effectiveness across moderating variables through meta-analysis.

CHAPTER III: A META-ANALYSIS

Introduction

Learning to read is fundamental to access other academic subject areas and critical for future success in school (Fluery et al., 2014), but students with autism spectrum disorder (ASD) are more likely to be placed at high risk for literacy failure due to delayed oral language development (Bishop & Snowling, 2004; Nation, Clarke, Wright, & Williams, 2006). While listening comprehension and early decoding ability are considered as a predictor of later reading achievement (Woolley, 2011), students with ASD often exhibit a unique discrepancy between well-developed decoding skills and poor comprehension skills (Nation, Clarke, Wright, & Williams, 2006; Whalen et al., 2010). Additionally, students with ASD may have difficulties making inferences from the text (Myles & Simpson, 2002), resolving anaphoric reference (O'Conner & Klein, 2004), deciphering meanings of words (Randi et al., 2010), and understanding abstract or metaphor (Knight & Sartini, 2015). Such challenges in reading may impede students with ASD from making meaningful progress in academic subject areas and working toward general education curriculums.

Recent educational legislations have placed an increased emphasis on the use of evidence-based practices (EBPs) to support all students, including students with ASD, to be successful in classrooms (e.g., Every Student Succeeds Act, 2015). Given that the prevalence of ASD has dramatically increased over the years, and 1 in 59 children is currently estimated to have an ASD diagnosis (Centers for Disease Control and Prevention, 2018), teachers are required to select and provide effective interventions to support students with ASD to be successful in classrooms. However, it is particularly true that much of the research base on interventions for students with ASD has focused on addressing core features of ASD, such as social-communication deficits and restrictive and repetitive behaviors. Such a limited research base on reading interventions for students with ASD may result in a limited knowledge base for teachers on selecting and using effective strategies to teach reading skills to this group of students. To promote the use of EBPs to teach reading, more research on identifying and suggesting effective reading interventions with high-quality empirical evidence should be conducted.

One increasingly popular option for presenting academic contents and motivating students with ASD is incorporating technology into educational programs (Kagohara et al., 2013; Ledbetter-Cho, O'Reilly, Lang, Watkins, & Lim, 2018). Technology devices (e.g., computers, tablets, and smartboards) have come into wide use in educational settings, and research findings have indicated that students with ASD prefer technology-based instruction and perform better when technology devices were used for the intervention (Shane & Albert, 2008). Given that many students with ASD have a relative strength in visual thinking process (Quill, 1997), they may take advantage of capitalizing on visuals through technology (Mayes & Calhoun, 2003).

The most common technology-based intervention that has been applied for students with ASD would be computer-assisted instruction (CAI). CAI refers to the use of a computer to support learning processes, present learning materials, or check learners' knowledge during intervention (Anohina, 2005). A number of empirical studies examined effects of CAI, and mostly literacy skills were targeted (Root, Stevenson, Davis, Geddes-Hall, & Test, 2017). Pennington (2010) conducted a literature review on using CAI to teach academics to students with ASD. A review of 15 CAI studies indicated positive effects of applying CAI for students with ASD, but Pennington commented at the end of this review that a lack of empirical control of these studies may cast a shadow over the effectiveness. Based on this limitation, Root et al.

(2017) recently conducted a quality review of research evidence on using CAI to teach academic skills to students with ASD. Analysis of articles with high-quality research evidence indicated that CAI can be considered as an EBP to improve academic skills of students with ASD.

Although empirical evidences of using tablets (e.g., iPad, Galaxy Tab) for students with ASD are currently relatively limited, tablets are widely used in many educational settings due to their potential benefits (Hong et al., 2017). Using tablets in school is less stigmatized than other assistive technology devices (e.g., a big speech generating device), and the tablet's portable, customizable, accessible, and affordable features enable educators to utilize it for a variety of educational purposes (Hong et al., 2017; Yee, 2012). Tablet-mediated interventions have been successfully implemented for students with ASD across various skill domains, such as social-communication skills (e.g., Flores et al., 2012; van der Meer et al., 2012), academic skills (e.g., Yakubova, Hughes, & Hornberger, 2015; El Zein et al., 2016), and challenging behaviors (e.g., Lee et al., 2015; Neely, Rispoli, Camargo, Davis, & Boles, 2013). While CAI studies mostly targeted literacy skills, tablets have been used to teach a variety of skills to students with ASD rather than to improve literacy skills only.

Previous reviews on technology-based interventions used for students with ASD have focused broadly on all types of skills (e.g., Hong et al., 2017; Kagohara et al., 2013) or focused only on CAI (e.g., Pennington, 2010; Ramdoss et al., 2011; Root et al., 2017). Recently, a number of meta-analysis studies were conducted to quantify the effects of technology-based interventions for students with ASD (Hong et al., 2017; Ledbetter-Cho et al., 2018; Sansosti, Doolan, Remaklus, Krupko, & Sansosti, 2015). Given the demands for using EBPs for students with ASD in classroom, more determinations of whether the intervention represents an EBP or not should be made based on rigorous procedures. In Sansosti et al. (2015), effectiveness of CAI for teaching various skill domains to students with ASD within school-based contexts was examined. Results of 28 article reviews indicated that CAI is a promising approach for students with ASD, but an absence of quality control may make this conclusion tenuous. More recently, two more meta-analysis studies (Hong et al., 2017; Ledbetter-Cho et al., 2018) were conducted to analyze effectiveness of using tablets to teach students with ASD. Hong et al. (2017) concluded that tablet-mediated interventions for students with ASD have moderate to large effect size across various skill domains. In Ledbetter-Cho et al. (2018), effectiveness of using touch-screen devices specifically for improving academic skills of students with ASD was examined, and targeted academic skills broadly included academic related skills, such as specific academic skills (e.g., writing, math, reading comprehension), task engagement, and challenging behaviors. Findings of this article implied moderate to large effects, but Ledbetter-Cho et al. (2018) pointed to a clear need for future research on the use of tablets for teaching specific academic skills.

The purpose of this meta-analysis was to extend previous literature reviews by focusing on the use of technology to teach reading skills to students with ASD. Specifically, this meta-analysis (a) systematically extracted research studies on technology-based reading interventions for students with ASD, (b) evaluated the research rigorousness by using design standards developed by What Works Clearinghouse (Kratochwill et al., 2010/2013), (c) calculated Tau-U scores to measure magnitudes of effects of technology-based reading interventions for students with ASD, and (d) compared the effects across moderating variables.

Research Questions

This study sought to answer the following research questions:

1. What is the magnitude of effect of interventions that used technology (e.g., computer, iPad) to teach reading skills to students with ASD?

2. Do study characteristics (i.e., participant characteristics, reading materials, technology, intervention components, targeted reading outcomes) moderate the magnitude of change in reading?

Method

Article Identification

A subset of articles identified in Chapter 2 was included for this review. The outcomes and search procedures for the quality review described in Chapter 2 were applied for this meta-analysis with inclusion of only single-case design studies that met the WWC quality indicators without or with reservations. A total of 27 single-case studies that incorporated technology into reading interventions for students with ASD were initially identified, and 14 of the studies met the WWC quality indicators without or with reservations. Due to the absence of baseline data, one alternating treatment study was excluded from the further analyses, and a total of 13 studies were included for this meta-analysis. The summary of search procedures with inclusion/exclusion criteria and quality evaluation procedures for single-case studies are summarized in Figure B4.

Variable Coding

For the purpose of this meta-analysis, each of the single-case studies that met the WWC quality indicators without or with reservation was coded based on the following coding variables: (a) participant characteristics (i.e., age, diagnosis), (b) reading material (i.e., type, grade level), (c) technology (i.e., device, role of technology), (d) intervention components (i.e., prompting, time delay, shared reading, CAI/IAI), and (e) reading outcome (i.e., comprehension, decoding). If participants did not have a diagnosis of ASD or outcomes were not related to reading (e.g., disruptive behavior, on-task behavior), the data were excluded from the analyses.

In the following cases, study variables were also excluded from further analyses: (a) a study variable was not explained in the article, which was coded as not reported (NR), or (b) a study variable did not fit any of the predetermined categories, which was coded as not applicable (NA). Definitions of coding variables are displayed in Table A6.

Participant characteristics. Variables related to participant characteristics were coded based on the participant's age and diagnosis. The age of participants were coded as: (a) elementary aged (i.e., ages 6–11), (b) secondary aged (i.e., ages 12–15), or (c) adolescent/adult (i.e., 16 or above). The diagnosis of participants were categorized as: (a) diagnosed with ASD/autism with no comorbid intellectual disability (ID) (i.e., reported IQ was at or above 70, diagnosed with Asperger's syndrome or high-functioning autism), or (b) diagnosed with ASD/autism and ID (i.e., reported IQ was below 70, had both ASD and ID diagnoses).

Reading materials. Variables related to reading materials were coded based on type and grade level of assigned texts for the study. Types of text were categorized to: (a) paragraph, and (b) word. Grade level of assigned texts were compared to each participant's chronological age and coded as: (a) yes if the texts were appropriate for participants' age or grade level, or (b) no if the texts were not appropriate for participants' age or grade level.

Technology. Variables of interest related to the use of technology included device and its role. Technology devices used for reading interventions were coded to: (a) computer (i.e., desktop computer, laptop), or (b) tablet (i.e., iPad, Galaxy Tab). The role of technology was coded as: (a) delivering if technology delivered reading instruction without pairing with interventionist-directed instruction, or (b) supporting if technology was paired with interventionist-directed instruction (e.g., constant time delay, shared reading).

Intervention components. Variables related to intervention components included prompting, time delay, shared reading, and CAI or IAI (iPad-assisted instruction). Prompting was categorized as: (a) hierarchy prompting if a series of predetermined prompting systems (e.g., least-to-most, most-to-least) was applied, (b) constant prompting if one prompting system (e.g., verbal prompt) was selected and used consistently during intervention sessions, or (c) no prompting if no systematic prompting strategies were utilized. Time delay was coded as: (a) yes if constant or progressive time delay procedures were utilized during technology-based reading intervention sessions, or (b) no if no time delay procedures were applied. Shared reading was coded either as present or absent only when reading comprehension or vocabulary skills were targeted in the reviewed study. Specifically, shared reading was categorized as: (a) yes if shared reading was implemented, (b) no if instructional methods (e.g., graphic organizer) other than shared reading were used, or (c) NA if reading comprehension or vocabulary skills were not targeted. CAI/IAI studies that aimed to improve decoding skills were further categorized based on its components. CAI/IAI were coded as: (a) CAI/IAI + Prompting if any systematic prompting strategies (e.g., lest-to-most prompt, verbal prompt) were utilized during decoding interventions, (b) CAI/IAI + Time Delay if CAI/IAI program included time delay strategies, (c) CAI/IAI + Prompting + Time Delay if CAI/IAI programs included both systematic prompting and time delay procedures, or (d) NA if CAI/IAI was not used to teach decoding skills.

Reading outcome. Targeted reading outcomes were broadly categorized as: (a) comprehension, or (b) decoding. Comprehension referred to an ability to understand meaning of written materials and included comprehension (e.g., answering comprehension questions) and vocabulary skills (e.g., matching words with definitions). Decoding was defined as an ability to read written materials aloud (e.g., reading sight words correctly).

Data Extraction

Fifty sets of data were extracted from the graphed data of 13 articles that met WWC design standards without or with reservations using a web-based data extraction program, WebPlotDigitizer (Rohatgi, 2017). This program was used to extract numeric data from graphic data from published studies. Each experimental graph was uploaded into the WebPlotDigitizer program, and the scale was set based on the *x* and *y* axes from the graph. A numerical value was extracted from each data point, and the extracted data were entered into an Excel spreadsheet.

Inter-rater Agreement

To evaluate accurate evaluation and coding of identified studies, trained second coders independently coded at least 25% of the articles for each stage of this study. Second coders were trained by the first author until they reached at least 90% of agreement on three consecutive articles. Inter-rater agreement (IRA) for each stage was calculated by dividing the agreements by agreements and disagreements and multiplying by 100 (Kennedy, 2005). The procedure for obtaining IRA for each stage of this study is described below.

Article search. One undergraduate student and one graduate student in special education were trained and independently reviewed at least 25% of articles for the title and abstract search (n = 154) and the full-text review (n = 15), and 100% of articles for the ancestral search (n = 27). The calculated IRA was 92% for the title and abstract search, 91% for the full-text review using inclusion/exclusion criteria, and 100% for the ancestral search.

Quality review. Following the training, two doctoral students in special education independently reviewed 100% of the identified articles (N = 27) based on WWC quality indicators for single-case designs. The calculated IRA was 94% and reached 100% of IRA after discussing all disagreements.

Descriptive coding. Two trained doctoral students in special education independently coded 100% of data sets ($N = 50$) from 13 articles that met the WWC quality indicators without or with reservations. If two coders coded identical information for each variable, it was considered as an agreement. Overall IRA was 95% across coding variables, and all disagreements were discussed until a consensus was obtained.

Data extraction. Fifteen out of 50 data sets (30%) were randomly selected for assessing IRA, and two coders independently extracted numeric data using WebPlotDigitizer. Numeric values extracted by the two coders were compared after rounding the values to whole numbers. If the difference in the numbers was less than one, it was considered as an agreement. If the difference in the rounded numbers was one or more, it was considered as a disagreement. The mean IRA was 96% for 15 data sets.

Data Analyses

To quantify the effects of technology-based reading interventions for students with ASD, the Tau-U effect size without baseline control was calculated using original software developed by one of the authors on the Maple platform (Maplesoft Version 16, 2012). Additionally, statistical significance tests were conducted using SAS (Version 9.4, 2018) software to analyze categorical variables.

Phase contrast selection. Two adjacent phases were contrasted to determine the magnitude of intervention effects (i.e., baseline-intervention). Only phase contrasts that showed independent demonstration of technology-based reading intervention were evaluated with an effect size, and generalization or maintenance data was excluded from the analyses. Each baseline-to-intervention phase contrast was evaluated with an effect size, thus an ABAB design produced two separate effect sizes (i.e., one from the first A-B contrast, one from the second A-B contrast). In the case of alternating treatment design studies that compared effects of technology-based reading intervention with teacher-directed interventions, only a participant's baseline data points and technology-based reading intervention were extracted for the analyses. If an intervention phase was not started immediately after a baseline phase, this phase contrast was excluded from the analyses.

Effect size. To determine the magnitude of intervention effects, a nonparametric statistical analysis of effect size, Tau-U (Parker, Vannest, Davis, & Sauber, 2011) was used in this analysis. Tau-U provides an effect size index by measuring nonoverlapping data between two phases. Each data point in the first phase (i.e., baseline) is compared with each data point in the second phase (i.e., intervention), and the difference between each data point across conditions represents the improvements over time (Davis, Mason, Davis, Mason, & Crutchfield, 2016). Tau-U analysis enables the calculation of exact *p* values and confidence intervals. Tau-U scores can be ranged from -1.0 to 1.0, and a score of 0 indicates no difference between phases (Parker et al., 2011). Negative Tau-U scores indicate decreased outcome values, and positive Tau-U scores indicate increased outcome values. As reading skills (e.g., comprehension, decoding) were targeted outcome variables of this review, Tau-U scores above 0 can indicate improvements in reading. Although the magnitude of effects should be interpreted contextually with caution, Tau-U scores can be interpreted based on the following criteria: (a) small effect: 0 – .65, (b) moderate effect: .66 – .92, and (c) large effect: .93 – 1 (Parker & Vannest, 2009).

Effect size aggregation. Effect sizes obtained from data sets were combined to determine omnibus effects and differences between moderators. Tau-U allows easy aggregation of multiple phase contrasts and utilizes the S distribution to determine the variance score (Var_S).

The obtained Tau-U effects were weighted by the inverse of the variance score (Var_S) and averaged.

Comparing effects. Statistical significance for categorical variables associated with participant characteristics and intervention components were examined to determine if there were differences in groups. Moderators with two categorical variables were evaluated with the Wilcoxon rank-sum test (Wilcoxon, 1945). If moderators included three or more categories, the Kruskal-Wallis one-way analysis of variance (Kruskal & Wallis, 1952) was utilized to calculate the difference between groups. If the result of Kruskal-Wallis analysis indicated a statistically significant difference between groups, significance between each pairwise combination of groups were further evaluated with the Dunn post-hoc test (Dunn, 1964).

Results

Quality Review

A total of 27 single-case studies were evaluated based on the WWC quality indicators, and 14 studies met the quality indicators without (n = 4, 15%) or with reservations (n = 10, 37%). The other 13 studies (48%) did not meet the quality indicators due to: (a) lack of interassesor agreement (IAA) data, (b) lack of demonstrations of experimental effect, or (c) insufficient number of data points per phase. Overall, 13 out of 27 studies met the WWC quality indicators without or with reservations and were included for the analyses. One alternating treatment design study (El Zein et al., 2016) met the quality indicators but was excluded for further analyses due to the lack of baseline control.

Descriptive Summary of Results

A total of 13 unique studies yielded 50 separate effect sizes with 33 participants. The omnibus Tau-U across all technology-based reading intervention studies was .89 CI_{95} [.83, .96].

Participant characteristics (i.e., age, diagnosis), reading materials (i.e., type, grade level), technology (i.e., device, role), intervention components (i.e., prompting, time delay, shared reading, CAI/IAI), and targeted reading outcomes (i.e., comprehension, decoding) were coded and analyzed to determine their impacts on the improvements in reading. Results of the analyses are presented in Table A7 and described below.

Participant Characteristics

Age. A total of 33 participants were included in 13 reviewed studies, and the majority of participants were elementary aged (*n* = 21, 64%) and included 33 unique contrasts. Six participants (18%) were middle school aged (8 contrasts), and the other six participants (18%) were at or above high school aged (9 contrasts). None of the participants were in the preschool age group. The calculated Tau-U scores for levels of age were .86 (*n* = 33; CI_{95} [.78, .94]) for elementary aged participants, 1 (*n* = 8; CI_{95} [.81, 1]) for middle school aged participants, and .95 (*n* = 9; CI_{95} [.79, .1]) for at or above high school aged participants (see Table A8). The Kruskal-Wallis test indicated no statistically significant difference between participants in the three levels of age ($p > .05$).

Diagnosis. Across 33 participants with ASD, an intellectual ability or comorbid diagnosis was reported for 26 participants (79%). Out of these 26 participants, 20 participants (60%) had both ASD and ID (30 contrasts). The other six participants (18%) had an ASD diagnosis without ID (8 contrasts). Tau-U effect sizes for diagnosis were .93 (*n* = 30; CI_{95} [.85, 1]) for participants with both ASD and ID and .73 (*n* = 8; CI_{95} [.57, .89]) for participants with ASD without ID. No statistically significant difference was found between participants in two levels of diagnoses (Wilcoxon $p = .16$)

Reading Materials

Type. Across the 13 studies, reading materials were presented either as a paragraph type (*n* = 5, 38%, 25 contrasts) or as a word type (*n* = 8, 62%). The obtained Tau-U scores for types of reading materials were .87 (*n* = 25; CI_{95} [.79, .96]) for paragraphs and .92 (*n* = 25; CI_{95} [.82, .1]) for words. Statistical significance testing showed no statistically significant difference between studies based on the types of reading materials (Wilcoxon $p = .96$).

Grade level. Six studies (46%) used grade-level reading materials (28 contrasts), and seven studies (54%) used reading materials that were not aligned with participant's age or grade level (22 contrasts). The Tau-U scores were .88 (*n* = 28; CI_{95} [.80, .97]) for grade-level materials and .92 (*n* = 22; CI_{95} [.81, .1]) for non-grade-level materials. Statistical significance testing showed no statistical difference between studies based on the levels of reading materials (Wilcoxon $p = .50$)

Technology

Device. Seven studies (54%) used computers (24 contrasts), and six studies (46%) used tablets (26 contrasts) to teach reading skills to students with ASD. The obtained Tau-U effect sizes were .85 (*n* = 24; CI_{95} [.75, .95]) for computers and .93 (*n* = 26; CI_{95} [.84, .1]) for tablets. No statistically significant difference was found between studies based on technology devices (Wilcoxon $p = .11$).

Role. Six studies (46%) utilized technology to deliver reading instruction without pairing with interventionist-directed instruction (27 contrasts), and seven studies (54%) used technology to support interventionist-directed reading instruction (23 contrasts). The obtained Tau-U scores for roles of technology were .86 (*n* = 27; CI_{95} [.77, .95]) for delivering and .92 (*n* = 23; CI_{95}

[.83, .1]) for supporting. Statistical significance testing showed no statistical difference between studies based on the roles of technology during reading interventions (Wilcoxon $p = .31$)

Intervention Components

Prompting. Four unique studies (31%) applied hierarchy prompting systems (e.g., least-to-most prompt), and four studies (31%) used constant prompting systems (e.g., using only verbal prompt). The other five studies (38%) did not include prompting systems as an intervention component. The Tau-U effect sizes were .93 ($n = 20$; CI_{95} [.84, 1]) for studies that involved hierarchy prompt, .80 ($n = 15$; CI_{95} [.78, 1]) for studies that involved constant prompt, and .91 ($n = 15$; CI_{95} [.68, .93]) for the studies that did not involve prompt. Kruskal-Wallis test indicated no statistically significant difference between studies based on the use of prompt ($p > .05$).

Time delay. Eight studies (62%) included time delay as a component of technology-based reading interventions, and five studies (38%) did not use time delay. The obtained Tau-U score was .95 ($n = 31$; CI_{95} [.87, 1]) for studies that included time delay and .80 ($n = 19$; CI_{95} [.67, .89]) for studies that did not include time delay. Statistical significance testing indicated a significant difference between studies based on the use of time delay (Wilcoxon $p = 0.01$) with a stronger effect demonstrated for interventions using time delay.

Shared reading. A total of seven studies (54%) targeted improving reading comprehension skills of participants, and three out of seven reading comprehension studies (43%) implemented a shared reading intervention. The other four reading comprehension studies (57%) utilized instructional strategies other than shared reading (e.g., graphic organizer). The Tau-U effect size was .90 ($n = 11$; CI_{95} [.77, 1]) for reading comprehension studies that included shared reading and .85 ($n = 24$; CI_{95} [.75, .95]) for reading comprehension studies that did not include shared reading. No statistically significant difference was found between reading comprehension studies based on the use of shared reading interventions (Wilcoxon $p = 0.98$).

CAI/IAI. Six studies (46%) used CAI or IAI software programs to teach decoding skills. Two out of six CAI/IAI studies (33%) involved prompting systems, and three CAI/IAI studies (50%) involved time delay as a part of the interventions. One CAI/IAI study (17%) involved both prompting and time delay strategies. The obtained Tau-U score was .89 ($n = 8$; CI_{95} [.71, 1]) for CAI/IAI studies that involved prompting, 1 ($n = 7$; CI_{95} [.82, 1]) for CAI/IAI studies that involved time delay, and .92 ($n = 4$; CI_{95} [.66, 1]) for CAI/IAI studies that involved both prompting and time delay. A Kruskal-Wallis test indicated statistically significant differences between CAI/IAI studies based on this variable ($p < .05$). However, the Dunn post-hoc test showed no statistically significant difference between CAI/IAI studies in three levels of intervention components.

Targeted Reading Outcomes

Seven studies (54%) aimed to teach reading comprehension skills (i.e., understanding meaning of vocabulary words, sentences, or paragraphs), and six studies (46%) aimed to teach decoding skills (i.e., reading words, sentences, or paragraphs aloud). The obtained Tau-U effect size was .87 ($n = 31$; CI_{95} [.79, .95]) for studies that targeted comprehension skills and .93 ($n = 19$; CI_{95} [.82, 1]) for studies that targeted decoding skills. Statistical significance testing showed no significant difference between studies based on targeted reading outcomes (Wilcoxon $p = .99$).

Discussion

This meta-analysis aimed to quantify the magnitude of effects of technology-based interventions targeting reading skills of students with ASD and determine if the effects were moderated by participant characteristics, reading materials, technology, intervention components, and targeted reading outcomes. A total of 13 single-case studies incorporated technology (i.e., computer, iPad) into reading interventions for students with ASD and demonstrated sufficient methodological rigor. It is worth noting that this meta-analysis evaluated methodological rigor of all reviewed articles using quality indicators (Kratochwill et al., 2010) and limited our analyses to studies that met the quality indicators without or with reservations to ensure the internal validity of each included study and its effects. This study extends the existing literature base of narrative synthesis and meta-analyses of computer- or tablet-mediated interventions across various skill domains (e.g., challenging behavior, self-help, social and communication, academic, employment, community access) by focusing on the use of technology to teach reading skills to individuals with ASD. In this section, findings of this meta-analysis are discussed with implications for research and practice, limitations, and directions for future research.

Overall Effect

The overall findings from 50 unique contrasts across 13 studies indicated a medium effect (Tau-U = .89; CI_{95} [.83, .96]) for technology-based reading interventions for students with ASD. Previous literature reviews concluded that incorporating technology into interventions for students with ASD is a promising practice (e.g., Hong et al., 2017; Kagohara et al., 2013; Ledbetter-Cho et al., 2018; Pennington, 2010; Root et al., 2017), but none of the studies sought to quantify the magnitude of effects of using technology specifically for teaching reading skills. Findings of this study are consistent with previous reviews that reported positive outcomes of technology-based interventions for students with ASD, and the magnitude of the overall effects suggest that methodologically rigorous technology-based interventions can lead to significant increases in reading skills of individuals with ASD.

Moderator Effect

In the following section, moderators that influence the effects of technology-based reading interventions are described. All contextual variables generated medium to large overall effects, and one moderator (i.e., time delay) was associated with statistically stronger effects.

Participant characteristics. Participants' age and diagnosis did not moderate the reading outcomes of 33 unique participants. Interventions implemented with all age (i.e., elementary, middle, high school and above) and diagnosis (i.e., ASD with ID, ASD without ID) categories showed medium to large overall effects (Tau-U range = .73 – 1). This result is consistent with the results of recent meta-analyses of technology-based interventions for individuals with ASD, which indicated that differences in age and functioning level did not lead to statistically significant differences in intervention outcomes (Hong et al., 2017; Ledbetter-Cho et al., 2018). This finding suggests that using technology can benefit students with ASD regardless of student age or diagnosis. However, it is important to note that less than half of the reviewed studies provided relevant assessment data necessary for determining comorbidity (e.g., IQ scores), and only six unique participants across two studies were reported to have ASD without ID. The relatively small sample may not be representative of the whole ASD population because individuals with ASD have a wide range of characteristics, and those other characteristics (e.g., intellectual ability, communication skills, behavioral issues) were not analyzed in this meta-analysis. Students with ASD and/or ID often have deep, varied, and complex educational needs (Knight, Huber, Kuntz, Carter, & Juarez, 2019). Having ID may impact reading and academic skills to a large extent, and delays in working memory and early literacy skills often exacerbate existing challenges that students with ASD have. The insufficient sample from the limited number of studies may have an impact on the overall results of this analysis. Additional research on technology-based reading interventions for students with ASD and/or ID is warranted to make more specific recommendations based on the intellectual ability of participants with ASD.

Reading materials. The moderator analysis on types and grade level of reading materials did not indicate statistically significant differences across 13 unique studies. All types (i.e., paragraph, word) and grade level (i.e., aligned with participant's grade, not aligned with participant's grade) categories demonstrated medium overall effects (Tau-U range = .87 – .92). This result supports previous experimental studies that indicated that using technology can benefit students with ASD to comprehend grade-level text (e.g., Alison, Root, Browder, & Wood, 2017; Browder, Root, Wood, & Alison, 2017; Spooner, Ahlgrim-Delzell, Kemp-Inman, & Wood, 2014) and recognize sight words (e.g., Coleman, Cherry, Moore, Park, & Cihak, 2015; Lee & Vail, 2004; Yaw, Skinner, Parkhurst, Taylor, Booher, & Chambers, 2011). Specifically, findings of the analyses indicate that technology can be effectively used to teach reading skills to students with ASD regardless of types and grade level of reading materials.

Technology. The types of technology devices and role of technology did not moderate reading outcomes. All types (i.e., computer, iPad) and roles of technology (i.e., delivering, supporting) categories generated medium to large overall effects (Tau-U range = .85 – .93), but studies that used a certain type of device for a certain purpose did not lead to statistically better reading outcomes than another. In reviewed studies, computers were typically used to deliver reading interventions without additional interventionist-directed interventions (Armstrong & Hughes, 2012; Coleman, Hurley, & Cihak, 2012; Coleman et al., 2015; Morlock, Reynolds, Fisher, & Comer, 2015; Saadatzi, Pennington, Welch, Graham, & Scott, 2017; Yaw et al., 2011), and tablets were used for the purpose of supporting interventionist-directed interventions to present reading materials that included various visual and auditory supports (Alison et al., 2017; Browder et al., 2017; Spooner et al., 2014; Spooner, Kemp-Inman, Ahlgrim-Delzell, Wood, & Ley Davis, 2015). Findings of this study suggest that using technology can potentially be beneficial for teaching reading skills to students with ASD regardless of its type and role within the intervention, and this can also be encouraging evidence that technology can be used in a variety of ways by educators to address the needs of the classroom or target students. It is possible that types and roles of technology did not moderate reading outcomes because technology served as a delivery mechanism for an intervention and the actual intervention components (e.g., time delay) moderate efficacy.

Intervention components. Prompting and time delay strategies applied to teach students across all targeted reading outcomes (i.e., comprehension, decoding), shared reading, and CAI/IAI programs were designed to specifically improve either comprehension (Alison et al., 2017; Spooner et al., 2014; Spooner et al., 2015) or decoding skills (Coleman et al., 2012; Coleman et al., 2015; Lee & Vail, 2004; Saadatzi et al., 2017; Yaw et al., 2011). The moderator analyses indicated that there was no statistically significant difference among the studies that incorporated a hierarchy prompting system (e.g., least-to-most), constant prompting system (e.g., verbal prompt only), and no prompting system. Although studies that used hierarchy (Tau-U = .93; CI_{95} [.84, 1]) and constant (Tau-U = .80; CI_{95} [.78, 1]) prompting systems produced medium to large overall effects, it did not lead to statistically stronger results than studies that did not use prompting systems. While incorporating prompting systems has a strong empirical evidence in teaching individuals with ASD (Wong et al., 2014), prompting is often used in conjunction with other evidence-based strategies, such as time delay and reinforcement (Cox, 2013). Therefore, it is possible that the presence or absence of systematic prompting strategies as an intervention component was not a critical factor for moderating reading outcomes across the 13 studies we analyzed.

Studies that included time delay as an intervention component demonstrated a statistically stronger effect than studies that did not include time delay. The use of time delay demonstrated large overall effects (Tau-U = .95; CI95 [.87, 1]) across eight unique studies. In those studies, time delay was incorporated into CAI programs that were designed to provide a brief delay between the initial instruction and additional instructional prompt (Coleman et al., 2012; Lee & Vail, 2004; Saadatzi et al., 2017; Yaw et al., 2011), or an interventionist utilized progressive or constant time delay to promote correct responses to comprehension questions (Alison et al., 2017; Browder et al., 2017; Spooner et al., 2014; Spooner et al., 2015). Findings of this study aligned with previous literature that indicated that the use of time delay can benefit students with ASD (Fleury, 2013). Specifically, this finding contributes to the existing literature base by demonstrating that incorporating time delay into technology-based reading interventions can significantly improve reading outcomes of students with ASD.

The moderator analyses indicated that implementing shared reading did not moderate reading outcomes across seven unique studies that targeted comprehension skills. Studies that included shared reading demonstrated medium overall effects (Tau-U = .90; CI_{95} [.77, 1]), but they did not yield a statistically better effect size than other studies that used other reading comprehension strategies other than shared reading (Tau-U = .85; CI_{95} [.75, .96]). In the four studies that did not implement shared reading, story maps (Browder et al., 2017), visual scripts (Ganz, Boles, Goodwyn, & Flores, 2014), and CAI/IAI programs that involved auditory and visual supports (Armstrong & Hughes, 2012; Smith, Spooner, & Wood, 2013) were used to teach comprehension skills. Findings of this study are align with the existing literature that suggested positive effects of shared reading (e.g., Alison et al., 2017; Kim et al., 2018; Spooner et al., 2014; Spooner et al., 2015), but its effects were not statistically greater than studies that used other research-based strategies (i.e., story map, visual script, CAI/IAI).

One of the common technology-based reading interventions implemented in the reviewed studies was using CAI/IAI programs, which were specifically designed to teach decoding skills (Coleman et al., 2012; Coleman et al., 2015; Lee & Vail, 2004; Morlock et al., 2015; Saadatzi et al., 2017; Yaw et al., 2011). All six of the studies utilized systematic instruction (e.g., prompting, time delay), and the moderator analyses indicated that there was no statistically significant difference in the combination of systematic instruction components (i.e., CAI/IAI + prompting, CAI/IAI + time delay, CAI/IAI + prompting + time delay). However, all CAI/IAI combination categories demonstrated medium overall effects across six unique studies (Tau-U range = .89 – 1). This finding suggests that incorporating systematic instruction (i.e., prompting and/or time delay) into CAI/IAI programs can potentially increase decoding skills of students with ASD.

Targeted reading outcomes. Targeted reading outcomes (i.e., comprehension, decoding) did not moderate reading outcomes across 13 unique studies, but all target outcome categories produced medium to large overall effects. All studies that targeted decoding skills utilized CAI/IAI programs, and the program delivered reading instruction without paring with interventionist-directed instruction. To increase comprehension, shared reading (Alison et al., 2017; Spooner et al., 2014; Spooner et al., 2015), CAI/IAI programs (Armstrong & Hughes, 2012; Smith et al., 2013), story maps (Browder et al., 2017), and visual script (Ganz et al., 2014) were utilized in seven studies.

Although each variation of reading interventions that specifically targeted decoding or comprehension skills was not intended to be analyzed within this study due to the limited phase contrasts, findings of this study suggest that technology-based reading intervention can lead to positive outcomes regardless of targeted reading skills.

Implications for Research and Practice

Although 27 studies that incorporated technology into reading interventions for students with ASD were initially identified, only 13 studies met the WWC quality indicators and were included for this meta-analysis. Due to the limited number of studies included for analysis, there was insufficient variability in the reviewed studies to examine more specific moderating variables. For example, reading materials used for the studies with methodological rigor were not able to be specifically classified based on the content, such as narrative or informative text. None of the studies used informative texts as reading materials (e.g., textbook), and all included studies used either paragraphs from narrative texts (e.g., storybook) or words. Although the National Reading Panel (NRP; 2000) suggests teaching all five reading components including phonemic awareness, phonics, fluency, vocabulary, and comprehension, targeted reading outcomes were not able to be further classified due to the lack of samples that targeted phonemic awareness, phonics, and fluency. Given that each reading component requires distinct but interconnected skills, effects of an instructional method may not be generalized across all reading components. To make more specific recommendations based on the targeted reading skills, more research with methodological rigor is warranted.

The overall findings of this study suggest that using technology has the potential to effectively improve reading skills of students with ASD, which may inform educators' selection of technology devices and its usage. Most studies utilized widely available devices (i.e., computer, iPad) and software programs (e.g., PowerPoint, Keynote, GoTalk Now, SMART Notebook), but surprisingly, only a few studies (Coleman et al., 2015; Morlock et al., 2015) investigated the effects of using commercially developed educational applications (i.e., Classroom Suite, GemIIni). Most studies utilized researcher-developed materials that were tailored for specific participants using software programs (e.g., PowerPoint, Keynote, GoTalk Now). Therefore, caution should be exercised when educators selectively adopt part of an intervention package or adapt the intervention to meet the needs of their students, as most reviewed studies implemented multi-component interventions, and positive effects may not be guaranteed by any single intervention component or combination of some components.

Findings of this study suggest that delivering reading instruction through CAI/IAI programs can have the potential to improve reading skills of students with ASD, but CAI/IAI studies did not yield better outcomes than studies that used technology to support interventionist directed instruction. It is possible that no significant difference was found between studies on the role of technology (i.e., delivering, supporting) because CAI/IAI programs served as a mode for delivering reading interventions rather than an actual intervention. Therefore, it is recommended for educators to carefully consider intervention components (e.g., time delay, prompting) when they develop or select appropriate CAI/IAI programs for their students.

With respect to intervention components, the results of this study suggest that using time delay can produce significantly better improvements in reading of students with ASD, but variables associated with prompting systems did not moderate reading outcomes. Time delay is a systematic procedure that provides a brief delay between the initial instruction and any additional instruction or prompts (Fleury, 2013), which means that it is typically used in conjunction with a prompting system (e.g., least-to-most prompting, graduated guidance). As exploring more specific or complex combinations of variables was not possible due to the limited samples of reviewed studies with high-quality research evidence, caution should be exercised when educators consider adopting time delay with other systematic instruction strategies (e.g., prompting).

Although technology-based interventions have the potential to be effectively implemented in inclusive classrooms in that technology can deliver reading instruction with no or minimal support from interventionists, none of the reviewed studies were implemented by natural interventionists when peers were present. Most of the studies that delivered reading instruction through CAI/IAI programs did not provide sufficient information on pretraining procedures to operate the programs or monitoring procedures to ensure that participants were fully engaged in the activities. While detailed description of the research procedures and measuring treatment fidelity is not required to meet WWC quality indicators, this information is critical in identifying step-by-step procedures that should be replicated to produce the positive outcomes as the study generated. In order to bridge the gap between research and practice, future research should describe all training or intervention procedures with sufficient details to ensure that educators can replicate the study procedures in practice. Findings of this meta-analysis cannot guarantee positive outcomes if technology-based reading interventions are implemented by natural interventionists in inclusive settings, so caution should be exercised when educators replicate a certain study for a group of students in inclusive settings.

Results of this study suggest that technology can be successfully incorporated into reading interventions for students with ASD as it can provide various modes of representation (e.g., graphics, sounds, highlighted features) and expression (e.g., touching a picture on an iPad). Universal Design for Learning (UDL) is a research-based instructional framework to optimize learning for all students with diverse needs by providing customized instructional goals, assessments, methods, and materials (CAST, 2018). Within the UDL framework, technology may have the potential to offer different means of representations, allow students to demonstrate their knowledge in a different way, and provide students with options to stimulate their motivations for learning. However, caution should be exercised when educators implement technology-based reading interventions within the UDL framework as positive findings of this study cannot be generalized to the effects of UDL.

Although a number of reviewed articles collected maintenance data, Tau-U effect sizes used in this meta-analysis were calculated based only on the contrasts between baseline and intervention phases. Therefore, the overall findings of this meta-analysis can support the immediate efficacy of technology-based reading interventions for students with ASD but cannot guarantee that the improved reading outcomes will be maintained after completion of the intervention. To maintain effects of the intervention over time, it is recommended for educators to continuously monitor students' progress and provide boosting sessions if necessary.

Limitations and Directions for Future Research

In this meta-analysis, Tau-U scores were calculated as a single effect size. Since there is no single statistical method to address all visual analysis issues of single-case research (Carter, 2013), future researchers would need to consider using multiple effect sizes to ensure statistical validity of meta-analyses for single-case research.

This meta-analysis included only peer-reviewed publications and excluded gray literature (e.g., dissertation, policy report, conference paper, book chapter, unpublished study) from the analyses. As published studies tend to have larger effect sizes than unpublished studies (Rothestein & Hopewell, 2009), the exclusion of gray literature may increase the risk of potential publication bias (Gage, Cook, & Reichow, 2017). To avoid the disproportionate representation of studies with significant findings and overestimated omnibus effect sizes, it is recommended that future meta-analyses include gray literature or provide a valid reason for the exclusion of gray literature (Gage et al., 2017).

This meta-analysis did not include maintenance or generalization data to quantify effects of technology-based reading interventions for students with ASD. Tau-U effect sizes were calculated based on the contrasts between two adjacent baseline and intervention phases, so effects of technology-based reading interventions discussed in this meta-analysis represented immediate intervention effects. None of the reviewed studies collected generalization data, but a number of studies measured maintenance outcomes. It is recommended that future research examine the effects of technology-based reading interventions on the maintenance or generalization of improved reading outcomes in individuals with ASD.

Last, although the calculated IRA (95%) indicated that descriptive coding was reliable among three coders, information related to participant characteristics and intervention components was difficult to extract due to insufficient detail. For example, time delay includes prompting strategies in nature, but the use of prompting systems was not specified by authors in many articles. Similarly, relevant assessment data (e.g., intellectual ability, verbal ability, ASD-specific rating scale data, reading assessment data) were provided for less than half of the reviewed studies. Insufficient information on participant characteristics and intervention components prevented analysis of other potentially moderating variables. Providing sufficient details are recommended for future research to promote replication of the study in applied settings.

CHAPTER IV: A SINGLE-CASE STUDY

Introduction

Comprehension is a complex metacognitive process that requires simultaneous application of many subskills, such as accessing text, understanding what is being asked, and constructing a response (Alison, Root, Browder, & Wood, 2017). Comprehending written text is fundamental to accessing information across all academic subject areas and succeeding in school (Head, Flores, & Shippen, 2018; Spooner, Ahlgrim-Delzell, Kemp-Inman, & Wood, 2014). Though there has been increased emphasis on improving literacy skill for all students (e.g., Common Core State Standards, 2010; National Institute for Literacy, 2001), students with autism spectrum disorder (ASD) often exhibit difficulties in learning to read without receiving explicit instruction that is tailored to address their unique needs. As legislation mandates the use of evidence-based practices to support students with disabilities, including students with ASD, to work toward grade-level academic standards (e.g., Every Student Succeeds Act, 2015 Individuals with Disabilities Education Improvement Act, 2004; No Child Left Behind, 2001), students with ASD should be provided effective reading interventions to achieve meaningful outcomes in academic subject areas, such as science. However, reading interventions have not been a priority for most students with ASD (Hudson & Test, 2011).

There has been a general assumption that students with ASD have a relative strength in academic subject areas (Nation, Clarke, Write, & Williams, 2006), but core symptoms of ASD, such as deficits in social communication and interaction, and restrictive and repetitive behaviors (American Psychiatric Association, 2013), may contribute challenges in achieving grade-level academic outcomes. Specifically, social communication skill is a strong predictor of reading comprehension (Ricketts et al., 2013) and delayed oral language development of students with

ASD may place them at high risk for failure in learning to read. Researchers have insisted that students with ASD frequently show unique discrepancies between well-developed decoding skills and poor comprehension skills (Nation et al., 2006; Whalen et al., 2009). This is further complicated for more complex academic content, such as science. Comprehension of science texts requires factual reading comprehension skills as well as other complex comprehension strategies, such as applying background knowledge to abstract connection, making inferences, and understanding metaphors (Knight, Wood, Spooner, Browder, & O'Brien, 2015). Although existing challenges that students with ASD face may compromise reading in the science content area, they should not be prevented from engaging in grade-level science texts because of their limited reading skills (Knight, Creech-Galloway, Karl, & Collins, 2017).

One of the instructional strategies that has been used to promote comprehension of grade-level texts for students with ASD is shared reading (Hudson & Test, 2011). The shared reading strategy focuses on active reader-listener interactions and involves two procedures: (a) reading a story aloud, and (b) providing supports for the student to interact with that are related to the story (Hudson & Test, 2011). During shared reading, reading partners (e.g., parent, teacher, therapist) guide the students by directing their attention to text, paring target vocabularies with meaning, and asking comprehension questions (Spooner et al., 2014). Shared reading interventions commonly include specific features, such as attention getters, repeated story lines, pictures paired with words, summarized text, and controlled vocabulary (Browder, Trela, & Jimenez, 2007). Shared reading has been successfully implemented to facilitate literacy development of students with developmental disabilities, including students with ASD (e.g., Browder, Mims, Spooner, Ahlgrim-Delzell, & Lee, 2008; Fleury et al., 2014; Kim, Rispoli, Lory, Gregori, & Brodhead, 2018; Muchetti, 2013; Spooner et al., 2014), and Hudson and Test (2011) reported that using shared reading has a moderate level of research evidence for students with expensive support needs. Recently, Kim et al. (2018) implemented shared reading to improve reading comprehension of grade-level narrative texts and task engagement of students with ASD, and all three participants exhibited increased reading outcomes. One of the limitations of this study was that the results were not generalizable for students with limited decoding skills because all participants had an ability to read text aloud with no or minimal supports in baseline.

While shared reading was designed to promote reading comprehension of all students, students with ASD who have difficulties decoding grade-level academic texts are more likely to require additional support within shared reading. Due to the extensive amount of vocabulary, decoding grade-level science texts can be challenging for many students with ASD. If students need to dedicate too much effort to decoding words, it can interfere with them comprehending the text (Brown, Oram-Cardy, & Johnson, 2013). To prevent this situation, an adult reading partner (e.g., researcher, parent, teacher) can read the text aloud for the students with ASD within shared reading (Alison et al., 2017). Another strategy to provide additional supports within shared reading in a less intrusive way would be using technology, such as eBooks. Recent research studies have shown that technology can be successfully incorporated into reading interventions for students with ASD (e.g., Knight et al., 2015; Spooner et al., 2014; Williams, Wright, Callaghan, Coughlan, 2002). Williams et al. (2002) reported that using eBooks was more motivating and yielded better reading outcomes than traditional books. More recently, Knight et al. (2015) used supported eText that included various features (e.g., text-to-speech, hyperlinks to vocabulary definitions, examples and non-examples) to teach science content to students with ASD. Using technology can have potential benefits for struggling readers with ASD in that technology can allow struggling readers with ASD to read the text aloud with no or minimal support from others (Alison et al., 2017; Williams et al., 2002) and provide various modes of responding (Spooner et al., 2014).

Purpose

The purpose of this proposed study was to provide preliminary data on the impact of using eBooks within shared reading for students with ASD. Specifically, this study will seek to answer the following research questions: (a) Is there a functional relationship between using adapted eBooks within shared reading and improvements in science comprehension of students with ASD? and (b) Is there a functional relationship between using adapted eBooks within shared reading and improvements in task engagement of students with ASD?

Method

Participants

Two female students and one male student with ASD aged 16, 18, and 17, respectively, participated in this study. All participants were recruited from an after-school program at a local center and were receiving special education services in public high schools. A director of the local center was asked to nominate students who met the following criteria: (a) diagnosed with ASD, (b) communicated primarily using spoken language, (c) required additional support in reading grade-level texts, and (d) did not have prior experience with shared reading. Approval for this research was obtained from parents/guardians through signed consents.

Jamie was a 16-year-old White female in the 10th grade. She was diagnosed with ASD at the age of 14 and had second diagnosis of language impairments and other health impairments. She received special education services in a resource room and participated in a general education classroom for less than 40% of the day. She had an IQ of 73 according to Wechsler Intelligence Scale for Children, 5th Edition (WISC-V). Jamie participated in state assessments in

English and language arts, mathematics, and science with accommodations (e.g., test read aloud to the student, extended testing time, additional breaks). Jamie's reading score was in the 15% percentile of the state assessment, and her Lexile was 625–775, which was a grade equivalent of 3rd to 4th grade. Her IEP goals included correctly answering 75% or more of the comprehension questions on the assessment when a passage was read aloud to her. Jamie was able to keep track of her schedules and compete her tasks on time, but she often demonstrated inappropriate interactions with adults and peers and refused to follow directions.

Kylie was a 18-year-old While female in the 11th grade. She was diagnosed with ASD and was also eligible for special education services based on intellectual disability and language impairment. She had an IQ of 58 according to the Woodcock-Johnson III Tests for Cognitive Ability, and her Adapted Behavior Assessment System, 2nd Edition (ABAS-II) composite score was 61. Kylie received special education services in a resource room and spent less than 40% of the day in a general education classroom. She participated in a life skill class 50 min per day with modified curriculum and took part in a general elective with her peers. Kylie did not take part in district or state assessments and was eligible to take alternative assessments. Based on her IEP, she had an ability to read short passages aloud and answer the direct questions with multiple-choice answers. However, she often struggled answering questions without answer choices and required paraprofessional's prompts to stay on task. At the time of the study, her IEP goals in reading included summarizing a passage using at least three details.

Cayden was a 17-year-old While male in the 11th grade. He was diagnosed with ASD and had second diagnosis of language impairments. Cayden received special education services in a resource room and spent less than 40% of the day in a general education classroom. He did not take part in the district or state assessments but in the alternative assessments. Cayden received community-based instruction 90 min per week and participated in vocational activities in the community to improve his employment skills once a week. In the community, he followed directions well but needed some supervision to stay on task and advocate for help when it is necessary. Cayden took part in a physical education class with his peers and received functional reading instruction in a life skill classroom 50 min per week. At the time of the study, his IEP goals in reading included reading a variety of text and answering questions with multiple-choice options with 80% of accuracy. He was also expected to use clues, such as the title and pictures, to identify the theme and details of the text.

Setting

All sessions were conducted in a separate classroom at a local center that offered after-school programs for individuals with disabilities in the Midwest of the United States. The classroom contained a large desk and chairs, and a video camera was set up for the purpose of data collection. The study lasted approximately 10 weeks, with students participating two to three days per week.

Reading Materials

One grade-level science textbook, *Prentice Hall Health* (Pruitt, Allegrante, & Prothrow-Stith, 2010), was selected for this study based on its alignment with: (a) secondary science standards, and (b) participants' interests and daily activities. This textbook is categorized under the science discipline and appropriate for secondary students (i.e., grades 9–12). The grade level of this textbook was aligned with all three participants of this study (i.e., 10th and 11th grade). The researcher and director of the local center reviewed the textbook and selected a chapter related to nutrients and digestion based on the participants' common interests and daily activities.

The selected chapter was divided into shorter sections and adapted to consistently include four paragraphs of 300 to 350 words. In each session, a new topic was introduced that was different from the previous sections (e.g., protein, fat). The original texts were not rewritten, but some sentences or phrases were deleted if the section included more than 350 words. No additional adaptations were made to the content (e.g., changing words, adding detailed explanations).

For the intervention sessions, the adapted texts were converted to an eBook format using Microsoft PowerPoint and Google Cloud Text-to-Speech and presented on a 9.4 × 6.6 inch iPad screen. Samples of reading materials used for intervention sessions and key features are described in Table A9. One section included six slides, and the text-to-speech function was added to all slides except for the last slide, which included only pictures. In the first slide, a key vocabulary word was presented with a definition, examples, and non-examples. This slide was used for pre-teaching a key vocabulary word before the participants start to read the text. In the next four slides, one paragraph of adapted text was presented at a time with a subheading. Keywords were highlighted in yellow, and at the end of the paragraph, the summary sentences were presented with a matched picture in a box. During reading, the participants were guided to use text-to-speech and focus on important details by using highlighted keywords and summarized sentences. The last slide presented four pictures that were inserted in each paragraph. This slide was used to provide a visual cue for the participants to retell what they read in each paragraph.

Measurement and Data Collection Procedures

Dependent variables. To evaluate the effects of using adapted eBooks within shared reading, two dependent variables were measured. The primary dependent variable of this study was comprehension of science content. After reading one section, the participants were asked to answer 10 multiple-choice questions that assessed factual understanding of the assigned text. Comprehension questions were presented on a separate piece of paper, and the participants were asked to read the questions and options and circle on the best answer. The multiple-choice questions were WH-questions (i.e., who, when, where, what, how, why) that asked the participants to find correct information directly from the assigned reading section (e.g., What are fats made out of? How many more calories does fat have than carbohydrates?). The participants were allowed to refer to the text or operate the text-to-speech function again before answering the questions. The percentage of independent and correct responses was calculated and graphed. Examples of prompted and non-prompted responses are presented in Table A10.

The secondary dependent variable of this study was task engagement. On-task and off-task behaviors were operationally defined (see Table A11), and reading task engagement was measured through 30 s momentary time sampling. An electronic cueing application was used to signal each 30 s interval, and the percentage of the intervals with on-task behaviors was calculated by the number of on-task intervals divided by the total number of intervals and multiplied by 100 (Kennedy, 2005).

Inter-observer agreement. Inter-observer agreement (IOA) data for each dependent variable was collected at least 30% of sessions for each participant (i.e., 45% for Jamie, 42% for Kylie, 38% for Cayden). These sessions were proportionately distributed across baseline and intervention phases (i.e., 36% for baseline, 42% for intervention). A second data collector, who was a Board Certified Behavior Analyst and a doctoral student in a special education program, reviewed 43% of sessions for reliability data. The first coder provided direct instruction on operational definitions and measuring each dependent variable before collecting IOA data. Using sample video recordings, the first coder conducted practice sessions with the second coder until the agreement reached a satisfactory level (i.e., above 80%). IOA data was collected by the total number of agreements divided by the total number of agreements plus the total number of disagreements and multiplied by 100 (Kennedy, 2005). The mean IOA was 100% for reading comprehension (range = 100–100%) and 99% for task engagement (range = 95–100%).

Procedural fidelity. Procedural fidelity was measured across at least 30% of baseline and intervention sessions (i.e., 36% for baseline, 42% for intervention) to ensure that all of the necessary procedures were implemented as intended. The same doctoral student was trained to document whether the interventionist completed each step based on the task-analysis checklist. Two different treatment fidelity checklists were used to measure the interventionist's adherence to the protocol (see Appendix C1 and C2). Fidelity was calculated as the number of accurately implemented steps divided by the total number of steps and multiplied by 100 (Kennedy, 2005). The calculated procedural fidelity was 100% (range = 100–100%) for baseline and 100% (range = 100–100%) for intervention.

Social validity. To evaluate social validity, researchers developed a simple questionnaire with seven questions and the three Likert scale options (i.e., 0 = No, 1 = I don't know, 2 = Yes) for participants. At the end of the study, the interventionist met with each participant individually to obtain his or her perspectives on the procedures and outcomes of the intervention. The questions were related to: (a) whether they enjoyed the reading sessions, (b) whether the inserted audio voice was helpful in understanding the text better, (c) whether learning a key vocabulary word with examples and nonexamples was helpful in understanding the text better, (d) whether a summary inserted in each page was helpful in understanding the text better, (e) whether retelling what they read to the interventionist was helpful in understanding the text better, (f) whether they perceived improvement in their reading skills, and (g) whether they wanted to read more eBooks. The social validity questionnaire used for this study is presented in Appendix C5.

Experimental Design

A single-subject, concurrent, multiple probe design across participants was used to examine the effects of using adapted science eBooks and shared reading. The study was designed to adhere to the quality standards for single-case studies developed by What Works Clearinghouse (Version 4.0, Kratochwill et al., 2010/2013): (a) the intervention began with the first participant while the others were in baseline and systematically manipulated when the participant demonstrated a stable or untherapeutic trend in baseline, (b) IOA was measured at least 30% of the sessions for all participants across conditions, and the average IOA was over 80%, (c) this study included three demonstrations of effects, and (d) there were at least five data points per condition.

Procedures

Each participant was exposed to baseline and intervention phases in a one-on-one format with a researcher. All sessions were conducted once per day, two to three times per week. The mean duration of sessions was 13 min (range = 10.5–18.5 min) for baseline and 32 min (range = 26–41 min) for intervention. The intervention sessions were approximately 19 minutes longer than the baseline sessions. The session was terminated either when the participant read the assigned material and answered comprehension questions or when the participant continuously engaged in off-task behaviors (e.g., refusing to read, making a noise, turning head away) for more than 10 min. At the end of all sessions, the participants were asked to answer 10 multiple-choice questions on a worksheet. To prevent the participants from answering incorrectly not because they did not fully understand the texts but because they did not fully understand the question, the interventionist read or reread the questions and choice options to participants if necessary. However, the interventionist did not paraphrase or rephrase any questions or options.

Baseline. At the beginning of the baseline sessions, the interventionist presented two hard-copy pages of adapted science texts and provided instruction to start reading and answer the questions (e.g., “Whenever you are ready, you can start to read and answer the questions.”). When the participant struggled to read a certain word aloud, the interventionist provided an immediate verbal prompt to read the word. The interventionist also redirected the participant to answer the question if the participant did not answer the question within 10 s of reading the question (e.g., “You can draw a circle on your best answer.”) However, no further prompting, error correction, or feedback was provided. At least five data points were collected during the baseline phase, and the intervention was introduced when the last three baseline data points of the primary variable (i.e., comprehension) demonstrated a stable or untherapeutic trend. The secondary data (i.e., task engagement) was not considered for changing phases because the major purpose of collecting engagement data was to demonstrate that a low level of task engagement was not a reason for poor reading comprehension.

Intervention. This study utilized similar shared reading procedures described by Kim et al. (2018), but the procedures were adapted for assisting high school students with reading science eBooks. At the beginning of each intervention session, a new section of the adapted science eBook was presented on the iPad screen and used as a reading material within shared reading. The shared reading intervention involved: (a) before reading, (b) during reading, and (c) after reading strategies. During *before reading*, the interventionist pre-taught one key vocabulary word of the section by using its definition, examples, and nonexamples. The participants were guided to operate text-to-speech to learn the definition of the word and go through examples and nonexamples with the interventionist. Then, the interventionist asked the participant to repeat the definition and provided verbal or gestural prompts if necessary.

During reading, the participant was asked to click the speaker icon for text-to-speech and share the contents with the interventionist. One paragraph was presented at a time, with a summary of the paragraph at the bottom of the slide. After reading a paragraph, the interventionist asked the participant to share some important details by asking WH-questions (e.g., "What are fats are made out of?" "Where you can find monounsaturated fats?"). If the participant had difficulties answering the questions, the interventionist prompted the participant to find the answer from the text (e.g., pointing to summarized sentences, asking to reread highlighted keywords) instead of telling the correct answer. This process was repeated when the participant read the remaining paragraphs.

After reading, four pictures that were inserted in the paragraphs were represented on the iPad. The interventionist asked the participant to retell important details they learned from the section by pointing to one picture at a time. If the participant had difficulties recalling any details related to a picture, the interventionist directed the participant to turn the pages and reread the summary of the specific paragraph. Then, the interventionist guided the participant to retell the details by using verbal and gestural prompts (e.g., "We read about this picture. Can you tell me something about it?"), modeling (e.g., "In this paragraph, we talked about two different types of unsaturated fats. Those were monounsaturated fats and polyunsaturated fats."), and feedback (e.g., "You are right. Please tell me where you can find monounsaturated fats.")

All intervention sessions included multiple opportunities for participants to answer both oral and written comprehension questions. Reading materials used for intervention included highlighted keywords and summarized sentences, which were designed to provide visual cues for the participants to focus on important details. Rather than simply correcting participants' answers, the interventionist taught the participants how to find the answer from the text by pointing to the highlighted keywords or summary sentences and redirecting them to focus more on those before answering questions. The intervention was completed when the participant met all of the following three criteria: (a) the participants partook in intervention sessions at least five times, (b) the last three primary data points (i.e., comprehension) were at or above 90%, and (c) the last three primary data points did not demonstrate a decreasing trend.

Effect Size Calculation

In addition to visual analysis, a nonparametric statistical analysis of effect size, Tau-U (Parker, Vannest, Davis, & Sauber, 2011), was calculated with a web-based Tau-U calculator for single-case research analysis (http://www.singlecaseresearch.org). Tau-U is used to report effect sizes in single-case studies and indicates the "percentage of non-overlap between phases" or "percentage of data showing improvements between phases" (Parker et al., 2011, p. 291). Tau-U ranges from 0 to 1 and is interpreted as small effects (i.e., 0–0.65), medium effects (i.e., 0.66–0.92), or large effects (i.e., 0.93–1.0) (Parker & Vannest, 2009).

Results

To evaluate the effects of using science eBooks within shared reading, we measured reading comprehension and task engagement of three high school students with ASD. The obtained data are displayed in Figure B5, and the mean, range, and Tau scores are presented in Table A12.

Visual Analysis

Jamie. During baseline, Jamie engaged in reading tasks during 93% of the intervals (range = 83–96%) but answered 36% of comprehension questions correctly (range = 10–50%).

Immediately after the intervention was introduced, her reading comprehension score increased to 70% and demonstrated a clear level change with no overlapping data with baseline (*M* = 93%, range = 70–100%). Jamie continuously displayed a stable increasing trend and reached 100% of reading comprehension in the third intervention sessions. In the next three intervention sessions, she also independently and correctly answered 100% of the reading comprehension questions. Discrepancies between reading comprehension and task engagement decreased during the intervention phase. Although the mean session duration increased from 12 min for baseline to 36 min for intervention, she demonstrated a higher level of task engagement (*M* = 99%, range = 95–100%) as compared to baseline (*M* = 93%, range = 83–96%). During the first intervention session, Jamie's task engagement slightly increased to 96% and showed a stable increasing trend. Her task engagement reached 100% in the third intervention session, and she exhibited 100% of task engagement during the next three consecutive sessions.

Kylie. During baseline, Kylie exhibited a high level of task engagement (*M* = 95%, range = 91–100%), but only answered 20% of comprehension questions correctly (range = 0–30%). Upon the introduction of intervention, her comprehension score immediately increased to 80% and showed a stable increasing trend (*M* = 93%, range = 80–100%). Kylie reached 100% of reading comprehension in the third intervention session, and she continuously scored 100% in the following sessions. The mean session duration increased from 14 min to 35 min, but Kylie maintained a high level of task engagement during intervention (*M* = 98%, range = 96–100%). In the first intervention session, Kylie's task engagement slightly increased to 96% and demonstrated a stable increasing trend until she reached 100% of task engagement in the fifth intervention session. The discrepancies between reading comprehension and task engagement Kylie showed during baseline noticeably decreased during intervention.

Cayden. Similar to the other two participants, Cayden also demonstrated a noticeable discrepancy between reading comprehension (M = 22%, range = 10–30%) and task engagement (M = 80%, range = 43–100%). However, he showed a wider range of task engagement than the others (i.e., 43–100%). With the introduction of intervention, his reading comprehension immediately increased to 80% and demonstrated a clear level change with no overlapping data with baseline (M = 88%, range = 70–100%). In the second intervention session, his reading comprehension score decreased to 70% but reached 100% of reading comprehension in the following intervention session. His comprehension score slightly decreased to 90% in the fourth intervention session, but he reached 100% of reading comprehension again in the fifth intervention session. The mean session duration increased from 13 min to 31 min, and Cayden demonstrated a more stable and higher level of task engagement (M = 98%, range = 96–100%) as compared to baseline (M = 80%, range = 43–100%). Upon the introduction of intervention, his task engagement increased to 96% and maintained the higher level of engagement until he reached 100% of task engagement in the fifth intervention session.

Effect Size

Baseline data on both dependent variables did not show undesirable trends, and thus we did not correct baseline. The omnibus Tau scores indicated large effects for comprehension (i.e., 1.00) and medium effects for task engagement (i.e., 0.80). All three participants' Tau scores for reading comprehension were 1.00, which indicates that 100% of data showed improvement between two phases with no overlapping data. Tau scores for task engagement were 0.93, 0.66, and 0.80 for Jamie, Kylie, and Cayden, respectively (see Table). These results suggested that all participants demonstrated positive improvements between two phases with large effects for Jamie and medium effects for Kylie and Cayden.

Social Validity

Upon the completion of the study, each participant was asked to complete the social validity questionnaire that included seven questions and three options (i.e., 0 = No, 1 = I don't know, 2 = Yes). All participants answered the seven questions positively, and there were no negative responses (i.e., $M = 2$, range = 2–2). Students indicated that they enjoyed reading sessions and expressed interest in reading more science eBooks in the future. They perceived that their reading skills improved during intervention, and they expressed more confidence in reading. They also positively reported that using eBooks with audio voice, learning a key vocabulary word before reading, having a summary at the end of each paragraph, and retelling what they read was helped them to understand the text better.

Discussion

The purpose of this study was to evaluate the effects of using science eBooks within shared reading on reading comprehension and task engagement of three high school students with ASD. The results of this study indicated that all three participants demonstrated improvements in reading comprehension through the multi-component shared reading intervention. Due to the high level of task engagement during baseline (above 80% in average), only one participant exhibited a clear functional relation between two phases. However, all participants demonstrated similar or higher levels of engagement during intervention sessions (above 97% in average) despite the increased mean session duration (i.e., 13 min for baseline, 32 min for intervention). The overall findings of this study add additional empirical support for using eBooks and shared reading as an instructional method for teaching high school students with ASD to comprehend grade-level science content.

Students with ASD often have difficulties comprehending texts (El Zein, Solis, Vaughn, & McCulley, 2014), and their existing challenges can be exacerbated when they read grade-level textbooks in content areas (Knight et al., 2015). As students enter secondary schools, the major purpose of reading shifts from understanding narrative text to learning from expository text (Knight et al., 2015). Those factors increase the necessity of individualized instruction to support secondary students with ASD to access and comprehend grade-level texts in content areas. Shared reading has been successfully applied as an instructional methods for students with developmental disabilities to improve comprehension skills (Hudson & Test, 2011). There has been a growing body of research on how technology can be incorporated into shared reading intervention (Alison et al., 2017; Browder, Root, Wood, & Alison, 2015; Spooner et al., 2014; Spooner, Kemp-Inman, Ahlgrim-Delzell, Wood, & Davis, 2015). Findings of this study align with past studies that suggested technology can be paired with shared reading and used to promote reading outcomes of students with ASD.

In this study, a variety of visual and auditory supports that have been hypothesized to improve reading comprehension for students with ASD were embedded into eBooks (e.g., text-to-speech, highlighted keywords, summary sentences, pictures). Inaccurate and slow decoding skills are generally considered as a common factor of comprehension problems (Brown et al., 2013; Perfetti, 1985), but not all students with ASD are able to reach proficient decoding skills. All three participants in this study were also able to decode short paragraphs below their grade levels but had difficulties decoding grade-level science texts due to unfamiliar vocabulary words. As an attempt to promote reading comprehension skills of students with reading difficulties, text-to-speech and other related read-aloud tools have been widely used (Wood, Moxley, Tighe, & Wagner, 2018). In previous research studies designed to improve reading comprehension skills of students with ASD, text-to-speech was effectively used to compensate for limited decoding skills and increase access to written materials (Alison et al., 2017; Knight et al., 2015; Spooner et al., 2014). Given that comprehension problems of three participants with ASD stemmed at least in part from their limited decoding skills, reducing the decoding requirement through text-to-speech possibly led to improvements in reading comprehension.

In addition to text-to-speech, the other embedded features of eBooks were tailored to support the interventionist-directed shared reading intervention package that involved three major components (i.e., before reading, during reading, after reading strategies). First, before reading, pre-teaching a key vocabulary word with definition, examples, and nonexamples may assist students with ASD in activating prior knowledge of science content. Extensive vocabulary and background knowledge are required to adequately comprehend science content (Knight et al., 2015), but students with ASD often have difficulties activating prior knowledge to comprehend text without supports (O'Connor & Klein, 2004). Findings of this study support that pre-teaching key vocabulary words and the activation of prior knowledge on the topic before reading can help students comprehend the science text. Second, during reading, each paragraph was presented individually with highlighted keywords, summarized sentences, and a matched picture. These visual cues were used to guide participants to focus on important details and find necessary information from the text. While fluent readers can decode and comprehend written materials simultaneously, students with ASD tend to miss content when they need to dedicate their efforts to decoding (Brown et al., 2013). During reading strategies were intended to guide participants to stop decoding after reading one paragraph and share the content with the interventionist, which possibly promoted reading comprehension. Third, after reading, participants were guided to retell important details of each paragraph using four pictures. This activity provided a final opportunity for participants to check their understanding of the topic and summarize what they learned from the section. Results of this study align with previous research and suggest story retelling can promote reading comprehension (Louis & Singh, 2017).

The secondary data of this study showed that all three high school students with ASD exhibited similar or higher levels of task engagement during intervention sessions despite the increased mean session duration (i.e., 32 min). Given that a school period typically lasts more than 30 min, the high levels of task engagement during short baseline sessions (i.e., 13 min in average) would be easily expected from the high school students participated in this study. However, as the session duration increased, levels of engagement remained at or above baseline levels. These data are particularly meaningful given that all three participants, who had some behavioral concerns related to following adults' directions or maintaining concentration on work tasks, engaged in reading activities at least 98% of the intervention sessions in average (i.e., 99% for Jamie, 98% for Kylie, 98% for Cayden). While problems in task engagement are often considered as a factor or low academic achievement, all three participants exhibited noticeable discrepancies between the high task engagement and low reading comprehension in baseline. Findings of this study could imply that participants' reading comprehension problems were not due to their lack of ability to engage in reading activities appropriately, which align with previous research (Kim et al., 2018).

Implications for Research and Practice

Positive findings of this study add empirical support that using eBooks within shared reading can be effective for teaching students with ASD in the science content area. All three participants also perceived that major features of the shared reading intervention package (e.g., text-to-speech, pre-teaching a key vocabulary word, answering comprehension questions, retelling) helped them to comprehend science content better. To apply this intervention package into practice and future research, the following considerations may need to be made.

First, although PowerPoint is commonly used in any educational settings, educators may need additional assistance to feel comfortable creating eBooks with technology. Educators may not have enough time to create eBooks for each lesson, and limited resources often permit them from developing and adapting eBooks that address needs of students. To minimize time and effort involved in creating a new eBook, we developed a template and utilized it for every intervention session. Depending on availability of resources, educators may prefer to use different software programs (e.g., Keynote, Google Slides, Pretzi) to develop and share eBooks. There are many existing eBooks available online, and some eBooks also include audio voices. If a student does not require text adaptation and can benefit from using text-to-speech, educators may consider using existing eBooks. While selectively adopting some features of eBooks used in this study (e.g., text-to-speech, highlighted keywords, summary sentences) may increase feasibility, caution should be exercised as we are uncertain which features of the eBook would lead to positive outcomes.

Second, we used a free web-based application, Google Cloud Text-to-Speech, to convert text into human-like speech. One benefit of this application is that it allows users to select male or female voices and adjust speed and pitch of speech, and it creates consistent speech for all intervention sessions. There are an increased number of text-to-speech applications available online, and it has been broaden educators' choice options to create audio voices. Another convenient way would be directly recording human voices. PowerPoint includes a voice recording function that can help users to easily record, re-record, and insert audio voices into the slides. In this study, the purpose of using text-to-speech was to reduce requirements for decoding to help the participants focus on comprehending the science content. When educators create audio voices, they would need to ensure that the tone, speed, and pitch of text-to-speech are appropriate for students. If students have difficulties reading text silently along with text-to-speech, educators may want to consider adjusting speed of speech or providing gestural prompts to support students to keep their eyes on the words currently spoken if necessary.

Third, this study investigated effects of using science eBooks within shared reading as an intervention package. When applying this intervention in practice, educators may want to adopt a few components from the package (e.g., implement only before and during reading strategies) or replace one component with another one (e.g., writing a summary paragraph instead of retelling important details) to tailor it for their own classroom situations. Although each component of this package intervention is a research-based strategy, educators need to remember that deviations from the shared reading intervention package may not guarantee the same positive outcomes.

Fourth, students with ASD may require direct training on how to find information from the text to answer different types of comprehension questions. During baseline sessions, all three participants rarely referred back to the assigned text when they were answering comprehension questions on their worksheet. They lacked skills to identify what information they needed to find to answer the comprehension question correctly and relied on their memory rather than checking details in the text again. Participants also had difficulties answering different types of comprehension questions (e.g., multiple-choice, open-ended, true/false questions). Kylie often struggled to answer open-ended questions during shared reading but demonstrated relative strengths in answering multiple-choice questions. Cayden was able to answer multiple-choice questions that asked him to find one correct option (e.g., “Where you can find unsaturated fats?”) but had difficulties identifying one incorrect option (e.g., “Which of the following is false about unsaturated fats?"). Therefore, educators may need to consider the best mode of answering to truly measure each student's reading comprehension skills and provide additional training to support them to learn how to answer specific types of questions.

Fifth, this study examined effects of adapted science eBooks within shared reading as an intervention package, so identifying core components of this intervention package was beyond our scope. Given the various needs of students with ASD in educational settings, additional research is warranted to identify the most critical intervention components and make more specific recommendations for practice.

Sixth, in this study, participants' task engagement was measured using 30 sec momentary time sampling. One of the major advantages of the momentary time sampling process is that researchers do not need to attend to a participant's behavior throughout the session (Kennedy, 2005). Momentary time sampling provides an estimate of behavior rather than capturing all occurrences. This recording system is typically used to capture behaviors that occur at a high rate with no clear beginning and end (Kennedy, 2005). While momentary time sampling is comparatively easy to implement in applied settings, it can underestimate the occurrence of off-task behaviors if a participant may engage in off-task behaviors throughout the interval but stop before the end of the interval. Depending on the topographies of off-task behaviors that the participant frequently demonstrates, researchers may consider using different measurement systems (e.g., partial interval recording) or adjusting the length of intervals (e.g., 10 sec) to provide a better estimate of target behaviors.

Limitations and Directions for Future Research

Despite the positive outcomes of this study, several limitations must be considered in using the findings to influence research and practice. First, all participants used verbal language as a primary mode of communication. Given that shared reading procedures implemented in this study were mainly based on active interaction between a student and an adult reading partner, the findings of this study may not be generalizable across students with ASD who have no or limited verbal communication skills. Future research should investigate ways to modify shared reading procedures for students with various verbal abilities, such as AAC users and English language learners with ASD.

Second, this study was implemented one-on-one in an after school classroom at a local center. However, the majority of academic instruction for students with ASD is provided in school, and delivering one-on-one instruction may not be realistic for many special education teachers and staff. It is recommended for future research to explore practical ways to apply the shared reading intervention for a group of students with and without disabilities in classroom settings.

Third, this study used adapted science eBooks within shared reading as an intervention package, so findings of this study cannot determine the most critical components to improve reading comprehension skills of students with ASD. Future researchers would need to conduct a component analysis to identify critical components that directly influence positive reading outcomes. It would also assist educators in deciding whether the adapted intervention can closely replicate positive outcomes of this study.

Fourth, since participants were not pre-tested on prior knowledge of vocabulary for each section, there is a possibility that they were more or less familiar with science content in some sections than the others, which could impact on their overall comprehension. Future research should attempt to measure prior knowledge on the topics and control for it across conditions.

Fifth, the high level of task engagement participants demonstrated in baseline made difficult to capture detailed changes between baseline and intervention phases. It is recommended for future research to investigate meaningful ways to measure task engagement and suggest more delicate measurement systems.

Conclusion

There has been an increased emphasis on supporting all students, including students with ASD, to gain access to grade-level academic content (ESSA, 2015). This study explored a way to promote reading comprehension in science content area for high school students with ASD. A grade-level science textbook was converted into an eBook that included various features (e.g., text-to-speech, highlighted keywords, summarized sentences), and the adapted eBook was used to support the interventionist-directed shared reading intervention. Positive outcomes of this study can add empirical support on the use of adapted eBooks with shared reading to gain access to grade level science content for students with ASD.

CHAPTER V: GENERAL DISCUSSION

The purpose of this dissertation was to investigate the effects of using technology to teach reading skills to students with ASD through the systematic quality review, meta-analysis, and single-case research evaluation. In Study 1, a systematic quality review was conducted to: (a) determine the quality of the extant research on technology-based reading interventions for students with ASD and (b) synthesize study characteristics related to participants, intervention components, technology usage, and outcomes for the studies that met the WWC quality indicators. In Study 2, a meta-analysis was conducted to: (a) quantify the magnitude of technology-based reading interventions for students with ASD and (b) determine if participant and intervention characteristics moderate intervention effects. In Study 3, a single-case multiple-probe design was applied to investigate the effects of using science eBooks that included various features (e.g., text-to-speech, summarized sentences, highlighted keywords, pictures) within shared reading on reading comprehension and task engagement of three high school students with ASD. All three studies found positive effects for incorporating technology into reading interventions for students with ASD and addressed several important gaps in the extant literature.

Technology is widely available in educational settings, but the quality of research backing up this practice has not been fully evaluated. There has been a growing body of research suggesting positive effects of using technology for students with ASD, but an absence of quality control may makes this conclusion tenuous. A number of systematic literature reviews (Kagohara et al., 2013; Knight et al., 2013; Pennington, 2010; Ramdoss et al., 2011; Root, Stevenson, Davis, Geddes-Hall, & Test, 2017) and meta-analyses (Ledbetter-Cho et al., 2018; Hong et al. 2017) were conducted to analyze the use of technology for students with ASD, but only a few of them (Root et al., 2017; Hong et al., 2017) controlled for experimental rigor of reviewed articles. Interpreting results from studies that might not meet quality indicators could lead to false positive conclusions in terms of the intervention effects. To address this gap, methodological rigor of reviewed articles was evaluated based on the WWC quality indicators in Study 1 and Study 2. In those studies, both descriptive synthesis and quantitative analyses were limited only to studies that met the quality indicators to ensure the internal validity of each study and its effects.

Additionally, Study 1 and Study 2 can have practical value in that those studies aimed to extend the existing literature by focusing on the use of technology to teach reading skills to students with ASD. A number of systematic literature reviews (e.g., Kagohara et al., 2013; Pennington, 2010; Ramdoss et al., 2011; Root et al., 2017) and meta-analyses (e.g., Hong et al., 2017; Ledbetter-Cho et al., 2018; Sansosti, Doolan, Remaklus, Krupko, & Sansosti, 2015 evaluated the effectiveness of technology-based interventions for students with ASD, but most studies focused only on CAI interventions or investigated its effects across) various skill domains (e.g., challenging behavior, daily living skills, social-communication skills, academic skills). Results of Study 1 and Study 2 suggest that incorporating technology (i.e., computer, tablet) into reading interventions is a promising practice and can lead to significant increases in reading of students with ASD. Such research would provide practitioners with important information on how technology can be utilized to teach reading skills to students with ASD in educational settings.

Although the results of Study 1 and Study 2 suggest promising evidence for using technology to teach reading skills to students with ASD, additional research on these topics is warranted. Specifically, none of the reviewed studies that demonstrated sufficient methodological rigor aimed to improve reading comprehension skills in academic subject areas, such as science. Given that the increased number of students with ASD are educated in a general education classroom (Cihak, Fahrenkrog, Ayers, & Smith, 2010) and high-quality instruction should be guaranteed to support them to work toward grade-level academic standards (ESSA, 2015), there has been a need to identify effective strategies to improve their academic outcomes in content areas. Results of Study 3 added empirical evidence on the use of an iPad to present reading materials that included various auditory and visual supports (e.g., text-to-speech, highlighted keywords, summarized sentences, pictures) within shared reading as a way to increase access to grade-level science textbooks. In Study 3, three high school students with ASD who had difficulties decoding grade-level texts participated. Decoding grade-level science texts can be challenging for many students with ASD due to the extensive amount of vocabulary, and if they need to dedicate a high level of effort to decoding words, it can interfere with their comprehension of the text (Brown, Oram-Cardy, & Johnson, 2013). Although shared reading was designed to promote reading comprehension of all learners, students with ASD who have limited decoding skills are more likely to require additional support within shared reading. Findings from Study 3 suggested that technology can allow struggling readers with ASD to read the text aloud with no or minimal supports from others, and using eBooks within shared reading can be potentially beneficial for teaching reading comprehension skills to students with ASD in the science content area.

Taken together, these findings provide additional support for the efficacy of incorporating technology into reading interventions for students with ASD. This dissertation suggest that technology (i.e., computer, tablet) can potentially benefit students with ASD to improve reading skills across sub-reading domains (e.g., decoding, vocabulary, comprehension), but findings of this dissertation cannot lead to the determination of core components of technology-based reading interventions for students with ASD. Depending on availability of resources, educators are often required to adapt the overall intervention procedures to meet the various needs of students with ASD in applied settings. There are an increased number of software programs available (e.g., PowerPoint, GoTalk Now, Google Cloud Text-to-Speech, Google Slides, Keynote), and it has been broaden educators' choice options to develop individualized materials that are tailored to addressed unique needs of their students. However, caution should be exercised as it is uncertain which components of technology-based intervention packages would lead to positive outcomes.

Findings of this dissertation implied that the evidence base on the use of technology to teach reading comprehension skills to secondary students with ASD in academic content areas (e.g., science, social studies) is comparatively limited. Moreover, using technology can have potential benefits for students with ASD who are educated in general education classrooms because technology can allow students to engage in academic activities with no or minimal supports of others, but none of the studies were implemented for a group of students when typically developing peers are presented. To address these gaps, future research would need to investigate practical ways to promote reading skills of secondary students with ASD and extend its effects to general education settings.

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APPENDIX A. TABLES

Table A1

The Adapted WWC Design Standards and Rating Criteria for Single-Case Studies

Design Standard	Rating
1. Independent Variable (IV)	
IV was systematically manipulated with researcher determining when and how the conditions changed	• Y: Yes • N: No
2. Inter-assessor Agreement (IAA)	
2-1. The outcome variable was measured systematically by more than one assessor	• Y: Yes • N: No
2-2. IAA was collected at least 20% of the data points across conditions	• Y: Yes • R: Collected >20%, not across conditions • N: <20%
2-3. The mean IAA was at or above 80% or 0.6 Cohen's Kappa	• Y: Yes • N: <80% or 0.6 Kappa
	Standard 2: Overall Rating • Y: All Y • R: Both Y and R • N: One or more N
3. Treatment Fidelity	
3-1. Treatment fidelity was assessed at least 20% of the intervention sessions across conditions	• Y: Yes • R: Collected >20%, not across conditions • N: <20% or not collected
3-2. The mean treatment fidelity was at or above 80%	• Y: Yes • N: <80%
	Standard 3: Overall Rating • Y: All Y • R: Both Y and R • N: One or more N

Design Standard	Rating
4. Phases and Data Points	
4-1. Reversal/Withdrawal	• Y: $\geq$ 4 phases with $\geq$ 5 points • R: $\geq$ 4 phase with 3-4 points • N: $\leq$ 3 phases or $\leq$ 2 points
4-2. Alternating Treatment	• Y: $\geq$ 5 points per condition with $\leq$ 2 consecutive points • R: $\geq$ 4 points per condition with $\leq$ 2 consecutive points • N: $\leq$ 3 points per condition with $\geq$ 3 consecutive points
4-3. Multiple-Baseline	• Y: $\geq$ 6 phases with $\geq$ 5 points • R: $\geq$ 6 phases with 3-4 points • N: $\leq$ 5 phases or $\leq$ 2 points
4-4. Multiple-Probe Design	• Y: $\geq$ 6 phases with $\geq$ 5 points • R: $\geq$ 6 phases with 3-4 points • N: $\leq$ 5 phases or $\leq$ 2 points
Additional Standards	
4-4-1. Probes within first 3 sessions	• Y: 3 probes within first 3 sessions across conditions • R: 1-2 probes within first 3 sessions across conditions • N: No probe within first 3 session in $\geq$ 1 conditions
4-4-2. Probes prior to intervention	• Y: 3 probes prior to intervention across conditions • R: 1-2 probes prior to intervention across conditions • N: No probe prior to intervention in $\geq$ 1 conditions
4-4-3. Probes after intervention	• Y: 1 probe after intervention in all conditions not receiving intervention • R: 1 probe after intervention in some conditions not receiving intervention • N: No probe after intervention
	Standard 4: Overall Rating Y: All Y R: Both Y and R N: One or more N
Final Rating *Treatment Fidelity scores were NOT considered for final rating	**Meet Standards without Reservations** : If all ratings were Y **Meet Standards with Reservations** : If ratings included both Y and R **Does Not Meet Standards** : If there was one or more N

Table A2

Results of Quality Evaluation for Group Design Studies

Individual-level Assignment Studies

Study	WWC Design Standards			Overall
	1. Design	2. Attrition	3. Baseline Equivalence	
Ahlgrim-Delzell et al. (2014)	RCT	Y	N/A	Y
Moore & Calvert (2000)	RCT	N/R	N/R	N
Serret et al. (2017)	QED	N/A	R (Word Segmentation Only)	R

Cluster-level Assignment Studies

Study	WWC Design Standards							Overall
	1. Attrition	2. Individuals Entering	3. Non-response	4. Baseline Equivalence	5. Analytic Sample	6. Attrition	7. Baseline Equivalence	
Whalen et al. (2010)	N	N/A	N/A	N/R	N/A	N/A	N/A	N

Note. Y = Meet the standard; R = Meet the standard with reservations; N = Does not meet the standard; N/A = Not applicable; N/R = Not reported; RCT = Randomized controlled trial; QED = Quasi-experimental design

Table A3

Results of Quality Evaluation of Single-Case Design Studies

Study	Design	IV	IRA	Treatment Fidelity*	Phases/ Data Points	Final Rating
		WWC Design Standards				
Ahlgrim-Delzell et al. (2012)	MPD	Y	N	Y	R	N
Alison et al. (2017)	MPD	Y	Y	R	R	R
Armstrong et al. (2012)	ATD	Y	R	N	Y	R
Bossler & Massaro (2003)	MBD	Y	N	N	R	N
Browder et al. (2017)	MPD	Y	Y	R	R	R
Chebli et al. (2017)	MPD	Y	Y	N	N	N
Chen et al. (2009)	ATD	Y	N	N	Y	N
Coleman-Martin et al. (2005)	RWD	Y	R	R	N	N
Coleman et al. (2012)	ATD	Y	R	R	Y	R
Coleman et al. (2015)	ATD	Y	Y	R	Y	Y
Crowley et al. (2013)	MBD	Y	N	N	N	N
El Zein et al. (2016)	ATD	Y	Y	Y	Y	Y
Ganz et al. (2014)	ATD	Y	Y	R	Y	Y
Hetzroni & Shalem (2005)	MPD	Y	N	Y	R	N
Knight et al. (2015)	MPD	Y	Y	Y	N	N
Lee & Vail (2004)	MPD	Y	Y	Y	R	R
Leytham et al. (2015)	MPD	Y	Y	R	N	N
McMahon et al. (2016)	MPD	Y	Y	Y	N	N

Study	Design	WWC Design Standards				Final Rating
		IV	IRA	Treatment Fidelity*	Phases/ Data Points	
Mechling et al. (2002)	MPD	Y	Y	Y	N	N
Morlock et al. (2015)	MBD	Y	R	N	R	R
Saadatzi et al. (2017)	MBD	Y	Y	Y	R	R
Smith et al. (2013)	MPD	Y	Y	Y	R	R
Spooner et al. (2014)	MPD	Y	Y	Y	R	R
Spooner et al. (2015)	MPD	Y	Y	Y	Y	Y
van der Meer et al. (2015)	MPD	Y	R	Y	N	N
Whitcomb et al. (2011)	MBD	Y	N	R	N	N
Yaw et al. (2011)	MBD	Y	R	N	R	R
Total (*N* = 27)	**# of Y** (%)	27 (100%)	15 (56%)	12 (44%)	7 (26%)	4 (15%)
	# of R (%)	N/A	6 (22%)	8 (30%)	11 (41%)	10 (37%)
	# of N (%)	0 (0%)	6 (22%)	7 (26%)	9 (33%)	13 (48%)

Note. * = Score was not considered for final rating; Y = Meet the standard; N = Does not meet the standard; R = Meet the standard with reservations; N/A = Not applicable; ATD = Alternating treatment design; MBD = Multiple-baseline design; MPD = Multiple-probe design; RWD = Reversal/withdrawal desig

Table A4

Study Narratives of Articles with High-Quality Research Evidence

Study	Participants	Settings	Design	Technology	Intervention	Interventionist	Outcomes	Effects	Results
Ahlgrim-Delzell et al. (2016)	*N*=31* *n*(treatment)=17 *n*(control)=14 *n*(male)=23 *n*(ASD)=13 Age: 5-14y *n*(K)=3 *n*(E)=20 *n*(M)=8 *AAC users	Self-contained classroom	RCT	iPad *GoTalk Now*	*Early Reading Skills Builder (ERSB)* - Phonics-based reading curriculum - Time delay, prompting, audio prompt	Teacher	*Phoneme identification* - Selecting the letters to match a voice phoneme *Blending sounds to identify words* - Selecting the written word to match a voice word *Decoding for picture-word-matching* - Reading the written word and select a picture to match the word *Total score* -Total score from the ERSB curriculum-based measurement	Strong Moderate Strong Strong	- There were statistically significant differences between two groups in phonemic identification, decoding, and total score - Blending sounds was not statistically significant - IRA: 100% - Fidelity: 95%
Alison et al. (2017)	*N*=3* *n*(male)=3 *n*(ASD)=3 Age: 8-10y *n*(E)=3 *ELLs	Self-contained classroom	SCR MPD	iPad *GoTalk Now*	*Technology-based shared story reading* - Time delay, prompting, modeling, audio prompt embedded in e-Text	Researcher	*WH pairings* - Independent and correct parings of WH words with definitions and examples *Comprehension* - Independent and correct responses to comprehension questions	Strong No effect	- All three participants demonstrated improvements in WH paring and comprehension - IOA: 98% for pairing, 100% for comprehension questions - Fidelity: 100%
Armstrong et al. (2012)	*N*=5 *n*(male)=5 *n*(ASD)=5 Age: 7-8y *n*(E)=5	N/R	SCR ATD	Computer *Wynn Wizard*	*Storybook intervention* - Repeated reading with interventionist, story retelling *Computer intervention* - Repeated reading with computer, audio/visual prompts, story retelling	Researcher	*Comprehension* - Number of correct responses to comprehension questions *Retelling* - Morrow's retelling score, which measures story structure elements (i.e., setting, theme, plot episodes, resolution, sequence)	No effect (0:5) N/A	- Neither of the storybook or computer interventions led to better outcomes than the other - IOA: 96% (comprehension), 93% (retelling) - Fidelity: N/R
Browder et al. (2017)	*N*=3 *n*(male)=2 *n*(ASD)=3 Age: 8-10y *n*(E)=3	Self-contained classroom	SCR MPD	iPad *SMART notebook©*	*Electronic story-mapping intervention* - Time delay, prompting, modeling, reinforcement - Story-map with audio prompt	Researcher	*Identification of story element* - Independent and correct pairings of story element words to definition *Labeling of the story elements* - Independent and correct labels of story elements *Comprehension* - Independent and correct responses to comprehension questions	Strong Strong Strong	- All three participants demonstrated improvements in pairing and labeling of story elements, and comprehension - Participants maintained high levels of performance overtime - IOA: Measured, but N/R - Fidelity: Measured, but N/R

Study	Participants	Settings	Design	Technology	Intervention	Interventionist	Outcomes	Effects	- Results
Coleman et al. (2012)	*N*=3 *n*(male)=3 *n*(ASD)=1 Age: 10-12y *n*(E)=2 *n*(M)=1	Self-contained classroom	SCR ATD	Computer *PowerPoint©*	*Techer-directed CTD* - Using flash cards - Time delay, modeling, verbal praise, error correction *Computer-assisted CTD* - Time delay, modeling, verbal praise, error correction	Intern teacher	*Sight word reading* - Percent of words read correctly - Number of trials to criterion	No effect (0:3)	- Compared to baseline, the participant with ASD (*n*=1) demonstrated improvements in both conditions - Neither of the conditions led to better outcomes than the other - IOA: 100% - Fidelity: 100%
Coleman et al. (2015)	*N*=3 *n*(male)=1 *n*(ASD)=2 Age: 9-11y *n*(E)=3	Self-contained classroom	SCR ATD	Computer *Classroom Suite*	*Teacher-directed simultaneous prompting* - Using flashcards - Verbal praise, error correction *Computer-assisted simultaneous prompting* - Audio prompt, reinforcement/error correction screen	Intern teacher	*Sight word reading* - Number of sight words recognized correctly	No effect (2:1)	- Compared to baseline, the participants with ASD (*n*=2) demonstrated improvements in sight word reading in both conditions - One participant with ASD performed better in the teacher-directed condition; and another participant with ASD did not perform better in either of the conditions - IOA: 100% - Fidelity: 98%
El Zein et al. (2016)	*N*=3 *n*(male)=3 *n*(ASD)=3 Age: 9-10y *n*(E)=3	University lab	SCR ATD	iPad *Space Voyage*	*Teacher-directed instruction* - Text preview strategy, graphic organizer - Token economy *iPad-assisted instruction* - IAI game guided to identify main idea - Token economy	Researcher	*Comprehension* - Percent of correct on curriculum-based probes *Task refusal* - Number of verbal protests, physical task refusal, or no response	No effect (0:3) No effect (0:3)	- Neither of the conditions led to better outcomes than the other - IOA: 100% (comprehension), 94% (task refusal) - Fidelity: 96%
Ganz et al. (2014)	*N*=3 *n*(male)=2 *n*(ASD)=3 Age: 8-14y *n*(E)=2 *n*(M)=1	Empty classroom at school (2 students) Home (1 student)	SCR ATD	iPad *iCommuni-cate*	*iPad-based visual script* - Using activities/videos, visual scripts, prompting, modeling *Non-treatment condition* - iPad was placed but was turned off	Researcher Generalization: School staff, mother, grandmother	*Unprompted noun/verb use* - Percent of unprompted noun/verb use following a question *Average prompt level* - Level of prompt to answer the question *Spontaneous comments* - Unprompted use of verbs/nouns within a sentence/phrase in context with video/action	No effect (0:3) N/A N/A	- All participants demonstrated improvements in the use of verbs/nouns and required less invasive prompt - One participant had mixed results in the spontaneous comments - IOA: 99% - Fidelity: All 100% except for one session (83%)

Study	Participants	Settings	Design	Technology	Intervention	Interventionist	Outcomes	Effects	- Results
Lee & Vail (2004)	*N*=4 *n*(male)=4 *n*(ASD)=1 Age: 6-7y *n*(E)=4	Self-contained classroom	SCR MPD	Computer *Word Wizard*	*Computer-based sight-word reading intervention* - Time delay, audio/visual prompts, verbal praise, feedback	Researcher	*Sight word recognition* - Percentage of correct responses	Strong	- The participant with ASD (*n*=1) demonstrated improvements in sight word recognition and generalized across modes and materials - IOA: 98.7% - Fidelity: 99.8%
Morlock et al. (2015)	*N*=3 *n*(male)=2 *n*(ASD)=3 Age: 17-18y *n*(H)=3	Empty classroom at school	SCR MBD	Computer *GemIIni*	*Video modeling* - Watching modeling videos for each target word 10 times per session	Researcher	*Word recognition* - Percentage of words card identified correctly *Word pronunciation* - Percent of words pronounced accurately	No effect Strong	- Two participants demonstrated improvements in word recognition, but one participant showed a high level of overlap between baseline and intervention - All three participants demonstrated improvements in word pronunciation - Improved outcomes were maintained overtime - IOA: 97%, 100%, 100% for each participant - Fidelity: NR
Saadatzi et al. (2017)	*N*=3 *n*(male)=3 *n*(ASD)=3 Age: 19-20y *n*(H)=1 *n*(A)=2	University lab	SCR MBD	Computer Researcher-developed program created in *Vizard*	*CAI including pedagogical agent (PA)* - Time delay, modeling, verbal praise, feedback delivered by PA	Researcher	*Sight word reading* - Percentage of words read correctly - Number of sessions to criterion	Strong	- All participants demonstrated increased engagement and correct interactions per minutes and decreased interfering behavior - IOA: 100% - Fidelity: 100%
Serret et al. (2017)	*N*=25 *n*(treatment)=12 *n*(control)=13 *n*(male)=21 *n*(ASD)=25 Age: 6-11y *n*(E)=25	Home	QED	Computer *SEMA-TIC*	*SEMA-TIC* - CAI game including word-drawing/sentence-3D animation associations, games with words, games without verbal instructions	Caregiver	*Word Segmentation* - Responses to literacy skill tasks **The other DVs did not meet the WWC standards*	Strong	- Only word segmentation met the baseline equivalence criteria and reviewed for the narrative synthesis - Participants in the experimental group had better performance in word segmentation
Smith et al. (2013)	*N*=3 *n*(male)=3 *n*(ASD)=3 Age: 11-12y *n*(E)=1 *n*(M)=2	General education classroom	SCR MPD	iPad *Keynote*®	*CAI instruction package* - CAI including audio support, prompts, error correction, and repetition	Researcher	*Identification of science terms* - Number of independent and correct responses made on assessment items	Strong	- All participants demonstrated improvements in science term identification - IOA: 100% - Fidelity: 100%

Study	Participants	Settings	Design	Technology	Intervention	Interventionist	Outcomes	Effects	- Results
Spooner et al. (2014)	*N*=4 *n*(male)=4 *n*(ASD)=4 Age: 8-12y *n*(E)=3 *n*(M)=1	Self-contained classroom	SCR MPD	iPad *GoTalk Now*©	*Shared stories* - Time delay, prompting, modeling, verbal praise, audio/visual prompts	Researcher	*Responses during shared story* - Independent and correct responses on 10-step shared story task analysis *Comprehension* - Independent and correct responses for comprehension questions	Strong Moderate	- All participants demonstrated improvements in comprehension and responses on task analysis - IOA: 96% - Fidelity: 98%
Spooner et al. (2015)	*N*=5 *n*(male)=2 *n*(ASD)=2 Age: 7-11y *n*(E)=5	Empty classroom at school	SCR MPD	iPad *GoTalk Now*©	*Shared stories* - Audio prompt, guiding questions, time delay, prompting	Researcher	*Responses during shared story* - Independent and correct responses on 10-step shared story task analysis *Comprehension* - Independent and correct responses for comprehension questions	Strong Moderate	- All participants demonstrated improvements in comprehension and responses on task analysis - IOA: 93% - Fidelity: 94% for shared stories, 93% for generalization training sessions
Yaw et al. (2011)	*N*=1 *n*(male)=1 *n*(ASD)=1 Age: 12y *n*(M)=1	Self-contained classroom	SCR MBD	Computer *Power Point*©	*Computer-based sight-word reading intervention* - Using Dolch words, audio prompt	Researcher	*Sight-word reading* - Number of words read correctly within 2sec	Strong	- The participant demonstrated improvements in sight-word reading in three different word sets - IOA: 100% - Fidelity: N/R

Note. IV = Independent variable; DV = Dependent variable; K = Kindergarten; E = Elementary school; M = Middle school; H = High school; A = Adult; ELL = English Language Learner; RCT = Randomized controlled trial; SCR = Single-case research; ATD = Alternating treatment design; MBD = Multiple-baseline design; MPD = Multiple-probe design; RWD = Reversal/Withdrawal Design; QED = Quasi-experimental design; TDI = Teacher-direct instruction; CAI = Computer-assisted instruction; IAI = iPad-assisted instruction

Table A5

Technology Usage

Hardware	Software	Key Features	Primary Role	Cost*	Articles First author (year)
Computer	PowerPoint©	Tool for developing materials - Presenting words with audio voice and pictures - Inserting reinforcement/error correction slides	Developing Materials	$99.99/year	Coleman (2012) Yaw (2011)
	Classroom Suite	Commercially developed CAI package - Web-based learning tool for K-5th graders with disabilities	Delivering Instruction	Service Discontinued	Coleman (2015)
	GemIIni	Commercially developed website - Providing video modeling for pronouncing words	Delivering Instruction	$98/month	Morlock (2015)
	SEMA-TIC	Commercially developed CAI package - Game format	Delivering Instruction	Not available	Serret (2017)
	Vizard	Tool for developing desktop applications - Used for making a virtual classroom	Developing Materials	Free	Saadatzi (2017)
	Word Wizard	Researcher developed CAI package - Providing sound, video, text, animation, verbal praise, and feedback	Delivering Instruction	Not available	Lee (2005)
	Wynn Wizard	Tool for converting to eTexts - Scanning and reading software - Providing audio voice along with highlighted keywords	Supporting Instruction	$395 ~ $595	Armstrong (2012)
iPad	GoTalk Now©	AAC application - Present texts with audio voice - Provide response opportunities	Supporting Instruction	$79.99	Ahlgrim-Delzell (2016) Alison (2017) Spooner (2014) Spooner (2015)

Hardware	Software	Key Features	Primary Role	Cost*	Articles First author (year)
iPad	iCommunicate	Application for designing visual supports - Presenting words with audio voice - Providing response opportunities	Supporting Instruction	$49.99	Ganz (2014)
	Keynote®	Tool for developing materials - Presenting verbal directions with texts - Providing response options and feedback	Developing Material	Free**	Smith (2013)
	Space Voyage	Commercially available IAI package - Game format - Guiding to find main ideas and noting details	Delivering Instruction	Service Discontinued	El Zein (2016)
	SMART Notebook©	Note taking application - Providing a touch-based story-map template	Supporting Instruction	Free	Browder (2017)

Note. * = All prices are based on US dollar; ** = Available only for Apple devices (e.g., iPad, iPhone, MacBook); CAI = Computer-assisted instruction; IAI = iPad-assisted instruction; Developing = Used for developing materials/programs; Supporting = Used for supporting interventionist-led reading interventions; Delivering = Used for delivering reading interventions with no additional instructions provided by interventionist

Table A6

Variable Definitions

Variables	Levels	Definitions
Participants Characteristics		
Age	Elementary Secondary Adolescent/Adult	Ages 6-11 Ages 12-15 Above 16
Diagnosis	ASD without ID	Reported IQ score was at or above 70; or participant description indicated that the participant had high-functioning autism or Asperger syndrome
	ASD with ID	Reported IQ score was less than 70; or participant description indicated that the participant had both ASD and ID diagnoses
	NR	IQ score was not reported; and intellectual ability could not be inferred from participant description
Reading Materials		
Types	Paragraph	Paragraphs of written materials (e.g., storybook, fiction, essay, textbook, non-fiction)
	Word	Words from a vocabulary list; sight words
Grade-Level	Yes	Level of reading materials was aligned with participant's age or grade (e.g., using a storybook appropriate for 5-7-year-old children to teach a 7-year-old participant with ASD)
	No	Level of reading materials was not aligned with participant's age or grade (e.g., teaching sight words to high school students with ASD)
Technology		
Device	Computer	Desktop computer; laptop
	Tablet	Tablet PC; iPad; Galaxy Tab
Role of Technology	Delivering	Technology delivered reading instruction without pairing with interventionist-directed instruction
	Supporting	Technology was paired with interventionist-directed instruction (e.g., constant time delay, shared reading)

Intervention Components		
Prompting	Hierarchy Prompting	Least-to-most or most-to-least prompting system was applied
	Constant Prompting	One prompting system (e.g., verbal prompt) was selected and used consistently during intervention
	No Prompting	Did not include prompting system to teach reading skills
Time Delay	Yes	Included constant or progressive time delay to teach reading skills
	No	Did not include time delay to teach reading skills
Shared Reading (For Comprehension)	Yes	Shared reading was used to teach comprehension or vocabulary skills
	No	Instructional methods other than shared reading were used to teach comprehension or vocabulary skills
	NA	Both reading comprehension and vocabulary skills were not targeted in the study
CAI/IAI (For Decoding)	CAI/IAI + Prompting	CAI/IAI included prompting strategies for teaching decoding skills
	CAI/IAI + TD	CAI/IAI included time delay strategies for teaching decoding skills
	CAI/IAI + Prompting + TD	CAI/IAI included both prompting and time delay strategies for teaching decoding skills
	NA	CAI/IAI was not used to teach decoding skills
Targeted Reading Outcomes		
Comprehension		Ability to understand meaning of written materials (e.g., matching words with definitions, answering comprehension questions, identifying key story elements)
Decoding		Ability to read written materials aloud (e.g., reading sight words correctly)

Note. ASD = Autism spectrum disorder; ID = Intellectual disability; CAI/IAI = Computer/iPad assisted instruction; TD = Time delay; NR = Not reported; NA = Not applicable

Table A7

Descriptive Information of Studies Included in Meta-Analysis

First Author (Year)	Participant	Age	Diagnosis	Reading Materials		Technology		Intervention Components				Reading Outcome
				Type	Grade level	Device	Role	Prompting	TD	SR	CAI/IAI	
Alison (2017)	Nathan	E	ASD+ID	P	Yes	Tablet	Supporting	Hierarchy	Yes	Yes	NA	C; SE
	Sal	E	ASD+ID	P	Yes	Tablet	Supporting	Hierarchy	Yes	Yes	NA	C; SE
	Juan	E	ASD+ID	P	Yes	Tablet	Supporting	Hierarchy	Yes	Yes	NA	C; SE
Armstrong (2012)	Chip	E	ASD w/o ID	P	Yes	Computer	Delivering	No	No	No	NA	C
	Ethan	E	ASD w/o ID	P	Yes	Computer	Delivering	No	No	No	NA	C
	Jurt	E	ASD w/o ID	P	Yes	Computer	Delivering	No	No	No	NA	C
	Brent	E	ASD w/o ID	P	Yes	Computer	Delivering	No	No	No	NA	C
	Henry	E	ASD w/o ID	P	Yes	Computer	Delivering	No	No	No	NA	C
Browder (2017)	Stuart	E	ASD+ID	P	Yes	Tablet	Supporting	Hierarchy	Yes	No	NA	C; V; SE
	Aaron	E	ASD w/o ID	P	Yes	Tablet	Supporting	Hierarchy	Yes	No	NA	C; V; SE
	Karen	E	ASD+ID	P	Yes	Tablet	Supporting	Hierarchy	Yes	No	NA	C; V; SE
Coleman (2012)	Kyle	M	ASD+ID	W	No	Computer	Delivering	No	Yes	NA	TD	D
Coleman (2015)	Kayla	E	ASD+ID	W	No	Computer	Delivering	Constant	No	NA	PT	D
	Dustin	E	ASD+ID	W	No					NA	PT	D
Ganz (2014)	Kyle	E	NR	W	No	Tablet	Supporting	Hierarchy	No	NA	NA	V
	Morgan	E	NR	W	No	Tablet	Supporting	Hierarchy	No	NA	NA	V
	Ross	M	NR	W	No	Tablet	Supporting	Hierarchy	No	NA	NA	V
Lee (2004)	David	E	ASD+ID	W	No	Computer	Delivering	Constant	Yes	NA	PT+TD	D
Morlock (2015)	Trevor	H	NR	W	No	Computer	Delivering	Constant	No	NA	PT	D
	Jack	H	NR	W	No	Computer	Delivering	Constant	No	NA	PT	D
	Sal	H	NR	W	No	Computer	Delivering	Constant	No	NA	PT	D
Saadatzi (2017)	Student J	A	ASD+ID	W	No	Computer	Delivering	No	Yes	NA	TD	D
	Student A	A	ASD+ID	W	No	Computer	Delivering	No	Yes	NA	TD	D
	Student M	H	ASD+ID	W	No	Computer	Delivering	No	Yes	NA	TD	D

First Author (Year)	Participant	Age	Diagnosis	Reading Materials		Technology		Intervention Components				Reading Outcome
				Type	Grade level	Device	Role	Prompting	TD	SR	CAI/IAI	
Smith (2013)	Matt	M	ASD+ID	W	Yes	Tablet	Delivering	Constant	No	No	NA	V
	David	E	ASD+ID	W	Yes	Tablet	Delivering	Constant	No	No	NA	V
	Ken	M	ASD+ID	W	Yes	Tablet	Delivering	Constant	No	No	NA	V
Spooner (2014)	Danny	M	ASD+ID	P	Yes	Tablet	Supporting	Hierarchy	Yes	Yes	NA	C
	Cameron	E	ASD+ID	P	Yes	Tablet	Supporting	Hierarchy	Yes	Yes	NA	C
	Liam	E	ASD+ID	P	Yes	Tablet	Supporting	Hierarchy	Yes	Yes	NA	C
	Sam	E	ASD+ID	P	Yes	Tablet	Supporting	Hierarchy	Yes	Yes	NA	C
Spooner (2015)	Sebrina	E	ASD+ID	P	Yes	Tablet	Supporting	Hierarchy	Yes	Yes	NA	C
Yaw (2011)	Craig	M	NR	W	No	Computer	Delivering	No	Yes	NA	TD	D

Note. E = Elementary (ages 6-11); M = Middle (ages 12-15); H = High (ages 16-19); A = Adult (above 20); ASD + ID = Autism spectrum disorder with intellectual disability; ASD w/o ID = Autism spectrum disorder without intellectual disability; NR = Not reported; NA = Not applicable; P = Paragraph; W = Word; TD = Time delay; SR = Shared reading; CAI/IAI = Computer or iPad assisted instruction; PT = Prompting; TD = Time delay; C = Comprehension; V = Vocabulary; D = Decoding; SE = Story elements

Table A8

Aggregated Results by Participant and Intervention Characteristics

Variables	Levels	Tau-U	95% CI	Studies	Subjects	Contrasts	ESs
Participant Characteristics							
Age	Elementary (ages 6-11)	.86	[.78, .94]	9	21	33	33
	Middle (ages 12-15)	1	[.81, 1]	4	6	8	8
	High + Adults (above 16)	.95	[.79, 1]	2	6	9	9
Diagnosis	ASD without ID	.73	[.57, .89]	2	6	8	8
	ASD with ID	.93	[.85, 1]	9	20	30	30
Reading Material							
Type	Paragraph	.87	[.79, .96]	5	16	25	25
	Word	.92	[.82, 1]	8	17	25	25
Grade Level	Yes	.88	[.80, .97]	6	19	28	28
	No	.92	[.81, 1]	7	14	22	22
Technology							
Device	Computer	.85	[.75, .95]	7	17	24	24
	Tablet	.93	[.84, 1]	6	16	26	26
Role of Technology	Delivering	.86	[.77, .95]	8	14	27	27
	Supporting	.92	[.83, 1]	5	19	23	23
Intervention Components							
Prompting	Hierarchy	.93	[.84, 1]	4	11	20	20
	Constant	.80	[.78, 1]	4	9	15	15
	No prompting	.91	[.68, .93]	5	13	15	15
Time Delay	Yes	.95	[.87, 1]	8	17	31	31
	No	.78	[.67, .89]	5	16	19	19
Shared Reading (Comprehension)	Yes	.90	[.77, 1]	3	8	11	11
	No	.85	[.75, .96]	4	11	20	20
CAI/IAI (Decoding)	CAI/IAI + Prompting	.89	[.71, 1]	2	5	8	8
	CAI/IAI + TD	1	[.82, 1]	3	5	7	7
	CAI/IAI + Prompting + TD	.92	[.66, 1]	1	1	4	4
Targeted Reading Outcomes							
Comprehension		.87	[.79, .95]	7	22	31	31
Decoding		.93	[.82, 1]	6	11	19	19

Note. CI = Confidence interval; ES = Effect size; ASD = Autism spectrum disorder; ID = Intellectual disability; CAI/IAI = Computer or iPad assisted instruction; TD = Time delay

Table A9

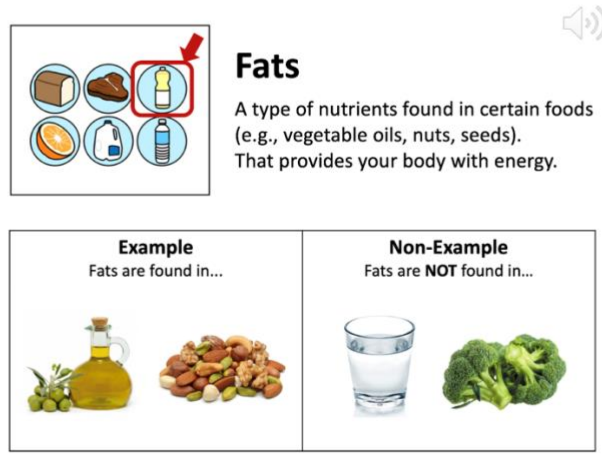
A Sample of Reading Materials Used for Before, During, and After Reading Strategies

<table>
<tr><th>Key Features</th><th>Sample Slides</th></tr>
<tr><td>

Before Reading (1st slide)
: Pre-teaching a key vocabulary word

- A key vocabulary word was presented with definition, examples, and nonexamples.
- A text-to-speech icon was inserted.

</td><td>

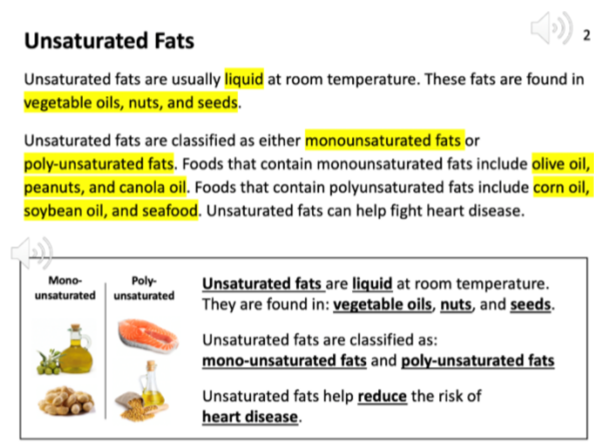


</td></tr>
<tr><td>

During Reading (2nd – 5th slide)
: Reading and sharing

- Keywords were highlighted in yellow
- A summary of each paragraph was provided with a matched picture
- Two text-to-speech icons were inserted (i.e., one for the text, one for the summary).

</td><td>

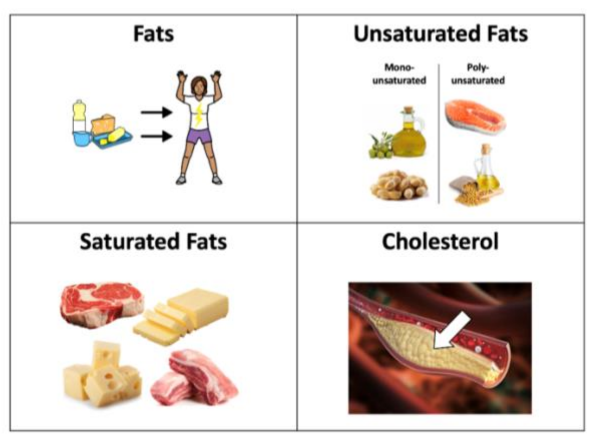


</td></tr>
<tr><td>

After Reading
: Retelling

Four pictures that were inserted in each paragraph were presented to provide a visual cue for participants to retell what they read.

</td><td>



</td></tr>
</table>

Table A10

Examples of Prompted and Non-prompted Answers

Prompted answers	Non-prompted answers
• Paraphrasing the comprehension questions and options • Pointing a specific keyword or sentence in the text • Asking the participant to reread a specific keyword or sentence in the text • Providing additional examples or explanations	• Reading the comprehension questions and choice options aloud • Asking the participants to circle the best answer if they do not respond 5 s after reading the question (e.g., "You can circle your best answer.") • Reminding the participant to refer to the text to find the answer (e.g., "You can find the answer from the text.")

*Adapted from Kim et al. (2018)

Table A11

Operational Definition of On-Task and Off-Task Behavior

	Definition	Examples
On-task behavior	Meaningfully participating in reading activities	Answering questions Asking questions Reading aloud Writing Pointing a picture or word Listening to the interventionist Looking at the interventionist or texts
Off-task behavior	Not participating in academic activities	Refusing to read Making a noise Turning head away Doodling Humming Talking about things not related to the assigned text

*Adapted from Kim et al. (2018)

Table A12

Mean, Range, and Tau Scores for Comprehension and Task Engagement

	Mean (Range)		
	Baseline	Intervention	Tau
Jamie			
Comprehension	36% (10–50%)	93% (70–100%)	1.00**
Engagement	93% (83–96%)	99% (95–100%)	0.93**
Kylie			
Comprehension	20% (0–30%)	93% (80–100%)	1.00**
Engagement	95% (91–100%)	98% (96–100%)	0.66*
Cayden			
Comprehension	22% (10–30%)	88% (70–100%)	1.00**
Engagement	80% (43–100%)	98% (96–100%)	0.80*
Omnibus ES			
Comprehension	-	-	1.00**
Engagement	-	-	0.80*

Note. ES = Effect size, **=Lange effects, *=Medium effects

APPENDIX B. FIGURES

*Adopted from The PRISMA Group (2009)

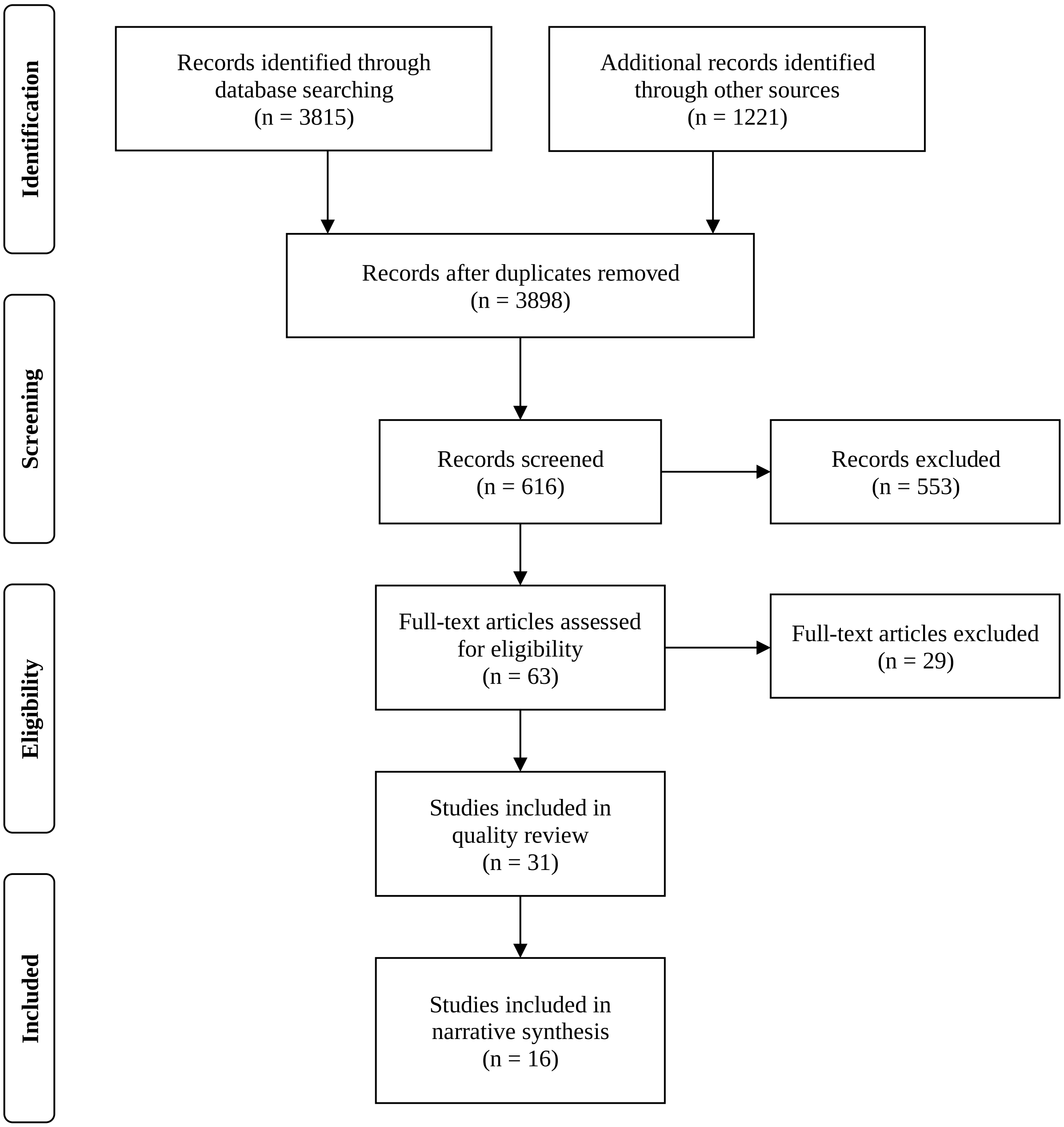
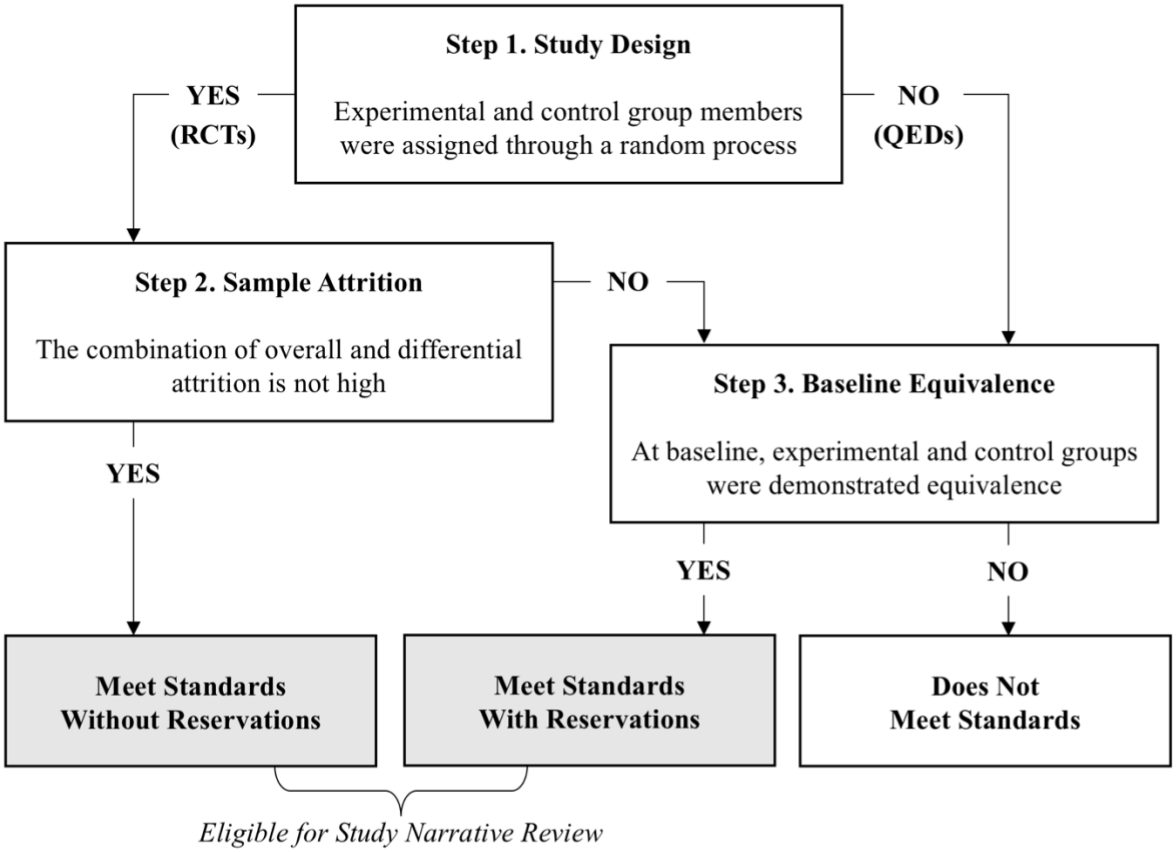
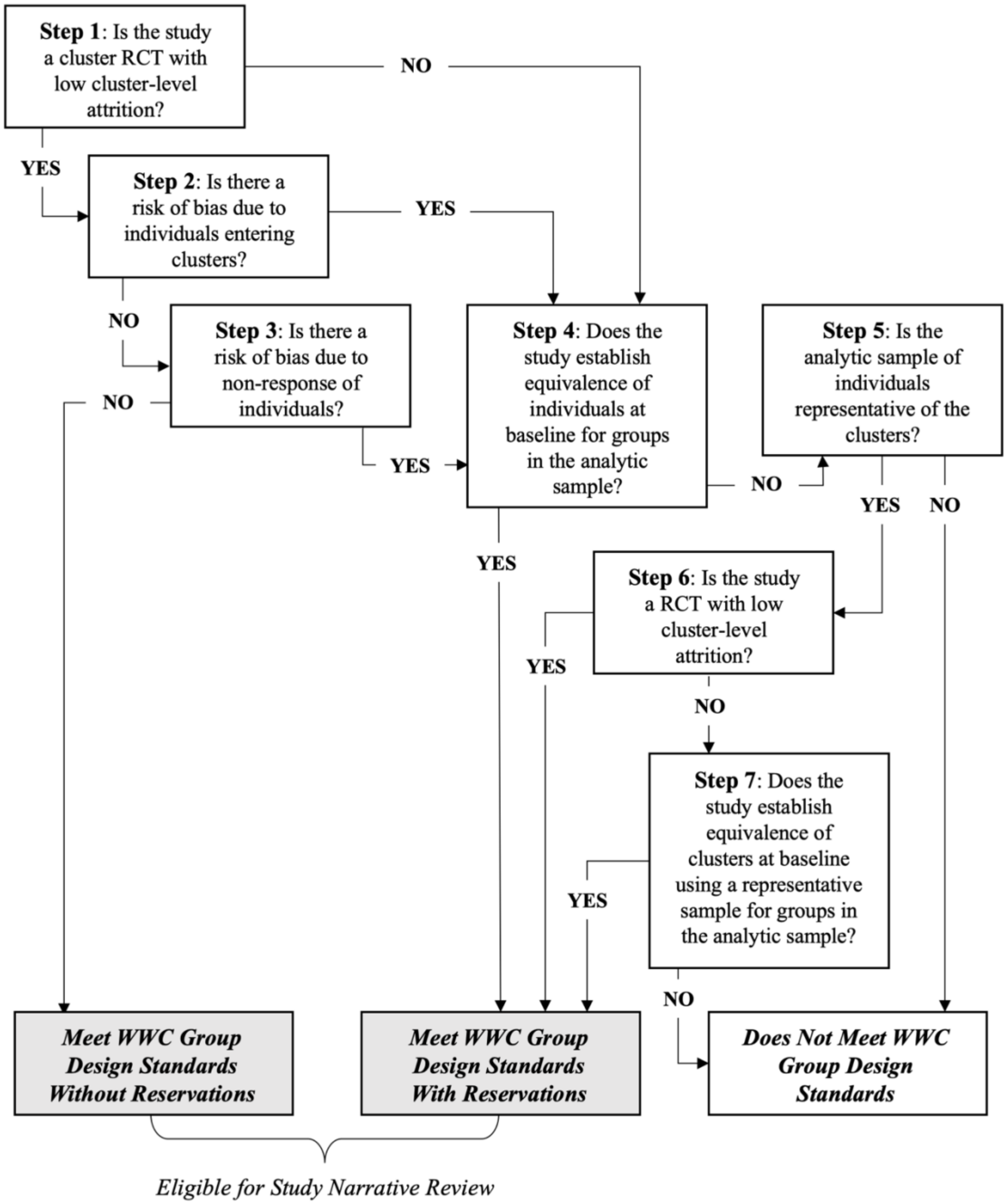


Figure B1. Article Search Procedures



Note. Retrieved from WWC standard handbook (ver. 4.0)

Figure B2. WWC Quality Evaluation Procedures for Individual-Level Group Design Studies



Note. Retrieved from WWC standard handbook (ver. 4.0)

Figure B3. WWC Quality Evaluation Procedures for Cluster-Level Group Design Studies

*Adopted from The PRISMA Group (2009)

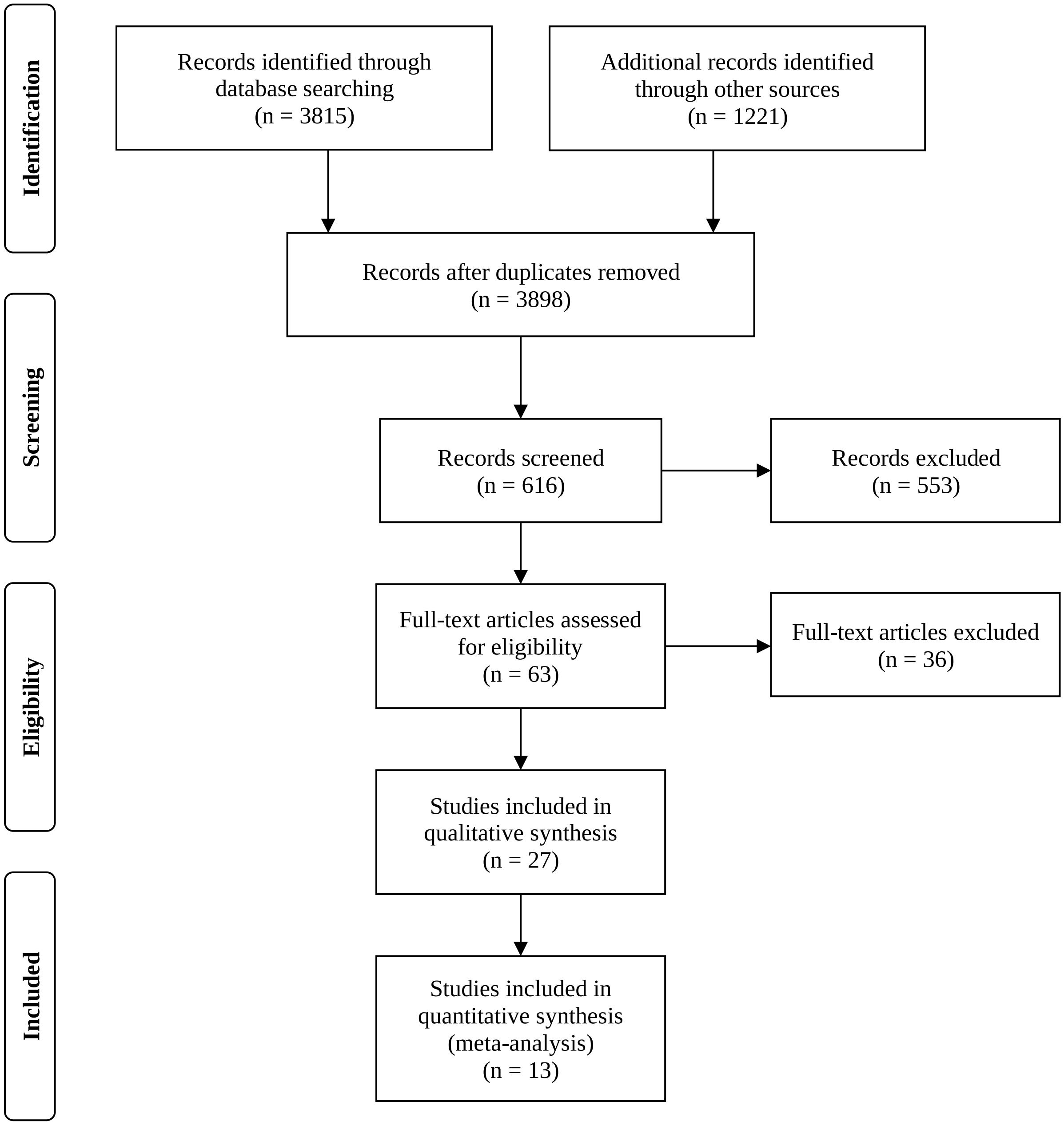


Figure B4. Literature Search and Quality Evaluation Procedures.

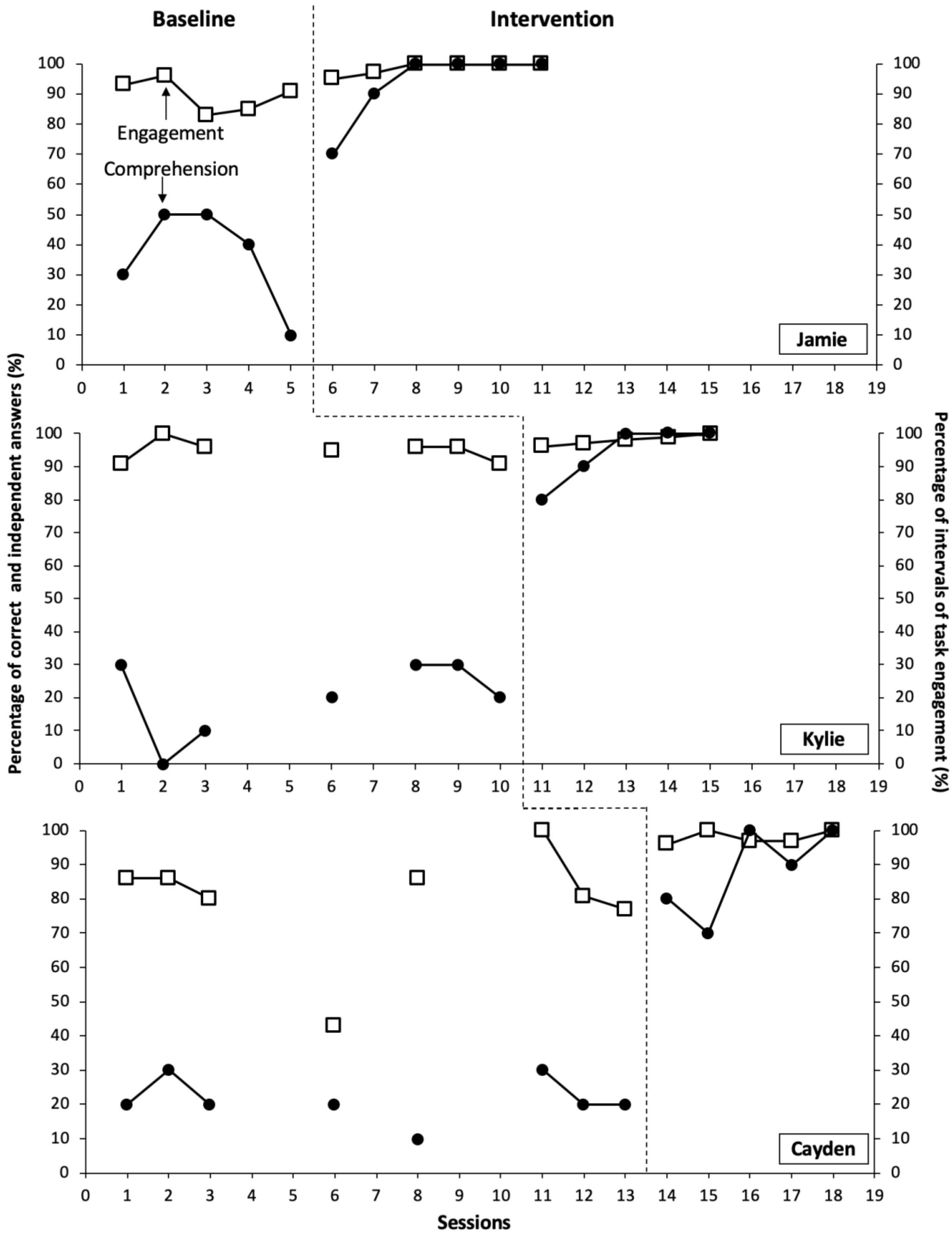


Figure B5. Results of the Shared Reading Intervention

APPENDIX C. DATA COLLECTION SHEETS

Appendix C1

Treatment Fidelity Checklist (Baseline)

Date:	Student:	Interventionist:	Observer:	Section:

Objective/Activity	Recording		
1. The interventionist presented one reading material and one worksheet on the table.	+	–	N/A
2. The interventionist provided an initial instruction to read the text and answer the question (e.g., “Whenever you’re ready, you can read the text and answer the questions”).	+	–	N/A
3. The interventionist provided immediate error corrections and prompts when the participant was reading.	+	–	N/A
4. When the participant indicated that he/she had completed reading, the interventionist asked the participant to start to answer the question.	+	–	N/A
5. The interventionist prompted the participant to read aloud the questions and options if necessary.	+	–	N/A
6. When the participant did not answer the question 10 seconds after reading the question, the interventionist redirected the participant answering the question (e.g., “You can read the question and options one more time,” “You can draw a circle on your best answer”)	+	–	N/A
7. The interventionist did not direct the participant to be on-task (e.g., telling the participant, “You should focus on reading,” or “Don’t do that”).	+	–	N/A
8. The interventionist terminated the session if the participant continuously engaged in off-task behaviors for 10 minutes.	+	–	N/A
TOTAL: ( ) / ( ) = ( )			

Appendix C2

Treatment Fidelity Checklist (Intervention)

Date:	Student:	Interventionist:	Observer:	Section:

Objective/Activity	Recording		
[Before Reading] Pre-teaching a key vocabulary word			
1. Interventionist presented a key vocabulary word page on an iPad screen.	+	–	N/A
2. Interventionist pre-taught the key vocabulary word of the section by using its definition.	+	–	N/A
3. Interventionist went through the examples and nonexamples.	+	–	N/A
4. Interventionist asked participant to repeat the definition of the word and provide verbal/gestural prompt if necessary.	+	–	N/A
[During Reading] Shared Reading			
5. Interventionist asked the participant to turn the page and click the speaker icon for text-to-speech.	+	–	N/A
6. Interventionist guided the participant to share what the participant learned in the *first* paragraph by asking comprehension questions.	+	–	N/A
7. Interventionist asked the participant to turn the page and click the speaker icon for text-to-speech.	+	–	N/A
8. Interventionist guided the participant to share what the participant learned in the *second* paragraph by asking comprehension questions.	+	–	N/A
9. Interventionist asked the participant to turn the page and click the speaker icon for text-to-speech.	+	–	N/A
10. Interventionist guided the participant to share what the participant learned in the *third* paragraph by asking comprehension questions.	+	–	N/A
11. Interventionist asked the participant to turn the page and click the speaker icon for text-to-speech.	+	–	N/A
12. Interventionist guided the participant to share what the participant learned in the *fourth* paragraph by asking comprehension questions.	+	–	N/A

[After Reading] Retelling			
13. Interventionist asked participant to turn the page or presented four pictures that were inserted in the section were presented on the iPad screen.	+	–	N/A
14. Interventionist asked participant to retell important details they learned from the section.	+	–	N/A
15. If necessary, interventionist provided verbal/gestural prompt to retell important details related to each of four pictures by using summary paragraphs.	+	–	N/A
[Reading Comprehension Assessment]			
16. A worksheet and a pencil were given to participant.	+	–	N/A
17. When participant indicated that he/she had completed reading, interventionist asked the participant to start to answer the question.			
18. When participant was reading questions and options aloud, interventionist provided prompts or error corrections if necessary.	+	–	N/A
19. If participant got incorrect answers, interventionist provided guided participant to find correct answers from the text.	+	–	N/A
[Throughout the session]			
20. The interventionist did not directly direct the participant to be on-task (e.g., telling the participant to focus on work or not to engage in off-task behaviors)	+	–	N/A
21. The interventionist terminated the session if the participant continuously engaged in off-task behaviors for 10 minutes.	+	–	N/A
TOTAL: ( ) / ( ) = ( )			

Appendix C3

Data Collection Sheet for Reading Comprehension

Date:	**Student:**	**Interventionist:**	**Observer:**	**Section:**

Question #	**Student Answer**				**Correct/Incorrect**		**Prompt**	
1	A	B	C	D	Correct	Incorrect	+	–
2	A	B	C	D	Correct	Incorrect	+	–
3	A	B	C	D	Correct	Incorrect	+	–
4	A	B	C	D	Correct	Incorrect	+	–
5	A	B	C	D	Correct	Incorrect	+	–
6	A	B	C	D	Correct	Incorrect	+	–
7	A	B	C	D	Correct	Incorrect	+	–
8	A	B	C	D	Correct	Incorrect	+	–
9	A	B	C	D	Correct	Incorrect	+	–
10	A	B	C	D	Correct	Incorrect	+	–
TOTAL: ( ) / ( ) = ( )								

Appendix C4

Data Collection Sheet for Task Engagement

Date:	**Student:**	**Interventionist:**	**Observer:**	**Section:**

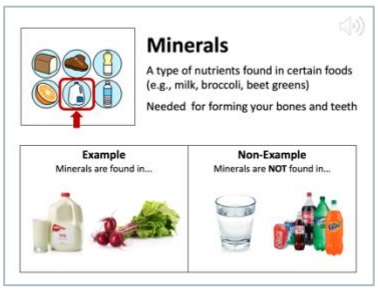
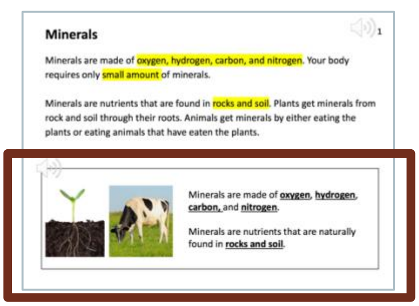
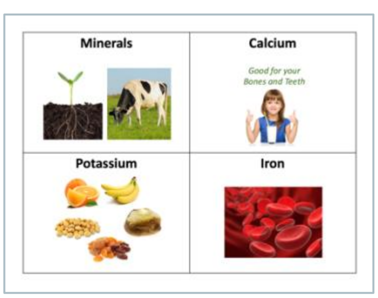
Operational Definition of Task Engagement

On-Task Behavior	Meaningfully participate in reading activities (e.g., answering the comprehension questions asking content related questions, reading aloud assigned texts, pointing a picture/text, following the interventionist's instruction, looking at the interventionist or reading materials, circling the options on the worksheet)
Off-Task Behavior	Do not meaningfully participate in reading activities (e.g., making a noise, do not look at the teacher or reading materials, doodling things not related to the reading activity, making out of context verbalization, out-of-seat, desk, or classroom)

Moment	On	Off	Moment	On	Off	Moment	On	Off
00:30	+	–	15:30	+	–	30:30	+	–
01:00	+	–	16:00	+	–	31:00	+	–
01:30	+	–	16:30	+	–	31:30	+	–
02:00	+	–	17:00	+	–	32:00	+	–
02:30	+	–	17:30	+	–	32:30	+	–
03:00	+	–	18:00	+	–	33:00	+	–
03:30	+	–	18:30	+	–	33:30	+	–
04:00	+	–	19:00	+	–	34:00	+	–
04:30	+	–	19:30	+	–	34:30	+	–
05:00	+	–	20:00	+	–	35:00	+	–
05:30	+	–	20:30	+	–	35:30	+	–
06:00	+	–	21:00	+	–	36:00	+	–
06:30	+	–	21:30	+	–	36:30	+	–
07:00	+	–	22:00	+	–	37:00	+	–
07:30	+	–	22:30	+	–	37:30	+	–
08:00	+	–	23:00	+	–	38:00	+	–
08:30	+	–	23:30	+	–	38:30	+	–
09:00	+	–	24:00	+	–	39:00	+	–
09:30	+	–	24:30	+	–	39:30	+	–
10:00	+	–	25:00	+	–	40:00	+	–
10:30	+	–	25:30	+	–	40:30	+	–
11:00	+	–	26:00	+	–	41:00	+	–
11:30	+	–	26:30	+	–	41:30	+	–
12:00	+	–	27:00	+	–	42:00	+	–
12:30	+	–	27:30	+	–	42:30	+	–
13:00	+	–	28:00	+	–	43:00	+	–
13:30	+	–	28:30	+	–	43:30	+	–
14:00	+	–	29:00	+	–	44:00	+	–
14:30	+	–	29:30	+	–	44:30	+	–
15:00	+	–	30:00	+	–	45:00	+	–
TOTAL = ( ) / ( ) = ( ) %								

Appendix C5

Social Validity Questionnaire

1. Reading sessions were interesting. I enjoyed it.	Yes	I don’t know	No
2. The iPad books had **audio voice**. It helped me to understand the text better. 	Yes	I don’t know	No
3. I talked about a **key word** with examples and non-examples. It helped me to understand the text better.  	Yes	I don’t know	No
4. There was a **summary** in each page. It helped me to understand the text better.  	Yes	I don’t know	No
5. I **talked about what I read** at last. It helped me to understand the text better.  	Yes	I don’t know	No
6. I think my reading skill is improved. I do better now.	Yes	I don’t know	No
7. I want to read more iPad books.	Yes	I don’t know	No