*Assistive Technology Outcomes and Benefits*
*Volume 10, Summer 2016, Volume 1* pp 51-73
 ISSN 1938-7261
Available online: www.atia.org/atob

# Supporting Literacy Achievement for Students with Intellectual Disability and Autism through Curricular Programs that Incorporate Assistive Technology

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**Acknowledgements**

Support for the research referenced within this article was provided by several grants and contracts including, in part, by Contract ED-IES-11-C-0027, ED-IES-13-C-0031, and ED-IES-14-C-0018 of the U.S. Department of Education, Institute of Education Sciences, awarded to The Attainment Company. The opinions expressed do not necessarily reflect the position or policy of the Department of Education, and no official endorsement should be inferred.

**Abstract**

Education professionals are challenged with re-evaluating the learning capacity of students with developmental disabilities (e.g., intellectual disabilities, autism). Assistive technology (AT) provides both the means for delivery of instruction and the measure of outcomes. Students with developmental disabilities are learning to read and develop general education English Language Arts (ELA) skills across the grade span. This article summarizes ten selected research studies that demonstrate gains of students with developmental disabilities, including individuals who use augmentative and alternative communication (AAC), who have made measurable strides in literacy general education ELA skills. This selected research focused on literacy interventions specifically created for students with developmental disabilities which incorporated the use of AT, use systematic instruction and shared stories, and are commercially available. The research studies include a range of literacy instruction from picture books and early literacy skills to adapted contemporary fiction novels grade aligned to general education secondary level ELA. In these research protocols, AT

facilitated both the delivery of instruction and measure of outcomes.

***Keywords***: literacy, assistive technology, autism, intellectual disability

## Introduction

Assistive technology (AT) has long been used to support instruction for students with developmental disabilities, including intellectual disability and/or autism spectrum disorder (Hourcade, Pilotte, West, & Parette, 2004). There is a plethora of research that demonstrates how AT has been used for skill acquisition across a variety of areas, including promoting choice (e.g., Stasolla, Caffo, Picucci, & Bosco, 2013), increasing social skills (e.g., Sigafoos, O'Reilly, Ganz, Lancioni, & Schlosser, 2005; Walton & Ingersoll, 2013), requesting personal needs (Lancioni, Singh, O'Reilly, Sigafoos, Green et al., 2011), and increasing overall communication (Ganz, Hong, & Goodwyn, 2013). The potential for AT to enhance educational experiences and outcomes for students with developmental disabilities has been fostered by the development of new technologies (e.g., communication apps on tablets), federal requirements for academic rigor (Individuals with Disabilities Education Act [IDEA], 2004; No Child Left Behind, 2003), student interest and engagement with technology (Cafiero, 2008), and groundbreaking research on the use of AT to provide meaningful access to the general curriculum (Knight, McKissick, & Saunders, 2013).

## Target Audience and Relevance

Five commercially available literacy curricula (*Pathways to Literacy*, *Early Literacy Skills Builder*, *Early Reading Skills Builder*, *Teaching to Standards: English-Language Arts*, and *Access: Language Arts*) combine AT and systematic instruction to provide students with developmental disabilities with the tools necessary for acquiring literacy skills. The purpose of this paper is to describe the integration of AT across these five programs and specify the outcomes and benefits of using programs with AT supports for students with developmental disabilities across a range of ages and grade levels. The audience for this paper includes special educators, related service providers (e.g., Occupational Therapists, Speech and Language Pathologists), and administrators who seek to provide students with developmental disabilities with evidence-based curricula for literacy and ELA across a continuum of ages, grades, and physical abilities.

## Assistive Technology Intervention

AT is described as "any item, piece of equipment or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain or improve functional capabilities of children with disabilities" (IDEA, 2004, sec. 602.1.a). The AT commonly used in literacy instruction has included both low and high technology items, such as Voice Output Communication Aids (VOCA) (e.g., Browder, Lee, Mims, 2011), printed response options (e.g., Hudson, Browder, & Wakeman, 2013), adapted text (e.g., Browder, Trela, Jimenez, 2007), graphic organizers (e.g., Mims, Hudson, & Browder, 2012), and iPads (e.g., Spooner, Kemp-Inman, Ahlgrim-Delzell, Wood, & Davis, 2015). Additionally, both systematic instruction (e.g., Ahlgrim-Delzell, Mims, Vintinner, 2014) and shared stories (e.g., Hudson & Test, 2013) have been commonly paired with AT to target increases in literacy and overall access to grade aligned English Language Arts (ELA) skills.

VOCAs provide an avenue for students without vocal-verbal ability to respond during literacy lessons (Erickson & Koppenhaver, 1995; Fenlon, McNabb, & Pidlypchak, 2010; Ruppar, 2013; Schlosser & Blischak, 2001).

Many studies have demonstrated the use of VOCAs to promote participation and demonstrate comprehension of targeted content (e.g., Bellon-Harn & Harn, 2008; Skotko, Koppenhaver, & Erickson, 2004; Soto, Yu, & Henneberry, 2007). For example, Browder, Mims, Spooner, Ahlgrim-Delzell, and Lee (2008) conducted a study targeting increases in engagement and comprehension during a shared story for three students with profound multiple disabilities. All three students used a VOCA to read the repeated storyline at the appropriate time and answer prediction and literal recall questions during the read aloud.

Providing response options where students point to an answer is another common form of AT used in literacy research (e.g., Erickson & Koppenhaver, 2005; Hudson, Browder, & Jimenez, 2014; Mims et al. 2012). When students are unable to generate a verbal response, providing response options with a range of distractors and targeted responses assist the student to identify the best response. For example, Hudson and Browder (2015) used a nine-option response board for each type of WH question (i.e., who, what, when, what or why) asked during a peer- delivered read aloud of an adapted novel for three students with moderate intellectual disability.

Adapted text provides an additional means for students with developmental disability to gain access to grade appropriate text. Providing students with significant disabilities access to grade-aligned adapted text reduces barriers to accessing text such as simplifying text complexity by reducing the Lexile level or adding picture or object supports to increase comprehension and overall engagement with text. The use of adapted text in literacy research involving students with developmental disability has become more common as a means to provide meaningful access to the same text as their nondisabled peers (e.g., Browder et al., 2007; Roberts & Leko, 2013). For example, Mucchetti (2013) conducted a study targeting the impact of teacher-led shared reading of adapted stories on the overall engagement and comprehension of four young children with autism. Books were adapted with visual supports, objects, and simplified text.

Graphic organizers can also be used to promote access to literacy and ELA. Graphic organizers have long been used for students with high incidence disabilities, but more recently have been applied to literacy and ELA interventions for students with developmental disabilities. For example, graphic organizers have been used to help students with developmental disabilities sequence story events (Mims et al., 2012), conduct student led research (Mims, Lee, Browder, Zakas, & Flynn, 2012), learn science concepts (Knight, Spooner, Browder, Smith, & Wood, 2013), improve comprehension of text-based recipes (Douglas, Ayres, Langone, & Bramlett, 2011), improve narrative text comprehension (Williamson, Carnahan, Birri, & Swoboda, 2015) and improve writing (Pennington & Delano, 2012). Research in this area is just beginning to scratch the surface regarding the use of graphic organizers for students with developmental disabilities.

Recent advances in technology have led to new applications of high-tech AT. Tablets, such as iPads, have been used as AT in classrooms to provide instructional support to students with disabilities. Kagohara et al. (2013) examined the literature and identified 15 studies in which these devices were used to deliver content or teach students with intellectual disability or autism spectrum disorder to access target stimuli. Additionally, research provides evidence of using supported electronic texts to promote access to academic content for students with disabilities (Clay, Zorfass, Brann, Kotula, & Smolkowski, 2009; Douglas, Ayres, Langone, Bell, & Meade, 2009). Features of supported electronic text, or e-text, that have a research base for supplementing learning include text-to-speech capabilities, visual supports, auditory supports, and graphic organizers (Douglas et al., 2009; Douglas, Ayres, Langone, & Bell, 2011). For example, Coyne, Pisha, Dalton, Zeph, and Smith (2010) and Wood, Browder, and Spooner (2015) conducted studies on the use of supported e-text to promote academic comprehension outcomes for students with developmental disabilities.

In addition to studies using supported electronic text, there are studies that have examined technologies including applications (apps) or Web-based programs for supporting academic outcomes for students with disabilities. For example, Okolo, Englert, Bouck, Heutsche, and Wang (2011) developed a Web-based learning environment (i.e., the Virtual History Museum) and taught students with and without disabilities to access social studies content online. Also, Spooner, Kemp-Inman, Ahlgrim-Delzell, Wood, and Davis (2014) examined the effects of a shared story delivered via the GoTalk NOW app on engagement and literacy responses for students with developmental disabilities. Similarly, Ahlgrim-Delzell et al. (2015) examined the effects of systematic instruction and the GoTalk NOW app on decoding skills for students with developmental disabilities.

A common thread throughout most of the research highlighted above is the use of instructional packages consisting of both AT and systematic instruction. Systematic instruction is a critical component in most research on literacy for students with developmental disabilities (Ahlgrim-Delzell et al., 2014). Systematic instruction is the practice of teaching specific skills and content through individually prescribed prompting, reinforcement, error correction, and fading procedures (Snell, 1983). Examples of systematic instructional techniques include time delay, task analysis, and least intrusive prompting. In a recent review of the literature on teaching academic skills for students with severe disabilities (Spooner, Knight, Browder, & Smith, 2012), two specific systematic instructional practices, time delay and task analytic instruction, were identified as evidence-based practices. Additionally, emerging research supports the use of a system of least prompts procedure for teaching comprehension (e.g., Hudson & Browder, 2014; Mims et al., 2012; Wood, Browder, & Flynn, 2015).

Constant time delay is an evidence-based practice for teaching sight word acquisition and other discrete skills to students with developmental disabilities. In the time delay response prompt system, the instructor selects one prompt (usually a model prompt). In an initial round of instruction, the instructor promotes errorless learning by delivering the directional cue (e.g., "Read this word.") followed immediately by the prompt (e.g., "This word is <u>cat</u>. Your turn.")). The instructor waits for the student to respond and provides verbal praise, even though the response was fully prompted. After several trials or sessions using this 0-second (s) delay procedure, the instructor inserts a brief and consistent pause (e.g., 4 s) between the delivery of the directional cue (e.g., "Read this word.") and the prompt (e.g., "This word is <u>cat</u>"). If the student responds independently before the prompt is delivered, the instructor delivers specific verbal praise. If the student waits for the prompt, the instructor delivers specific verbal praise, but with less intensity. If the student makes an error, the instructor corrects the error by demonstrating the correct response and directs the student to repeat the correct response.

The system of least prompts, or least intrusive prompting, is another response prompt procedure that has been used to teach complex literacy skills, such as answering comprehension questions, to students with developmental disabilities (e.g., Mims et al., 2012). In this procedure, the instructor selects a hierarchy of prompts, from least intrusive to most intrusive, to help students determine the correct answer. For instance, when asked a comprehension question, the instructor first waits for the student to respond independently. If the student does not respond after a predetermined wait time (e.g., 5 s), the instructor delivers the first level of prompt (the least intrusive prompt). For example, "I heard the answer in the text. Listen." Then the instructor rereads a portion (e.g., three sentences) of the text containing the target answer. If the student still cannot answer the question after 5 s, the instructor delivers a more intrusive prompt (e.g., "I heard the answer in the text. Listen." The instructor rereads one sentence with the target answer.) Finally, if the student still cannot answer independently after 5 s, the instructor delivers a controlling prompt (typically a model prompt). For example, "Listen, I heard the answer in the text. Cat. Touch cat." Students can select response options from an array of choices or provide answers without response options.

Critical features of systematic instruction include reinforcement, fading, and error correction. Correct responses should be reinforced immediately with specific feedback. Additionally, all systematic instruction includes a plan for fading supports. To avoid prompt dependency, instructors must select methods that gradually and systematically withdraw the level or frequency of supports. In constant time delay, supports are faded by the insertion of the wait time between the delivery of the directional cue and the controlling prompt. In a system of least prompts, the supports are self-fading; as students become more successful in locating answers in the text, they will not require as many prompts from the hierarchy.

Considering the findings that supported that features of low- and high-tech devices can increase access to literacy when combined with evidence-based systematic instruction, the use of AT is a viable strategy that educators can use for increasing academic skills, including emergent reading and reading skills (Carnahan, Williamson, Hollingshead, & Israel, 2012). When the philosophy of the least dangerous assumption (Donnellan, 1984), which promotes assumed competence, is applied to all students, educators can promote access to meaningful literacy instruction for students with developmental disabilities across a continuum of skills and topic areas. By pairing this access with high quality technology-based systematic instruction, educators can increase opportunities for student success.

## Literacy Programs with AT Components

Five commercially available curricular programs (*Pathways to Literacy*, *Early Literacy Skills Builder*, *Early Reading Skills Builder*, *Teaching to Standards: English-Language Arts*, and *Access: Language Arts*, see *Table 1*) address a range of literacy skills through systematic and explicit instruction and AT. Ten research studies demonstrate literacy gains that resulted from the use of these five programs by students with developmental disabilities, as described in *Table 2*. These ten research studies were selected for this paper because they encompass the body of research for the five curricula, with a focus on integrated AT. Other studies were conducted on individual components of these curricula (e.g., Mims, Browder, Baker, Lee, & Spooner, 2009), but the selected studies for this paper were chosen because they were the studies on the comprehensive program versus the iterative studies on components of the programs. Collectively, the programs include instruction for students with developmental disabilities from pre-K to secondary grades. The content spans from pre-reading skills (e.g., text awareness and engagement) to emergent reading skills (e.g., phonological and phonemic awareness) to early reading skills (e.g., decoding and text comprehension). Specifically, foundational literacy instruction is provided by *Pathways to Literacy (Pathways)*, followed by early literacy in *Early Literacy Skills Builder* (*ELSB*), to early reading in *Early Reading Skills Builder* (*ERSB*), to grade-aligned secondary English Language Arts curriculum with the blended product *Teaching to Standards: English/Language Arts* and *Access: Language Arts* (*TTS:ELA/ALA*). See *Table 1* for a summary of each product focus, target population, product description and AT features. Across the programs, students can access materials aligned with their grade level. For example, adapted texts from the *TTS:ELA* program include grade-aligned texts that have been rewritten at an accessible readability level for students with developmental disability who are emergent or early readers (approximately a second grade readability level).

### *Pathways to Literacy (Pathways)*

At the beginning of the literacy continuum is *Pathways to Literacy*. The curriculum is divided into five levels which systematically build students from an early concrete symbolic level to a more abstract symbolic level and is meant for students at a very early understanding of emergent literacy, including those with significant, multiple disabilities who do not consistently use words, pictures, or other symbols to communicate. *Pathways to Literacy* is focused on increasing overall awareness and engagement. *Pathways* builds on the research from Blyden (1988), Browder, Mims, Spooner, Ahlgirm-Delzell, and Lee (2008), and Mims, Browder, Baker, Lee, and Spooner (2009) which have all investigated successful methods to increase engagement, awareness, and comprehension during literacy lessons. The scope and sequence for *Pathways* focuses on a variety of objectives (e.g., attends to reader by reacting to name read in text; locates object on the page when asked to "read" with me; identifies title of story; identifies book from nonbook) while moving from Level 1 to 5. AT is integrated into all levels with alternative response options. Level 1 focuses on the student engaging with a book and Level 2 focuses on students choosing a response. In Level 3 the students use objects to respond and gradually shift to responding with picture symbols paired with objects in Level 4 to only picture symbols in Level 5. All objectives are taught using systematic and direct instructional strategies. For example, task analytic instruction is used along with response prompting strategies such as time delay and System of Least Intrusive Prompts. Lessons are scripted to ensure fidelity of implementation and include procedures for reinforcement and error correction. Additionally, lessons can be individualized so learners with a variety of exceptionalities can participate. For example, a student at the awareness level with a cortical visual impairment may turn her head toward the book to indicate understanding that it is time to open the book. While the focus of the curriculum is to promote early emergent literacy such as concept of print, the potential barriers for engagement, expression, and representation often seen for students with severe, multiple disabilities are minimized as AT supports are added and individualized based on student characteristics.

Research by Browder, Lee, and Mims (2011) used a multiple probe across participants/response modes design to investigate the effects of *Pathways* on engagement and comprehension of three elementary students with multiple, severe disabilities. During the intervention the teachers used scripted task analytic lessons with systematic prompting from the curriculum, but all lessons were individualized based on three types of students including a student who used eye gaze to respond, a student who used a point response, and a student who was visually impaired and used salient objects to represent response options or text from the story (e.g., when reading a story about baseball, the student would be presented with a baseball) to respond. Results indicated all three students showed gains in both comprehension and engagement.

### *The Early Literacy Skills Builder (ELSB)*

The *ELSB* is divided into two sections called *Building with Sounds* and *Building with Stories*. *Building with Sounds* focuses on early literacy skills including concepts of print and four of the five essential components of reading instruction identified by the National Reading Panel (2000) phonemic awareness, phonics, vocabulary, and comprehension. Concepts of print include skills such as text pointing, completing a repeated story line, and selecting a word to complete a sentence. Phonemic awareness skills consist of syllable and phoneme segmentation. Phonics skills include letter-sound correspondence, identification of first and last sounds in words, finding pictures that begin and end with a specific sound, pointing to letters in segmented words, and pointing to pictures that represent segmented words. Vocabulary teaches sight word identification for irregular, non-decodable words and picture vocabulary. Students respond to questions about text that is read to them to answer literal and inferential questions to develop listening comprehension. The *Building with Stories* section reinforces these skills by providing teachers with a task analysis for engaging students in reading grade-level adapted text. AT is integrated with alternate response modes including VOCAs.

*ELSB* is available in print, software, and app. The software and app include professional narration, prompting, and error correction using systematic instructional strategies and assessment. The *ELSB* provides multiple ways for students to access, engage, and respond to the instruction. Using the print version, teachers provide the systematic instruction with a scripted text. The print version provides special adaptations for those who are nonverbal and use augmentative and alternative communication (AAC) to communicate. Although students are encouraged to verbalize to approximate phonemic sounds, they can point, use adaptive switches connected to AAC devices, or eye gaze to response boards. Materials can be enlarged and printed for students with visual impairments.

The systematic instruction is embedded into the computer software and app versions. Students use the mouse, touch, or an adaptive switch to select their responses. Touching options can include adaptive devices such as a head pointer. An adaptive switch can be used with the scanning option whereby students stop the scan across response options to select their answer. The size and color of the text can be changed as needed for students with visual impairment. The pace of the lessons and volume can be changed providing longer response times for students with processing difficulties or hearing impairment. Response options are randomly placed on the screen so they appear in a different order to avoid memorizing the placement of correct answers.

The *ELSB* was created and evaluated after one year and three years using a randomized control design with elementary school age students with moderate-to-severe intellectual disability, including some students with autism and some who were nonverbal (Browder, Ahlgrim-Delzell, Courtade, Gibbs, & Flowers, 2008; Browder, Ahlgrim-Delzell, Flowers, & Baker, 2012). Both studies found statistically significant interaction effects between treatment/control groups and pre-posttest. The treatment group outperformed control group in convention of reading, phonemic awareness, and decoding at both one year and three years of instruction. In addition to using statistical significance to evaluate the effect of the *ELSB* curriculum, the magnitude of the effect as measured by Cohen's $d$, also provided such evidence. Cohen's $d$ is a standardized measure of the amount of the effect in standard deviation units and can be compared across studies. There were large effects for conventions of reading for both groups after one year of instruction as both groups received this intervention ($d$ = 1.57 treatment, $d$ = 1.24 for control). There was a large effect for phonics skills (including phonemic awareness and decoding skills) for the treatment group receiving the *ELSB* ($d$ = 1.35) and a moderate effect for phonics skills for the control group ($d$ = .51) indicating a larger effect for the *ELSB* after one year of instruction. After three years of instruction, the magnitude of the difference between the treatment and control groups was moderate for both conventions of reading ($d$ = .49) and phonics ($d$ = .44). Both statistical significance and effect size estimates indicate that the *ELSB* is an effective intervention to teach early literacy skills, including conventions of reading and phonics, for students with intellectual disability and autism.

### *The Early Reading Skills Builder (ERSB)*

The next product in the continuum of literacy, covering the scope and sequence of beginning reading, is *ERSB*. The *ERSB* scope and sequence includes phonics instruction for English language reading up to the second grade level and reading comprehension. *ERSB* is a blended (i.e., technology integrated) curriculum available as an iPad app, or computer software format fully integrated into the curriculum protocol. The integrated AT uniquely provides the opportunity for students who are unable or reluctant to sound out the phonemic elements of the English language to have the technology sound out, blend, and segment phonemes into real words. At the end of each lesson, students read connected text using non-decodable sight words and decodable words using the phonemic elements that they have been taught. The multi-year reading instruction curriculum spans 26 levels where students learn to identify individual phonemes and phoneme blends, blend and segment words, decode words to identify pictures, read connected text, and answer literal comprehension questions about the text. The technology also provides for randomization of answers and distractor options, and the same adaptive interfaces as described for *ELSB*. Students are moved to the next level once competence is gained on the current level as a result of automatically tracking student progress. Systematic instructional elements integrated into the *ERSB* technology include constant time delay, stimulus prompting, least intrusive prompting, reinforcement, error correction, and fading.

A functional relation was established between the intervention and the percentage of correct responses on phoneme identification, blending and decoding across participants in the single-case, multiple-baseline research study (Ahlgrim-Delzell, Browder, & Wood, 2014). In the second *ERSB* research study (Ahlgrim-Delzell, Browder, Wood, Stanger, Preston, & Kemp-Inman, in press), a randomized control research protocol, statistically significant interaction effects were found between treatment/control groups. The treatment group outperformed the control group in phoneme identification, decoding and total score. No significant interaction effect was found for blending. The lack of a statistically significant difference for the blending skill may reflect learning that occurred in the control group while students participated in shared stories activities. HLM analysis found the time + intervention interaction model to be the best fit. Inclusion of teacher and student level characteristics did not improve model fit.

### *Teaching to Standards: English Language Arts (TTS: ELA) and Access Language Arts (ALA)*

English Language Arts aligned to middle school content is made accessible to students with developmental disabilities through the products *TTS:ELA* and *ALA*. AT is integrated with *TTS: ELA* in a variety of ways. First *TTS: ELA* is applicable to learners who are using photographs, picture symbols, or beginning to use words, and it provides response options in each of these formats for students to use to answer grade aligned skills such as comprehension, vocabulary, poetry skills, play terminology, writing, and student led research. The curriculum includes four Theme-based Units that use fictional novels (e.g., *The Outsiders*), nonfiction text (e.g., *Sadako and the Thousand Paper Cranes*), informational text (on topics such as Ghandi), poems (e.g., *Still I Rise* by Maya Angelou), and plays (e.g., *The Diary of Anne Frank*) all aligned to the theme of the unit (e.g., Social Justice). Each unit contains eight scripted lessons that teach the grade aligned ELA skills using systematic and direct instructional strategies such as constant time delay, system of least prompts, model lead test (MLT), error correction, and reinforcement strategies. In addition to these materials, *Access: Language Arts* (*ALA*) was developed both as an app and software as a supplement to the paper curriculum, *TS: ELA*. *ALA* incorporates the systematic instructional strategies into the program and includes other features such as automatic data collection. The app is divided into both a vocabulary and comprehension component as well as an opinion writing component. Students are provided access to the same adapted grade-appropriate texts seen in the paper curriculum. These texts are read aloud and include interactive features such as underlined vocabulary words within the text that can be selected with the definition provided. To teach vocabulary, constant time delay is incorporated for both identification and definition and includes two rounds of 0-s. delay and one round of 5-s. delay. To promote comprehension, the system of least prompts has been programmed into the software and app to provide a hierarchy of prompts similar to those described in the introduction of this paper. The opinion writing component (under development as *ALA II*) is broken down into instruction on the format of the paragraph (i.e., introduction sentence, opinion sentence, two reason sentences, and a conclusion sentence) and an opportunity for students to write their own opinion paragraph based on the text read (e.g., "I think it was good/bad that Ponyboy was a Greaser."). The system of least prompts and MLT are used with this technology to promote grade-aligned skills in writing.

Several studies have been conducted on both the *TTS: ELA* and *ALA*. First, a study by Mims, Lee, Browder, Zakas, and Flynn (2012) was conducted with 15 middle school students with mild to severe developmental disabilities using *TTS:ELA*. Using a single group, pre-, post-test design, students received instruction using the theme-based scripted lessons from *TTS: ELA*. Students participated in a curriculum based pre- and post-test both before instruction and after eight weeks of instruction (one week per lesson). Differences in scores from pre- to post-test were calculated with a nonparametric, related samples test (i.e., The Wilcoxon Signed Rank Test). The ESs for significant differences were determined with Cohen's $d$. Results indicated significant gains for vocabulary ($d$ = 1.31, $p$ = .005), and comprehension of familiar text ($d$ = .93, p = .017). Although not statistically significant, moderate gains were made for comprehension of unfamiliar text ($d$ = .52), poetry ($d$ = .48), research ($d$ = .40), and writing ($d$ = .45).

In a second study on *TTS:ELA*, the researchers added a control group as well as a generalization measure, which was an assessment testing the same skills taught, but using texts the students had never been exposed to (Lee, Mims, Browder, Ahlgrim-Delzell, in preparation). A non-equivalent group research design with a pre-posttest was used to examine the effects of instruction on Unit Four of the curriculum with 30 middle grade students with developmental disabilities. Two repeated measures of ANOVA were used to examine the group interaction effects on the total score of the direct (familiar) and the indirect (unfamiliar) items. Results showed statistically significant interaction effects for vocabulary identification and definition, comprehension, story grammar, figurative language, writing skills, and research skills in both the direct Curriculum Based Measure as well as the generalization measure (indirect assessment). In both cases, the treatment group outperformed the control group.

In addition to research on *TTS:ELA*, a few studies have been conducted on *ALA*. First, a study by Mims and Stanger (in submission) used a multiple probe design across participants to investigate the effects of the app focused on teaching vocabulary identification, definition, and comprehension across Bloom's taxonomy using grade- appropriate adapted nonfiction text with three students with moderate to severe developmental disabilities. Results indicated a functional relationship between the app and targeted vocabulary and comprehension.

A second study (Mims, Stanger, Sears, & White, in preparation) replicated the Mims and Stanger study, but this study focused on a fictional novel (i.e., *The Outsiders*) delivered via the app, *ALA*. A functional relationship was established between the intervention and the percentage of unprompted correct responses to vocabulary identification, definition, and comprehension questions (e.g., application, literal recall, inferential, analysis, sequence, main character, etc.) for all four students with developmental disabilities.

Finally, a third study investigated the effects of the writing component of the *ALA* app (Mims, Stanger, Pennington, White, Sears, and Strickler, (in preparation). Using multiple probe design across participants, three students with developmental disabilities were provided instruction via the app on components of writing an opinion paragraph and constructing their own opinion paragraph after reading a grade-appropriate adapted text. Results indicated a functional relationship was established between the intervention and the dependent variable, which included the percentage of unprompted correct steps of writing process.

## AT Outcomes and Benefits

While none of the research studies that examined the effects of the five programs specifically measured the differential effects of AT outcomes, all studies demonstrated positive effects of the literacy interventions with AT supports for students with developmental disabilities. The following section will describe potential outcomes and benefits of the AT embedded in the programs, specific evidence of these benefits, and a description of how AT may have supported student outcomes.

**Potential outcomes and benefits.** The five programs included AT supports that have the potential to support literacy skill acquisition for students with developmental disabilities. Specifically, AT potentially increased student engagement, student understanding of the skills and content, and increased access to communicating responses across skills. With an increase in engagement with the curricula, students acquired access to the grade-aligned content. With an increase in the response modes, students were able to demonstrate their knowledge. In this way, AT facilitated student learning and an increase in knowledge gained across the curricular area was measured.

**Evidence of outcomes and benefits.** In the ten research summaries, there were a total of 208 participants from ages six to 14, or grades K to middle school (see Table 2 for the citation, age or grade of participants, and student description). While all of the research participants had a diagnosis under the broad term 'developmental disabilities' and most were identified as having an IQ of 55 or below, the IQ range across all of the studies was 31 to 86. Some participants had an additional diagnosis of Rett syndrome, Down syndrome, autism, physical, or sensory disability. More than a third of the participating students were also described as being non-verbal. The non-verbal participants included nonsymbolic communicators, including those whose modes of communication included gestures, sounds, facial expressions, and vocalizations (*Pathways*) and symbolic communicators who used pointing or eye gazing to pictures to respond to instruction (*ELSB* and *ERSB*). At the opposite end of the literacy continuum with the *Access: Language Arts* research studies, middle school age participants were measured to be reading at the Pre-K/K level and used an iPad.

**How AT supported outcomes and benefits.** Access to the curricular content was possible through the AT integrated into the curricula. In each case, AT provided for multiple means of representation, multiple means of engagement, and multiple means of expression. Across the five curricular products, AT features included alternate response modes including pointing, eye gaze, single and double switches, VOCAs, adapted text, and graphic organizers, which were incorporated in both print form and tablet format (e.g., iPads).Technology products added professional narration with highlighting, integrated vocabulary instruction with error correction, automatic randomization of selections, and automated student assessment including automated advancement where the instructing adult sets the advancement criterion. See Table 1 for specific AT features per product. VOCAs were used across products for making selections and participating in re-telling of a repeated story line. The AT features in each product provided for multiple means of engagement and multiple means of response modes which allowed for students to access the curriculum and demonstrate knowledge in literacy.

## AT Outcomes - Literacy Outcomes

Across the variety of research designs and analyses as listed in Table 2, there are consistent findings of positive student outcomes in achieving gains in literacy made possible through the integrated AT. The studies accessed a variety of grade level literature formats ranging from picture books to grade-aligned fiction novels, non-fiction, poetry, and writing opinion paragraphs. Across the studies, the literacy outcomes that were measured and shown to improve include: listening comprehension, engagement, conventions of reading, phonemic awareness, phonics (decoding), reading comprehension, vocabulary, research skills, and writing. Please see Table 2 for details.

## Discussion

Within this paper we have demonstrated how AT, when integrated within an instructional protocol as a part of a literacy curriculum, provides measurable gains for students with developmental disabilities in literacy and ELA. Measurable gains were the result of the multiple ways that a student was provided access to the curriculum through AT, and the multiple ways in which a student was able to demonstrate his/her knowledge, through AT. As demonstrated through these examples, all students can achieve measurable increases in literacy and ELA when provided with access and instructional strategies. Special educators, including teachers, specialists, Occupational Therapists, Speech and Language Pathologists and administrators, can replicate success in the classroom by seeking literacy curricula with a scope and sequence tied to standards in literacy where AT is integrated into the curricular protocol. AT provides a means for students with developmental disabilities to make independent selections, receive best practice instruction across modalities, and demonstrate measureable competence. As a result, students with developmental disabilities have increased opportunities to develop lifelong skills associated with higher levels of literacy or reading ability, and an appreciation for both literature and literacy. A major finding from this body of research is that students, across all of the curricula, made measurable gains in literacy achievement. Gains occurred across ages, grades, ethnicity, and disability. Students improved on measures of conventions of reading (e.g., orientation of reading material, turning pages, text pointing) phonological awareness, phonics, listening and reading comprehension, writing, research skills, and engagement. Students made gains in comprehension and engagement measures of shared stories (*Pathways*); knowledge of conventions of reading, phonemic awareness, and beginning decoding skills (*ELSB*), and measures of phoneme identification and decoding for picture-word matching (*ERSB*). Additionally, students made gains for vocabulary and text comprehension (e.g., questions related to story elements, prediction, figurative language, and main idea), and writing skills (*TTS: ELA*, *ALA*). Every curriculum integrated AT which provided student instruction, allowed for student generated responses, and measured assessment outcomes.

Listening comprehension skills were not limited to literal comprehension. Students who participated in the *TTS: ELA* and *ALA* programs answered questions about familiar and unfamiliar text across levels of Bloom's Taxonomy (Bloom et al., 1956). For example, students responded to higher-order thinking questions about figurative language, author's purpose, and main idea. Text types spanned fiction, nonfiction, and poetry, and students applied ELA skills to research activities. Finally, students completed writing assignments, including writing about an opinion. AT was integral for student production and assessment.

An important benefit of these programs is increased access to standards-based literacy instruction and progress in literacy achievement for students with developmental disabilities, including students who use AAC (i.e., VOCA or response options). Students from kindergarten to 8th grade improved in their development of understanding text they heard or read independently. Comprehension measures and strategies were varied across several formats to promote generalization of skills to untrained texts (e.g., varying the pictures used to represent objects in comprehension texts in *ELSB* and *ERSB*; varying words used in programs to discourage memorization). Accessing texts, of all varieties, and understanding the content are vital lifelong skills that have the potential to improve the quality of life for all students. Particularly for students with developmental disabilities, increased opportunities for grade-aligned literacy instruction can increase access to the general curriculum, provide more opportunities for students to interact with peers without disabilities, and promote the development of a life-long appreciation of both literature and literacy (Browder et al., 2009; Jackson, Ryndak, & Wehmeyer, 2008-2009). Through carefully designed curricular programs that combine elements of both AT and systematic instruction, research indicates students with disabilities can gain important ELA skills.

## Implications for Practice

The programs (*Pathways, ELSB, ERSB, TTS: ELA*, and *ALA*) examined by the body of literature reviewed in this paper all made use of many of the same specific strategies. That is, all programs were scripted, explicit, and systematic. Four of the programs (*ELSB*, *ERSB*, *TTS: ELA*, and *ALA*) incorporated constant time delay procedures to teach discrete foundational literacy skills, such as letter or word identification, phoneme identification, blending sounds, or matching vocabulary from the literature with definitions. An implication for teachers is to first model pointing to or saying the target response, then repeat the trial with a 4 or 5 s delay embedded between delivery of the instructional cue (e.g., "Show me the letter that makes the /m/ sound") and the delivery of the controlling prompt (e.g., the teacher points to the letter "m"). *ELSB* software and app, *ERSB* and *ALA* all provide systematic instruction integrated within the technology platform of delivery, serving as a model for teaching instruction and best practice delivery with automated error correction.

There is also evidence from all five of the programs that supports the use of a least intrusive prompting method to teach complex literacy skills, including literal or inferential text comprehension, knowledge of story elements, sequencing, main idea, and poetry. Teachers can use a traditional verbal-model, physical prompting hierarchy to teach the steps of a chained sequenced (such as ordering events in a story) or a modified hierarchy that gradually reduces the amount of target text to guide students to locate answers to comprehension questions independently. Additionally, findings from all of the studies support the use of consistent error correction procedures (e.g., "No, ___ is the answer. Show me ___.") and reinforcement, typically in the form of specific verbal praise (e.g., "Yes! ___ is the answer! Great job reading ___."). Within the software and app programs (e.g., *ALA*), reinforcement with specific verbal praise is automatically delivered in response to student input and selection.

In all of the studies reviewed, either low- or high-tech AT was incorporated into the program components. An implication for teachers, therapists and specialists is to provide students with low- or high-tech response options to promote participation in literacy instruction. Students can point to letters, words, or picture symbols with words to indicate an answer to literacy questions (e.g., *Pathways, ELSB*, *TTS: ELA*). Alternatively, software or tablets can be used to provide response options that include audio (e.g., *ELSB*, *ERSB*, *ALA*). Students can use software or an app on an iPad to select buttons that will voice individual phoneme sounds (e.g., *ERSB*). Using this capability, students who also have communication support needs can blend sounds and segment words using an iPad. Students can also access texts via an iPad, which can include supportive text features, including highlighted text and professional narration (e.g., *ERSB*, *ALA*).

**Conclusion**

The evidence from the ten research studies discussed and reviewed in this paper suggests students with developmental disabilities can learn a wide range of literacy skills, including reading connected text and higher-order comprehension. More research is needed as replication by other researchers to help to corroborate these findings. When we approach reading as a science, and incorporate systematic instruction (instructional practices with a strong evidence-base for teaching a range of skills to this population), then teaching literacy skills to students with developmental disabilities becomes a successful and exciting endeavor. The addition of AT, both as a low- and high-tech mechanism for supporting learning, increases student voice by providing students with a means to communicate literacy knowledge. Overall, no matter where students are in their academic achievements in literacy, there is a curriculum and an approach that will yield measurable results.

**Declarations**

The content is solely the responsibility of the authors and does not necessarily represent the official views of ATIA. The authors disclosed financial relationships with Attainment and no non-financial relationships.

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**** Asterisks denote research studies that provided the foundation for this manuscript. These publications are described in Table 2: Summary of Research Studies.***


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***Table 1: Comparison of Five Literacy Products***

| ***Product Name -*** **Curriculum Focus** | **Target Population** | **Product Description** | **AT Features** |
|---|---|---|---|
| *Pathways to Literacy* Literacy for Early Communicators | Students with significant developmental disabilities combined with physical or sensory disability, including those who are nonverbal, who do not consistently use words, pictures, or other symbols to communicate | Scripted lessons for five levels with three story books provide strategies to increase awareness and engagement in story reading while systematically building comprehension for early communicators participating in emergent literacy skills such as phonological awareness and print principals engaging in activities that include viewing pictures and objects in a book, retelling stories, and building vocabulary. | Response options include real objects, pictures of real objects, pictures representing real objects and instructions for programming a VOCA to read a repeated story line and answer prediction and literal recall questions during a read aloud. |
| *Early Literacy Skills Builder (ELSB)* Early Literacy | Elementary age students with developmental disabilities including those who are nonverbal who use words, pictures, or other symbols to communicate. | Multi-year scripted curriculum with 7 levels. The scope and sequence includes 14 literacy skills and an assessment protocol at each level. | Curriculum is available as print, computer software, or app. Systematic instruction is embedded into software. Response options accommodate pointing, eye gazing, and switches to select pictures, letter, and words and VOCAs. Materials can be enlarged. Text color, volume, and pace of the lessons can be changed in the software. Response options are randomized. |
| *Early Reading Skills Builder (ERSB)* | Students with disabilities who are (a) nonverbal or require communication | Multi-year reading curriculum that spans 26 levels where students learn to identify individual phonemes and | This is a blended curriculum (i.e., technology is integrated). Students can access lessons via |

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| Early Reading | supports, (b) have acquired basic literacy skills such as concepts of print and phonemic awareness, and (c) are ready to learn to read. | phoneme blends, blend and segment words, decode words to identify pictures, read connected text, and answer literal comprehension questions about the text. Constant time delay procedures, error correction procedures, reinforcement, are built into the program to teach letter-sound identification, blending, decoding, and sight word identification. A system of least prompts procedure is used to teach segmenting and text comprehension.<br><br>Scope and sequence includes phonics instruction for English language reading up to the second grade level with reading comprehension. | an iPad app or cross-platform software. These formats provide students who are unable or reluctant to sound out the phonemic elements of the English language to use the technology to produce letter sounds. Students can (with the support of technology) produce individual sounds or blend sounds to form words.<br><br>The technology interface provides professionally narrated systematic instruction with error correction, integrated randomization of answer selections, automated student assessment, and advancement to the next level after achieving competency (i.e., the program will advance students to the next level only after the student achieves the predetermined criteria for mastery). |
| *Teaching to Standards: English Language Arts*<br><br>Grade Aligned English Language Arts for Middle School | Secondary students (Middle School or High School), with developmental disabilities and/or autism who have a range of literacy skills from communicating with pictures to reading. | 32 progressive scripted lessons incorporate evidence-based teaching procedures and are organized into four theme-based units: Change, Values and Decision Making, Social Justice, and Global Awareness. Provides literacy instruction across Bloom's Taxonomy | Adapted text for grade-appropriate novels, picture cards used as response options, and graphic organizers.<br><br>The curriculum provides materials at three literacy levels: object/photo, concrete symbols, and text. |

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| | | (Bloom et al., 1956) aligned with upper elementary to secondary standards in English Language Arts including story grammar, comprehension, vocabulary, and writing. | |
| *Access: Language Arts*<br><br>Comprehension, and writing with Middle School aligned English Language Arts | Secondary students with developmental disabilities and/or autism in Middle School or High School who have access to an iPad or computer who have a range of reading levels from pre-K to second grade. | App and software with adapted non-fiction and fiction (under development) stories from TTS:ELA across all four Units. The adapted text in ALA complements the scripted plays included in TTS:ELA.<br><br>Comprehension questions in ALA offer greater depth than those included in the TTS:ELA curriculum. | Professionally narrated read alouds with highlighting the adapted text (grade-aligned books), vocabulary instruction, prompting, integrated systematic instruction with error correction, randomization of answer selections, and automated student assessment.<br><br>Alternative access includes built in scanning with single or double switch access. |

***Table 2: Summary of Research Studies***

| Citation | Participants<br><br># in study<br><br>Age or grade<br><br>Disability | Research Design | Outcomes/Results |
|---|---|---|---|
| **Curriculum Focus - *Product Name*** | | | |
| Literacy for Early Communicators – *Pathways* | | | |
| Browder, Lee, & Mims (2011) | 3 students<br><br>Age 6/8/9<br><br>MD/NV | Single-case multiple probe across participants | A functional relationship was established between the intervention and number of correct responses on comprehension and engagement across response modes (i.e., eye gaze, object selection, touch). |
| Early Literacy – *ELSB* | | | |
| Browder, Ahlgrim-Delzell, Courtade, Gibbs, & Flowers (2008) | 23 students<br><br>Grade-K-4<br><br>Mod./Severe ID &/or ASD (6), NV(12) | Pre-test, post-test randomized control blocked by teacher | Both *ELSB* studies found statistically significant interaction effects between treatment/control groups and pre- and post-test. The treatment group outperformed control group in convention of reading, phonemic awareness, and phonics skills after one year and three years. Effect size estimates after three years found a moderate effect in favor of the treatment group. |
| Browder, Ahlgrim-Delzell, Flowers, & Baker (2012) | 93 students<br><br>Grade-K-5<br><br>Mod./severe ID; ASD (35), NV (42) | Pre-test, post-test randomized control blocked by teacher across 3 years | |
| Early Reading –*ERSB* | | | |
| Ahlgrim-Delzell, Browder, & Wood (2014) | 3 students<br><br>Age 7/8/10<br><br>IQ 54/31/44, DS, ASD | Single-case multiple-baseline across participants | A functional relationship was established between the intervention and percentage of correct responses on phoneme identification, blending and decoding. |

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| Ahlgrim-Delzell, Browder, Wood, Stanger, Preston, & Kemp-Inman (in press) | 31 students<br><br>Grade K-8<br><br>ID or DD, IQ range 40-86, ASD (13) | Pre-test, post-test randomized control blocked by teacher | Statistically significant interaction effects between treatment/control groups and pre-/post-test. The treatment group outperformed the control group in phoneme identification, decoding and total score. No significant interaction effect for blending. HLM analysis found the time + intervention interaction model the best fit. Inclusion of teacher and student level characteristics did not improve model fit. |
| Secondary - *ELA TS:ELA* | | | |
| Mims, Lee, Browder, Zakas, & Flynn (2012) | 15 students<br><br>Middle School<br><br>Mild/Mod./Severe ID or DD ASD (9) | Single-group, pre-, post-test | Statistically significant gains with large effects for vocabulary and comprehension of familiar text. Although not statistically significant, moderate effects were made for comprehension of unfamiliar text, poetry, research, and writing. |
| Lee, Mims, Browder, Ahlgrim-Delzell (in preparation) | 30 students<br><br>Middle School<br><br>Mod/Severe ID or DD | Pre-test, post-test non-equivalent groups | Statistically significant interaction effects for vocabulary identification and definition, comprehension, story grammar, figurative language, writing skills, and research skills. The treatment group outperformed the control group. |
| Secondary ELA - *Access: Language Arts* | | | |
| Mims & Stanger (in submission) | 3 students<br><br>Age 10/13/14<br><br>IQ 50/40/59, ASD, MD | Single-case multiple probe across participants | Functional relationship was established between the intervention and the percentage of unprompted correct questions answered to nonfiction text read aloud. |
| Mims, Stanger, Sears, & White (in preparation)<br><br>Mims, Stanger, Pennington, White, Sears, | 4 students<br><br>Age 9/12<br><br>IQ <40/50, Rett Syndrome (1) & ASD (1) | Single-case multiple probe across participants | Functional relationship was established between the intervention and the percentage of unprompted correct questions answered to a fictional novel read aloud. |

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| & Strickler (in preparation) | 3 students<br><br>Age 9/12,<br><br>IQ 50/<50/<40 | Single-case multiple probe across participants | Functional relationship was established between the intervention and the percentage of unprompted correct opinion writing responses. |

*ASD- Autism Spectrum Disorder; MD- Multiple Disabilities; NV- Nonverbal; DS-Down Syndrome; ID Intellectual Disability; DD- Developmental Disability