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Investment vs. Return: Outcomes of Special Education Technology Research in Literacy for Students with Mild Disabilities

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Abstract

This article presents a review of the research on technology integration in the area of literacy for individuals with mild disabilities. It describes relevant legislation, including how special education technology is impacted by the No Child Left Behind Act (2001). Included studies focus on research in the core content areas of reading and written language most likely to impact inclusive classrooms. In the area of reading, research has investigated such technologies as the use of computer-assisted instruction and text-to-speech synthesis in reading instruction. Written language research in special education technology has studied the use of word processors, text-to-speech synthesis, word prediction, and spelling and grammar checkers.

Legislative Background

In 1997, the U.S. Congress reauthorized the Individuals with Disabilities in Education Act (IDEA Amendments of 1997), requiring that all students with disabilities be considered for assistive technology. Described as a defining moment for special education technology, this act opened the field to all students with disabilities (Edyburn, 2000). As the field matured, several categories of special education technology have developed. Blackhurst and Lahm (2000) defined the field by identifying these six categories: the technology of teaching, or systematic methods of teaching such as applied behavioral analysis; assistive technology, or specially designed or purchased devices intended to make the environment accessible; medical technology, or machines designed to help people with unique medical issues; technology productivity tools; information technology; and instructional technology.

This article will focus on studies of the effectiveness of the latter three technologies, which are those used by the largest group of students with disabilities, students with mild disabilities. This group is made up of students with learning disabilities, mild emotional disabilities, and mild intellectual disabilities, making up 59% of the special education population in 2003-2004 (National Center for Education Statistics, 2005) and those most likely to be in the general education classroom. Since the 1997 IDEA amendments, the special education field has been working to find technology solutions for these individuals within the larger scope of serving the rest of the special education population and increasing their success in inclusive classrooms.

A specific learning disability (LD) is defined by IDEA as a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which may manifest itself in an imperfect ability to listen, speak, read, write, spell, or to do mathematical calculations. The term includes such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The term does not include children who have learning disabilities that are primarily the result of visual, hearing, or motor handicaps, or mental retardation, or emotional disturbance, or of environmental, cultural, or economic disadvantage (Individuals with Disabilities Education Improvement Act, 2004).

This definition has been actuated in the past by identifying students with learning disabilities as those children whose learning potential is average or above, as measured by an intelligence test with achievement scores indicating a discrepancy from what expected scores would be in core areas like reading, writing, and mathematics. The most recent reauthorization of IDEA allows an alternate definition of students with learning disabilities to include children who continue to fail even after the use of scientifically proven interventions in their deficit areas (National Center for Learning Disabilities, 2009).

The instructional placement for students with learning disabilities usually is the general education classroom, with some special education instructional support in the general classroom or in a special education classroom. Students with learning disabilities are often found in any regular education elementary classroom, middle school classroom, or high school classroom. They often attend postsecondary programming.

An emotional-behavioral disability is defined as a condition exhibiting one or more of the following characteristics over a long time, and to a marked degree, that adversely affects a student's educational performance, such as: an inability to learn that cannot be explained by intellectual, sensory, or other health factors; an inability to build or maintain satisfactory interpersonal relationships with peers and teachers; inappropriate types of behavior or feelings associated with personal or school problems; a general mood of unhappiness or depression; a tendency to develop physical symptoms or fears associated with personal or school problems.

The term includes schizophrenia, but the term does not apply to children who are socially maladjusted, unless it is determined that they have an emotional disturbance (Individuals with Disabilities Education Improvement Act, 2004). Students with mild emotional-behavioral disabilities are chiefly educated in the general education classroom with a behavioral plan built into their Individual Educational Plan (IEP) designed to address their behavioral deficits.

These students require a priority focus on behavior to impact classroom academics. They can be students whose externalizing, or acting out behaviors, make them significantly different from their classmates, or whose internalizing behaviors, such as anxiety and withdrawal, are impacting their education. Intellectual skills can vary with this group, but intelligence must not be the reason they are having academic problems.

The federal definition for intellectual disabilities is "significantly sub-average general intellectual functioning existing concurrently with deficits in adaptive behavior and manifested during the developmental period that adversely affects a child's educational performance" (Individuals with Disabilities Education Improvement Act, 2004). Students with mild intellectual disabilities have a learning potential that is at least 2 standard deviations below average. They are often instructed in the general education classroom with additional instructional support. They have some difficulties with cognitive skills and must be scaffolded in their instruction but generally can function within the general education curriculum. These students can achieve academic levels that make them successful in postsecondary settings, although they would not likely attend postsecondary education that requires reading levels above sixth grade.

The federal government requires that every student considered for placement in special education also be considered for assistive technology and assistive technology service. IDEA provides definitions of assistive technology devices and assistive technology services: an assistive technology device is 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 individuals with disabilities. The term does not include a medical device that is surgically implanted or the replacement of such device (Individuals with Disabilities Education Improvement Act, 2004). An assistive technology service is defined under IDEA as any service that directly assists a child with a disability in the selection, acquisition, or use of an assistive technology device. This service includes

1. The evaluation of the needs of such child, including a functional evaluation of the child in the child's customary environment;
2. Purchasing, leasing, or otherwise providing for the acquisition of assistive technology devices by such child;
3. Selecting, designing, fitting, customizing, adapting, applying, maintaining, repairing, or replacing of assistive technology devices;
4. Coordinating and using other therapies, interventions, or services with assistive technology devices, such as those associated with existing education and rehabilitation plans and programs;
5. Training or technical assistance for such child, or where appropriate, the family of such child; and
6. Training or technical assistance for professionals (including individuals providing education and rehabilitation services), employers, or other individuals who

> provide services to, employ, or are otherwise substantially involved in the major life functions of such child. (Individuals with Disabilities Education Improvement Act, 2004)

The Technology-Related Assistance for Individuals with Disabilities Act of 1988 (Tech Act) enhanced opportunities for individuals with disabilities to benefit from technology. The initial Tech Act focused on funding technology efforts to enhance the functional skills of individuals with disabilities. When the Tech Act was amended in 1994 , the focus was expanded to include the use of assistive technology in all environments for individual with disabilities. The 1998 reauthorization defined assistive technology and assistive technology service in a way that was consistent with the 1997 version of the IDEA (National Assistive Technology Research Institute, 2006).

In 2004, the Tech Act was renewed once again, but this time more funds were permitted for use by individuals in such services as checking out equipment, training in the use of equipment, transition, and financing, while still not permitting direct pay for devices. This version of the act also required reports to the government on technology/service effectiveness (Council for Exceptional Children, 2005).

Although the use of assistive technology expanded over the last 20 years, so has the level of accountability for students with disabilities. Increasingly, students with disabilities have been included in state assessments, with the expectation for students with disabilities to meet the same high standards as their grade-level peers. In the 1997 version of IDEA, all but the bottom 2% of the students with disabilities were required to be included in the state assessments. Since this time, not only were students identified by their IEP team for assistive technology accommodations in the general education classroom, but also for assistive technology accommodations for their standardized assessments.

This provision also became the part of the No Child Left Behind Act of 2001 (NCLB), which requires that students with disabilities have access to the standardized assessments and make annual yearly progress. To do this, NCLB permits the students to take advantage of accommodations, including assistive technology, that are recommended for them to use while taking their tests (U.S. Department of Education, 2003). In addition, the provisions of NCLB required the use of scientifically proven instructional techniques for failing students. This provision implies that if assistive technology is a research-proven instructional tool, it is applicable and encouraged under NCLB.

The National Education Technology Plan (U.S. Dept. of Education, 2004) promoted the use of technology to help meet the accountability goals of NCLB. To achieve these goals, the plan suggested that tech-savvy teachers and leaders must be trained and should provide increased access to the Internet and e-learning. However, if these technology goals are to be met, research-proven assistive technology for students with disabilities must also be included in teacher training. If students with disabilities cannot access digital resources for learning, these goals are not being met and, indeed, are a violation of the provisions of free and appropriate access to education required by IDEA (Individuals with Disabilities Education Improvement Act, 2004). Thus, it became the responsibility of districts to provide professional development for teachers and access to technology for students with disabilities.

Research on what constitutes effective use of assistive technology for students with disabilities has paralleled the development of policy changes aimed at enhancing the use of assistive technology. As changes in policy have increasingly required the inclusion of students with disabilities in accountability standards and emphasized the use of scientifically proven instructional techniques, including those with technology, knowledge of methods proven successful becomes important to the entire school community. This review will continue with a focus on research involving technology integration in literacy with students having mild disabilities (learning disabled, behavior disordered, and mildly intellectually disabled) who are most likely to be included with their peers in the general classroom and who must be included in state-required standardized assessment programs. In an effort to help general educators develop an awareness of research-based technology applications that support the literacy development of students with mild disabilities, the following summary of research is categorized by tools that promote reading development and tools that promote the development of written expression.

Review of the Literature

Reading

Studies of technology use with students with disabilities in the area of reading have investigated such strategies as using multimedia to improve reading, using voice recognition to improve reading skills, and using text-to-speech synthesis to compensate for reading deficits.

Several studies investigated the effects of using multimedia technology for students with reading problems. Boone and Higgins (1993) investigated the effectiveness of using hypermedia texts as supplements to a K-3 basal reading approach. During the first year, the hypermedia texts provided vocabulary and decoding support, text-to-speech synthesis, analysis of words, animated pictures, definitions, synonyms, and digitized speech. In the second year, the hypermedia texts added syntactic and semantic assistance, and graphical connections between pronouns and their referents. During the third year, comprehension techniques were added.

Using the MacMillan Standardized Reading Test, Boone and Higgins (1993) determined that reading basals with multimedia-supplemented instruction for students with mild disabilities was as effective as normal instruction and, in some cases, better. Overall, year 1 results on MacMillan for kindergarten students with lower reading scores demonstrated a significant difference of .000; for first grade overall results were not significant; second grade results were significant at .000; and third grade results were significant at .042. Year 2 results were not included for kindergarten; however, all subtests for students with lower abilities were significant, with the exception of spatial abilities.First grade overall test results were significant for the low groups at .000; second grade results were significant at .001; and third grade results were higher overall for students with lower abilities.

Year 3 results for kindergarten students with lower abilities were significant at the .022 level. The results for first grade students with mild disabilities were nonsignificant, as were those of second and third grade. Results of this research demonstrated the effectiveness of the multimedia texts for the lowest achieving group during the initial 2 years, with the final year demonstrating no significant difference.

Boyle et al. (2003) examined the effects of a CD/ROM audio textbook with 67 special education history students. The first experimental group used the audio text plus the SLiCK strategy and received instruction in using recorded texts in conjunction with an organizational strategy. The SLiCK strategy included the following tasks: <u>S</u>et it up, <u>L</u>ook ahead, <u>C</u>omprehend, and <u>K</u>eep it together. It functioned as a note-taking strategy. The second experimental group used the audio text and listened to recorded texts only. The third group, the control group, did not receive a recorded text or an organizational strategy but relied only on traditional teacher-based instruction for support.

Pre and post measures of knowledge were administered to assess effectiveness, as well as short-term quizzes administered periodically throughout the study. ANOVA results indicated an effect on group ($p < .05$), test ($p < .05$) and the interaction of group by test ($p < .001$) when comparing the groups using the CD-ROM with the group not using the CD-ROM. There was no significant difference between the groups who used the CD-ROM. The quizzes demonstrated a significant effect of the quiz ($p < .05$) but no effect on group. The groups with the audio text scored consistently higher than the control group. These results demonstrated the effectiveness of the audio textbook but failed to demonstrate the effectiveness of the SLiCK strategy. Researchers noted that the students might not have used the SLiCK strategy correctly, thus confusing the results.

Students with reading problems not only need reading assistance but also have difficulty accessing text-based information presented in their content classes. Using multimedia project assignments, Elder-Hinshaw, Manset-Williamson, Nelson, and Dunn, (2006) were able to include technology in a summer reading clinic. Multimedia inquiry projects were chosen because they complemented the development of reading comprehension skills for students. Students used a reading strategy to identify and summarize main ideas using topics chosen to support the goals and standards of the academic curriculum. Students were given one 25-minute session per day 4 days per week for 5 weeks.

In a computer lab, the students were introduced to the project, and provided with materials. They then viewed examples of PowerPoint presentations. As part of the Web-based research, students used a speech synthesizer to read the text, accommodating their reading deficits. After students identified their research topics, the inquiry process was explained, and sessions were dedicated to gathering information, creating storyboards, and developing the PowerPoint projects that were then presented to an audience. Project evaluation rubrics addressed students' inquiry processes, ability to focus on the research question, organization of the project, and the use of graphics and sound in their presentations.

Results for all the students were judged as meeting criteria, with use of sound and graphics at the "excels" level. These results suggest that use of multimedia inquiry projects has the potential to increase engagement for students with reading disabilities and help them apply reading comprehension strategies.

Beck (2002) examined the effects of assistive technology used with multimedia on emergent literacy with a group of 10 three-year-old children with developmental delays. The children were in school for 2.5 hours per day for 5 days a week and experienced several assistive technology devices throughout the school day. Picture Communication Symbols (http://www.mayer-johnson.com/) adapted books, a BIGmack (http://www.ablenetinc.com/home.aspx), and a computer with Intellikeys, Intellipics, and Overlay Maker (all at http://www.intellitools.com/) were utilized to help meet the goals and objectives identified in the IEPs of the children. Using Intellipics and Overlay Maker, the books created included graphics, sound, and movement on each page. These books were then included in one of the four centers in the room. Children were afforded individual time on the computer to read the books.

Anecdotal data, checklists, and observations were used to collect data. Without the use of Intellipics, the children were not seen to be interacting with the books; rather they were only looking at them. With the introduction of Intellipics, reading became interactive, and the children began to work independently. For language circle, a BIGmack single-message communication device was programmed to repeat a story's line, thus allowing children who were unable to participate previously to contribute by simply activating a switch. The adapted books provided access to and enhanced the reading process in several ways: with the use of a single switch a child could independently read an entire book, pages were turned for the child, the text was spoken, and illustrations of the story moved across the screen.

An Intellipics rubric was created to assess the four criterion for successful completion: (a) activate the switch, (b) receptively identify picture communication symbols on each page of activity, (c) expressively identify picture communication symbols on each page of activity, and (c) repeat spoken text. On criteria 1, 9 out of 10 children were able to activate the single switch independently. On criteria 2, four children were able to point to all picture symbols independently, four required a verbal prompt to complete the task, and two were unable to perform the task. On criteria 3, three children were able to name all picture symbols independently, five required a verbal prompt to complete the task, and two were unable to perform the task. On criteria 4, two children were able to repeat the entire spoken text, four children repeated most of the spoken text, and four did not attempt to complete the task.

A second promising approach to helping students with mild disabilities in the area of reading is the use of voice recognition. Raskind and Higgins (1999) compared two groups of students with learning disabilities. One group used voice recognition and one group received standard computer instruction. For 16 weeks, students in the voice recognition group were given 50 minutes of instruction during which students were allowed to do their own assignments or were given written assignments. Students using voice recognition were required to use the technology to complete the assignments.

Using pretests and posttests on reading skills, including phonological, orthographic, semantics, metacognitive reading skills, and memory skills, the group using voice recognition demonstrated a significantly greater improvement in many areas over the group receiving standard computer instruction. Areas of improvement included word recognition ($p < .0001$), spelling ($p < .002$), and reading comprehension ($p < .002$) as measured by the Wide Range Achievement Test-3. Phonological skills also demonstrated a significant difference, while the other areas of reading processing failed to demonstrate a statistical difference.

In another experiment with voice recognition technology, Higgins and Raskind (2000) investigated the use of voice recognition systems as an assistive technology to compensate for reading and spelling deficits. In this study, the researchers compared the effects of discrete and continuous voice recognition in 39 students (ages 9 to 18) with learning disabilities. Discrete voice recognition is voice recognition in which the user must pause between each dictated word. Continuous speech recognition is voice recognition that permits the user to speak normally.

During the first semester, 19 were assigned to a group that used discrete speech systems for 50 minutes per week for 16 weeks, writing on topics of their own selection, while 20 students received general computer instruction. In the second semester, another group with 13 students used continuous speech recognition to write on topics of their own choice. Using pretests and posttests on five reading-related measures, the researchers determined that both experimental groups demonstrated significant improvement in word recognition ($p = .002$ with effect size 1.125 for discrete and $p = .018$ with effect size 1.0 for continuous) and reading comprehension compared to a control group ($p = .788$

with effect size .1). In addition, the discrete group demonstrated significant gain in phonological skills ($p = .018$ with effect size .77).

Text-to-speech synthesis and digitized speech have also proven to have potential when used as a supplementary reading technology for students with disabilities. Hebert and Murdock (1994) investigated the acquisition of vocabulary for students with learning disabilities under three different situations: no speech, synthesized speech, and digitized speech. Synthesized speech is speech produced by typing text on the screen, resulting in a robotic sounding voice. Digitized speech is speech that has been recorded and digitized, resulting in a normal-sounding voice. Three sixth-grade students with learning disabilities were given 25 words daily for 6 days using each of the treatments, using an alternating treatments design.

Results demonstrated that two students performed better when learning vocabulary words with speech than when using CAI without speech. One student raised his vocabulary score from a baseline score of 30% correct to 50.8% with synthesized speech and 65% with digitized speech. The second student raised his baseline from 40% to 70.8% with synthesized speech and 85.2% with digitized speech. The third student improved his scores from 18.3% to 30.8% with digitized speech and 50% when using CAI with synthesized speech. Their results indicated that the use of digitized speech improved vocabulary acquisition over reading text without the assistance of digitized voice.

Dawson, Venn, and Gunter (2000) compared the reading fluency of students with behavioral disabilities. Three groups were identified: those using no reading model for assistance, students using the teacher to model reading one passage at a time, and students using text-to-speech synthesis software that presented the text on the screen while it was read (without dynamic highlighting). An alternating treatment design was used to compare the three conditions. While the students consistently performed best with the teacher as the model, mean results demonstrated that fluency increased in students with emotional/behavioral disorders when listening to text-to-speech before reading the text themselves. Results were similar when researchers measured accuracy in the three conditions: the teacher model resulted in the highest means of accurately read words, while text-to-speech resulted in higher numbers of correctly read words than when students had no models.

Lance, McPhillips, Mulhern, and Wylie (2006) studied the effect of text-to-speech, combined with other assistive reading tools, on reading comprehension, homophone error detection, spelling self-check and word meaning. Researchers assigned 93 secondary students to three groups: a group using assistive technology, Read and Write Gold, Version 6 (Texthelp, 2002), a writing program featuring speech synthesis, a spellchecker, a homophone tool, and a dictionary; a group using a standard word processor only; and a group functioning as a control. Groups were matched by a researcher-created test of reading comprehension. Students were trained to use the tools and then given activities to practice using them. Assessments were computer adaptations of paper-based reading comprehension assessments, with two parallel versions designed to minimize transfer from pretest to posttest. Additional assessments were created to measure vocabulary meaning and proofreading.

Results measuring the effect of the speech synthesis demonstrated a significant improvement for the text-to-speech group ($p < .005$). Dictionary tools demonstrated an improvement for the assistive technology group ($p < .0001$) and the word processing group ($p < .0001$). The homophone tool results for the assistive technology group also demonstrated a significance ($p < .0001$). These results demonstrated the effectiveness of the assistive technology tool to benefit students with mild reading disabilities.

Campbell and Mechling (2009) studied the effectiveness of teaching phonics with SMART Board technology with three students with learning disabilities. Researchers used the SMART Board with Powerpoint to present the 52 letter sounds and letter names, both upper case and lower case, with instruction and assessment on specific selected letters for each of the three students. Researchers also wanted to measure incidental learning and, thus, measured the learning of all the letters by all the students, not just their assigned letters. Those letters not specifically assigned to a student became the incidental learning that was assessed.

During each session, 104 trials were used in which each of 52 randomly appearing letters were presented, with the researcher taking turns asking the students to identify their letters and sounds. Researchers measured the naming of the selected letter sounds by the target group, naming of letter sounds by other students who experienced the instruction incidentally during the instruction of the small group, naming of the letter names by the target group, and naming of the letter names by the other students who heard them incidentally as instruction occurred with the target group. Assessment was done with probes at the beginning of the instruction and at the end of the instruction.

Results demonstrated the effectiveness of the SMART Board instruction combined with the multimedia features of Powerpoint, as all three students gained mastery of their target letters using six sessions of instruction for the first two sets of letters and 12 sessions for the third set. Maintenance probes given later indicated that all students maintained the ability to name the sounds of their target letter sets for 50 days for Set 1, 31 days for Set 2, and 3 days for Set 3.

Incidental measures indicated positive results also, with one student increasing his naming of other students' letter sounds from 16.7% to 83.3%, a second increasing his naming from 33.3% to 83.3%, and the final student increasing hers from 25% to 58.3%. Similar results were found in letter naming with one increase from 88.9% to 100%, another from 61.6% to 88.9%, and the third from 66.7% to 72.2%. Thus, the study was able to demonstrate the effectiveness of SMART Board technology combined with computer-assisted instruction for students with learning disabilities.

Studies have demonstrated the advantage in using technology to scaffold learning for students with disabilities in the area of reading. Multimedia projects, voice recognition, text-to-speech synthesis, and SMART board technology provide effective scaffolds for students with disabilities to increase their reading skills. Assistive technology devices have also been shown to produce positive results with students with reading problems.

Written Expression

Several researchers have studied the use of technology to support writing for students with disabilities. These studies have looked at the use of graphic organizers, word prediction, and word processors.

The use of graphic organizers for students with disabilities has been the focus of several studies of technology-supported writing. Anderson-Inman, Knox-Quinn, and Horney (1996) studied students with learning disabilities in three high schools whose use of computers included study skills software. Students with learning disabilities were selected from middle school and high school volunteers who were able to participate during the 2 years of the study. Researchers spoke to faculty in the schools involved to identify characteristics of students for the study. Data was then collected on the students, including formal intelligence measures, literacy tests, writing assessments, study skills tests, and informal measures of handwriting, typing skills, and study skills. These data were used to assign the students to the appropriate group.

Researchers used these results to divide students into three groups based on their levels of utilizing the computer. The three groups were identified as follows: power users were students who used the technology as much as possible for their study skills; prompted users were students who used the computer but had to be prompted to use it as a tool for studying textbook material; and reluctant users had basic computer skills but rarely used them to support their study skills.

The researchers taught the students a repertoire of study skills using Inspiration during the project. These skills included real-time notetaking, studying a textbook, and synthesizing information with Inspiration. Using one-way ANOVA tests, the researchers then compared assessment results among the three groups. They found statistically significant differences in IQ between the three groups, with the highest IQ scores found in the power users group ($p < .001$).

ANOVA results on reading skills for all three groups were not significant for all reading areas except word comprehension results, significant at $p < .002$. Writing score differences between the user groups were not found to be significant, nor were study skills results. Typing speeds, however, were found to have statistical differences in adoption ($0 < .05$), although researchers cautioned about these results while suggesting that the power users tended to be better typists. Results from this research suggest that for students with learning disabilities, the highest adopters were most often those students with higher intelligence measures, higher word comprehension rates, and faster typing speeds.

Sturm and Rankin-Erickson (2002) studied the effects of concept mapping on the expository writing of middle students with reading disabilities, with some students identified as disabled and others identified as having reading difficulties but not identified for special education. Twelve middle school students with learning disabilities were included in the study. A repeated measures within-subject design was used. Writing condition was the variable as researchers compared the use of no concept map, the use of hand-mapping, and the use of computer-mapping software, specifically Inspiration. Measures of attitude toward writing were also taken. Assessment was done through descriptive essays that were scored based on the number of words, the syntactic maturity, the T-units (or a main clause with its syntactical units), and a holistic rating given by the researcher and a second rater whose interrater reliability was measured at .80.

Results using repeated ANOVAs on the quantitative elements demonstrated significance for number of words, number of T-units, and writing quality. Tukey pairwise comparisons on all three conditions using the number of words were greater in the writing sample than on the baseline sample, as were the T-unit results and the writing quality. Syntactic units failed to demonstrate significance.

Nonsignificant results were obtained for syntactic complexity and writing attitude. Visual inspection of the mean scores of the results showed an increase over time in all three conditions. Results demonstrated that students improved regardless of the condition that was used during writing instruction. Researchers felt that the results seemed to demonstrate that mapping helps students generate and organize ideas but not increase the complexity of their sentences.

Word prediction, like graphic organizing software, works as a scaffold to writing for students with mild disabilities. While using a word processor, word prediction provides a list of suggested words following the typing of initial letters of the word. This technology was the focus of a study by MacArthur (1998) investigating technology-supported journal writing by students with disabilities. Using word processing with speech synthesis and word prediction with five students ages 9 and 10 with learning disabilities and severe writing problems, MacArthur found that both legibility and spelling improved in four of the five students in written dialogue journals. The baseline scores for correct spelling ranged from 42% to 75%, while the writing baseline scores ranged from 55% to 85%. Legibility and correctly spelled words increased for four of the five students to the 90%-100% range.

MacArthur (1999) again studied the effects of word prediction on spelling, number of words produced, and number of legible words using three students with severe writing problems in a private school for students with learning disabilities. Reporting on two different studies in the same article, researchers used an alternating design for each study, where the students utilized handwriting, writing with a word processor, and writing with word prediction to develop written products.

In the first study, quality measures were made on journals. Results were mixed. In this first study, only one student demonstrated an increase of 12% to 14% higher spelling score using word prediction, while the other two failed to demonstrate differences in spelling. For composing rates, using the word processor with word prediction took substantially longer than when not using word prediction. Because the researcher believed that the writing product failed to take advantage of the power of word prediction, a second study was conducted with the same three students using more difficult material. Using dictated passages written at the students' reading levels, students used all three writing methods to copy the spoken passages.

For this study, the two students who previously had no differences demonstrated consistently higher numbers of legible words when using word prediction, an increase from 11% to 17%, while the third student demonstrated no difference. Mean scores of correctly spelled words were also higher by 21% to 23%. Handwriting speeds, however, were faster than when students were using both word processing and word prediction. Results of these two studies demonstrated that using word prediction could result in improvements in quality of the writing of students with mild disabilities.

Zhang (2000) used a software program of a design similar to a word prediction program over a school year with five fifth-grade students with learning disabilities. The computer-writing tool, ROBO Writer (Brooks & Zhang, 1992) is a word processor from which students can select from a bank of words offered by the program. The subjects for this study attended a K-8 parochial school and were reported to be lacking motivation, often refusing to participate in writing activities and having problems with sentences, paragraphs, spelling, and other mechanics of written expression.

A writing curriculum was specifically designed for these five students incorporating ROBO Writer. The students met in a computer lab for three 20-minute sessions per week, with three preservice teachers from a nearby college assisting the students as mentors. ROBO Writer allowed students to develop their ideas without worrying about their writing skills. The design of the study was a case study, with four written pieces evaluated holistically. Results showed a positive effect on written expression assignments, as holistic measures revealed a trend for improvement for all students on each written product developed using ROBO Writer.

Several researchers have studied the use of a word processor without any additional scaffolds and have found mixed results for students with mild disabilities (Hetzroni & Schrieber, 2004; MacArthur & Graham, 1987). While Hetzroni and Schrieber found increases in the quality of student's writing products when using a word processor, MacArthur and Graham found insignificant differences in the final product with and without the word processor. However, other researchers examining the addition of strategy instruction for revising the writing product found significant results (Graham & MacArthur, 1988; MacArthur, Graham, Schwartz, & Shafer, 1995; Stoddard & MacArthur, 1992).

MacArthur and Graham (1987) investigated the writing of 11 fifth- and sixth-grade students with learning disabilities. Initially, students were asked to rate their writing, to respond to what they liked or found difficult about their writing, and to identify their preferred method of writing, either by hand or with a word processor. Students then wrote three stories using handwriting, word processing, and dictation. Students were permitted one revision session for handwriting and word processor, but not for their dictation session. For each session, students had a pictoral prompt. Following the writing sessions, students were asked to pick the story that their friends would like best and state whether they preferred handwriting or word processing.

Products were analyzed for language complexity, mechanical errors, quality, and composing rate. Results showed that dictated stories were significantly longer, were of better quality, and had fewer grammatical errors, while the handwritten and word processed products differed significantly only in composing rate and revisions ($p < .05$). The word processed story composition rate was about half of the handwritten product. Seven students preferred their dictated story while three picked the word-processed story, and one student preferred the handwritten product.

Hetzroni and Shrieber (2004) studied the effects of a word processor on the performance of three students with writing disabilities during regular classroom activities at the junior high level. Students selected were enrolled in seventh-grade general education classes and were formally diagnosed with learning disabilities in the area of written expression, specifically in spelling, penmanship, and copying text. The first phase of the study established a baseline and monitored the use of traditional paper-and-pencil materials followed by a training session to teach the students how to use a computer. The next phase included having the students use a computer for all in-class assignments. Computers were then withdrawn, and students had to again use only paper-and-pencil materials. In the last phase of the study, computers were reintroduced, and the overall organization and structure of the writing, spelling errors, and number of words used were examined.

The data were analyzed to measure frequency of spelling errors in final products, percentage of oral reading errors in final products, total number of words produced in the final product, and the text structure and organization. An ABAB design with withdrawal between Phases B1 and A2 was used. Final products demonstrated a significant difference between handwritten and computer generated writing in number of spelling mistakes, reading errors, organization, and structure, but not in number of words per text.

When teachers add writing instruction to the word-processed product, results are somewhat more positive, according to MacArthur, Graham and their colleagues (MacArthur et al., 1995; Graham & MacArthur, 1988; Stoddard & MacArthur, 1993). Graham and MacArthur (1988) studied a method for teaching students with learning disabilities to revise essays written on the word processor. Baseline data on selected writing behaviors of three students with learning disabilities were taken. Students were trained to revise their essays to a criterion level. Twelve essays were randomly selected to rate for the number of revisions, types of revisions, additions, deletions, substitutions, rearrangements, number of words, spelling errors, and mechanical errors. Results demonstrated that students increased their number of revisions from the baseline and increased the quality of their revisions, looking beyond simple mechanical mistakes.

Peer review with word processing was the focus of a study by Stoddard and MacArthur (1993). The design of the study was a multiple probe across paired subjects design using seventh- and eighth-grade students with learning disabilities. Writing products were done using word processors. Peer reviewers were trained to ask questions to guide the student toward specific content areas in need of revision. Revisions were then followed by another peer review for mechanics. Audiotapes of the sessions demonstrated that all peer editors incorporated all of the revision questions at least once. Final compositions were analyzed for number of words, mechanics, quality, and change in quality between drafts.

Resulting revisions showed increased improvement in content, length, and quality. These increases in the revisions were measured as nonsurface revisions, surface revisions, quality, length, and mechanical revisions. In addition, researchers were able to measure increases in revisions to handwritten compositions. Measured increases, however, were uneven among the students, with the increase of content revisions in all but one student and increases in mechanics revisions in all but two. These results demonstrated that peer reviews had an impact on the quality of the product.

MacArthur et al. (1995) also looked at peer revision using a group of 65 students with learning disabilities as the experimental group and 62 students as a control group. A second year of the research used 48 experimental students and 32 control students. Teachers provided a series of writing assignments in different genres. Peer-revision was used and measures of quality previously identified by Huot (1990) were used. Compositions were scored on an 8-point scale with 1 as the lowest and 8 as the highest. Raters looked at aspects such as content, organization, and style but were directed to disregard mechanical errors. Raters chose low, high, and medium examples to act as anchor points for assigning a rating to the products. Students were randomly assigned to either the handwriting control group or the word processing experimental group.

Significant differences were found between the experimental and control group in the quality of the narrative composition ($p = .012$) and in improvements between pretests and posttests of both the narrative ($p < .001$) and the informative ($p < .001$). In addition, there was significance in length of the narrative writing selection ($p = .046$), and decreases in spelling errors on both the narrative selection ($p < .001$) and the informative selection ($p < .001$). No significant differences were found in capitalization and punctuation. Results demonstrated the effectiveness of the combination of word processors and peer revision strategies for students with learning disabilities.

Studies have demonstrated the effectiveness of technology with writing instruction for students with mild disabilities. Graphic organizers have helped students with disabilities to better organize their writing. Word prediction programs have been shown to bypass spelling and writing difficulties effectively for students with mild disabilities. Finally, word processors and word processors with additional writing strategies have helped students with disabilities generate written products more effectively and with improved levels of quality.

Summary of Research

Technology has been shown to have mixed results as a tool for students with mild disabilities, but in general, has demonstrated a benefit for these students. In reading, the addition of technology enhances the learning environment and results in largely significant improvements. In written expression, results of tools such as speech synthesis and word prediction have been demonstrated to often have a positive impact on students with disabilities. In summary, integrating technology into instruction for students with mild disabilities seems to provide an academic gain for them.

Future Directions

Research has, for the most part, shown promise for students with disabilities to benefit from the integration of technology into instruction. Most recently, researchers have defined the term universal design for learning (UDL) as designing flexible learning environments that make learning accessible to all (Rose & Meyer, 2000). To facilitate a more flexible learning environment, researchers are promoting the use of a National File Format (NFF) for digital curriculum materials to allow all students with literacy difficulties to benefit from accessible text (Stahl & Aronica, 2002). They are promoting a plan for universally designed lessons that use NFF and can permit access by students with various learning styles (Rose & Meyer, 2002).

The US government has demonstrated its interest in supporting this use of technology for students with disabilities in the latest iteration of the IDEA. In the 2004 amendments to the IDEA, Congress accepted the National Instructional Materials Accessibility Standard (NIMAS; http://nimas.cast.org/) as a NFF standard and urged education organizations to coordinate with NIMAS for the purchase of accessible materials (Center for Applied Special Technology, 2006). NIMAS is a format for digitizing text materials so that they can be made accessible for students with disabilities.

UDL, as a new paradigm for technology-scaffolded instruction for students with mild disabilities, has been introduced to aid the student with disabilities to succeed in the general education classroom (Hitchcock & Stahl, 2003). In order to encourage accountability for all students, both IDEA and NCLB encouraged the use of the principles of universal design for learning (Hitchcock & Stahl, 2005).

Given the charge to make effective instruction available to all students, future research must explore the effectiveness of universally designed curriculum materials. Many of the past studies looked at individual scaffolding elements that are built into UDL, but there is a need to research the effectiveness of UDL materials that include multiple technology-based scaffolds and to investigate how students can use UDL materials effectively.

A few researchers are beginning to investigate this area. An example of research that used multiple technology-based scaffolds in its UDL design is a study by Twyman and Tindal (2006). These researchers developed social studies materials that utilized scaffolds such as simplified text, a linked concept map, conceptually organized text, and text-to-speech synthesis (http://www.brtprojects.org/cyberschool/history/). They randomly assigned two intact groups of 11th and 12th graders to the experimental group and the control group. Within these groups, they randomly assigned 27 students identified as having reading and writing disabilities.

Using these materials, students were assessed with three different instruments: a vocabulary-matching instrument with terms selected to match the concepts of the material, a maze activity that was also specifically designed to reflect concepts of the material, and an extended response that asked the students to summarize and explain the material. The vocabulary assessment was validated with Cronbach's alpha with internal consistency measures of .73 and .91.

The maze activity had three forms that were correlated with a required .017 p-value expected. The extended response items were graded by trained graduate students with high interrater reliabilities. The results showed the vocabulary measurement failed to demonstrate statistically significant results ($p = .11$). However, a posthoc power analysis demonstrated that with a larger sample, results would have been significant. The maze results also failed to demonstrate significance, although students did demonstrate improvement using the UDL materials. The extended response results demonstrated a near-significant result. Interviews with the teacher later indicated that students in the experimental group were engaged with the material and more participatory than the control group. The researchers concluded that conceptually based materials could be used successfully for students with disabilities.

This kind of research represents the types of studies that need to continue. If UDL offers the access to standards-based instruction that is needed to allow students with mild disabilities to succeed in inclusive settings, teachers need to know the most effective and efficient ways to develop and use technology-scaffolded instruction. They need information on how students can take advantage of the technology-based tools built into the software and to be reassured through sound studies that this is an effective method for meeting accountability standards.

Implications for Teachers

Research on use of technology for students with mild disabilities shows promise for today's classroom teachers. No longer is this simply a body of research of interest only to the special educator. Its results are important to all teachers and teacher educators. The movement toward full inclusion and the requirements of high academic standards for all students ensures that all teachers need to be knowledgeable of promising technology uses with students with disabilities. Indeed, NCLB requires not only that these students take the same assessments as general education students, but that research-proven teaching strategies be used for all students, which would include the studies described here.

Studies have demonstrated the effectiveness of integrating technology into the instruction of students with mild disabilities to reinforce reading skills. Adding multimedia elements such as CD-ROMs to reading instruction with students with disabilities was demonstrated to be an effective tool for increasing reading skills, motivation, and access to reading materials (Boone & Higgins, 1993; Boyle et al, 2003; Elder-Hinshaw et al., 2006). Raskind and Higgins (1999) demonstrated the effectiveness of voice recognition as a method for increasing phonological skills, word recognition, and reading comprehension. Several studies demonstrated the effectiveness of text-to-speech synthesis when measuring vocabulary acquisition, fluency, word meaning, spelling, and comprehension (Dawson et al., 2000; Hebert & Murdock, 1994; Lance et al., 2006).

Technology use has been shown to be beneficial when used as a tool for scaffolding the writing skills of students with mild disabilities. Word prediction has been shown to improve spelling, legibility, and grammar (MacArthur, 1998). Use of graphic organizers was found to be an effective tool in writing and attitude toward writing (Sturm & Rankin-Erickson, 2002), although the most frequent adopters of this software seem to be students with higher levels of intelligence among those with mild disabilities (Anderson-Inman et al., 1996).

If a teacher has access only to a word processor in the classroom, researchers have demonstrated the benefit to students with mild disabilities in the area of writing. Hetzroni and Shriever (2004) demonstrated the benefits of word processing when comparing it with handwritten products. While MacArthur and his associates had mixed results when comparing written products with products from a word processor for students with mild disabilities (MacArthur & Graham, 1987; MacArthur et al., 1987), they demonstrated that, if a teacher couples a word processor with instruction during the revision process, the results are significant (Graham & MacArthur, 1988; Stoddard & MacArthur, 1992). Zhang (2000) demonstrated that if the word processor used speech synthesis, students with disabilities were able to identify their mistakes in writing, thereby improving their written product. If a teacher adds any or all of these technology elements to writing instruction, research has shown that it will often improve the writing product of students with mild disabilities.

Because of the benefits of technology integration for students with mild disabilities and because students with mild disabilities may be found in every classroom, every teacher should be aware that the integration of technology for these students can facilitate their learning.

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