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Benefits and Limitations of Technology Use for Students with Reading and Writing Disorders in the General Education Classroom: A Systematic Review

By Brigid Ovitt

This issue of **NASET's LD Report** was written by Brigid Ovitt. This systematic research review addresses the gap between claims that specific technologies or classes of technology are effective in improving affective and objective academic performance of secondary students with specific learning disability (SLD) and research supporting those claims. The purpose of this review was to examine and synthesize research over the past ten years detailing the effects of educational technology on secondary students with reading and writing disorders. A comprehensive search of educational and psychological research yielded ten studies addressing the effectiveness of specific technologies addressing the academic experience of secondary students with SLD in reading, writing, or both. Just under half of the studies indicated that the technologies they examined can have positive effects on learning when used in conjunction with effective teaching. Twenty percent of the studies indicated that the technologies they studied were effective in increasing students' academic engagement and self-perception. Thirty percent of the studies indicated that the technology they focused on had neutral or detrimental effects. Overall, this review of literature indicates that while technology can benefit students with SLD in high school and middle school, the benefit is by no means uniform across technologies, and the technologies studied do not substitute for engaged, effective teaching.

Abstract

This systematic research review addresses the gap between claims that specific technologies or classes of technology are effective in improving affective and objective academic performance of secondary students with specific learning disability (SLD) and research supporting those claims. The purpose of this review was to examine and synthesize research over the past ten years detailing the effects of educational technology on secondary students with reading and writing disorders. A comprehensive search of educational and psychological research yielded ten studies addressing the effectiveness of specific technologies addressing the academic experience of secondary students with SLD in reading, writing, or both. Just under half of the studies indicated that the technologies they examined can have positive effects on learning when used in conjunction with effective teaching. Twenty percent of the studies indicated that the technologies they studied were effective in increasing students' academic engagement and self-perception. Thirty percent of the studies indicated that the technology they focused on had neutral or detrimental effects. Overall, this review of literature indicates that while technology can benefit students with SLD in high school and middle school, the benefit is by no means uniform across technologies, and the technologies studied do not substitute for engaged, effective teaching.

Benefits and Limitations of Technology Use for Students with Reading and Writing Disorders in the General Education Classroom: A Systematic Review

More than one third of children served in special education in the United States qualify under the category of specific learning disability (SLD) (U.S. Department of Education, 2015). Of those, most have a disorder involving reading or writing or both. Federal law requires that schools make accommodation for disabled students (Americans with Disabilities Act, 1990); that states make assistive technology available to people with disabilities across the lifespan (Assistive Technology Act, 2004), and that schools provide free and appropriate education to students with disabilities in the least restrictive environment (Individuals with Disabilities Education Improvement Act, 2004). Increasingly, teachers, students, parents, and school districts have relied on technology to make it possible for students with disabilities to participate fully, meaningfully and successfully in general education classrooms.

In the last ten years there has been a significant increase in technologies focused on helping students with reading and writing disorders to overcome them or bypass them in order to gain access to the general education curriculum at the same time and in the same place as their typically developing peers. A fifteen-minute Google search turned up over fifty products, all advertised by websites which tout their ability to help students with reading and writing disorders. These claims are sometimes supported by testimonials, but never by research (Kurzweil Education, n.d.; Ginger Labs, 2014; Inspiration Software, 2015; Evernote Corporation, 2015; Livescribe, 2007-2015).

Several universities and non-profits sponsor websites that suggest technologies for struggling readers and writers (e.g. Regents of University of Michigan, 2014; Yale Center for Dyslexia and Creativity, 2015; WETA Public Broadcasting, 2015), but these, too, lack support of empirical studies. Their suggestions are characterized by this explanation on the University of Michigan website: “We carefully consider each app before we add it, ensuring that it claims to help dyslexics in ways that are in line with the evidence on how to help dyslexics” (Regents of University of Michigan, 2014)—they consider the products’ claims but do not ensure the claims have merit. While those who need technologies to ameliorate effects of reading and writing SLD’s have more choices than ever, it can be dizzying to evaluate the many products and decide which particular product or even which general class of products is the best fit for an individual student.

The purpose of this research review was to examine and synthesize research published in the last ten years detailing the extent to which compensatory educational technology allows secondary students with learning disabilities in reading and writing to participate fully in the general education curriculum, to learn from the general education curriculum, and to feel competent and comfortable among their non-disabled peers. The justification for this review was that there has been a proliferation in the number and kinds of technology to help students with learning disabilities in reading and writing, and it is important for teachers and parents to know the extent to which these aids work in promoting participation, self-efficacy, and learning in order to guide decisions regarding where to invest technology resources. The review was limited to secondary students (middle and high school, ages eleven to twenty-one) because as students mature and move farther away from elementary school, they are more on their own, and the self-sufficiency promised by assistive, compensatory educational technology becomes more important. In addition, while there seems to be a substantial body of research on the effects of technology on elementary students or on K-12 students with SLD, the research specifically on secondary students with SLD and technology is scant. The review was limited to research published in the last ten years because advances in technology over the course of that time increases the possibility that research focusing on earlier technology might be obsolete.

Method

Articles were identified by electronic searches of PsychINFO and ERIC. Search terms included the following: technology, dyslexia, learning disorders, learning disabilities, reading disorders, reading disabilities, writing disorders, writing disabilities, computer assisted instruction, assistive device, assistive technology, computer assisted learning, computer generated, livescribe, electronic, electronic book, e-book, ebook, e-reader, electronic reader, ereader, kurzweil, notability, graphic organizers, electronic graphic organizers, computer generated graphic organizers, story maps, and cognitive maps. All searches employed filters for secondary school, learning disorders and the time frame of the review (2006-present).

Technology and dyslexia turned up no articles on either ERIC or PsychINFO. Dyslexia and computer turned up no articles on ERIC and eighty on PsychINFO. Computer assisted learning and dyslexia turned up no articles on PsychINFO. Educational technology and learning disorders turned up 275 articles on ERIC. Assistive device and dyslexia turned up three articles on PsychINFO. Dyslexia and computer assisted instruction turned up seven articles on PsychINFO. Learning disabilities and computer assisted instruction turned up twenty-four articles on PsychINFO. Learning disabilities and assistive tech turned up nineteen articles on PsychINFO. Dyslexia and assistive device turned up five articles on PsychINFO. Dyslexia and educational technology turned up three articles on PsychINFO. Learning disabilities and educational technology turned up twenty eight articles on PsychINFO. Learning Disabilities and Kurtzweil turned up one article on PsychINFO. Dyslexia and Kurtzweil turned up one article on PsychINFO. Learning Disabilities and Smart pen turned up no articles on PsychINFO. Dyslexia and smart pen turned up no articles on PsychINFO. Learning disability and e reader turned up no articles on PsychINFO. Learning disability and ereader turned up no articles on PsychINFO. Learning disability and electronic reader turned up seven articles on PsychINFO. Dyslexia and e reader turned up zero articles on PsychINFO. Dyslexia and ereader turned up no articles on PsychINFO. Dyslexia and electronic reader turned up no articles on PsychINFO. Learning Disabilities and assistive technology turned up twelve articles on ERIC. Dyslexia and technology turned up seven articles on ERIC. Learning disability and technology turned up one hundred twenty seven articles on ERIC. Learning disabilities, computers, writing turned up twenty one articles on ERIC. Learning disabilities and e-reader (and its variations) turned up no articles on ERIC. Reading pen turned up one article on ERIC and one on PsychINFO. Graphic organizer, computer turned up sixteen articles on PsychINFO and no articles on ERIC. Assistive reading software turned up six articles on PsychINFO and one on ERIC.

Studies included in the review met the following criteria: (a) they were empirical studies of a specific technological product (e.g. Inspiration 6) or a specific type of technology (e.g. electronic graphic organizers); (b) the article was published in a peer-reviewed journal; (c) participants were secondary students (age twelve to twenty-one) and had a diagnosis of reading or writing disorders or dyslexia, and (d) the articles were published between 2006 and 2015. Studies in which participants had more than one diagnosis were not excluded, nor were studies that included students without IDEA eligibility along with students with eligibility. Studies focused on students with reading or writing difficulties or low reading or writing achievement were excluded unless students had been diagnosed with SLD or were receiving special education and related services for SLD. Studies were excluded if participants were in elementary school even if some participants were in the age range that is typically associated with middle school. Similarly, studies were excluded if they focused on higher education even if some students' ages were typical of secondary school.

Results

Ten articles met all of these criteria. Findings ranged from clear evidence of benefit of technology to students with SLD, to very little evidence of benefit of technology to students with SLD. Almost all studies indicated that the technology in question was beneficial only in conjunction with, rather than in place of, effective teaching.

Hornickel, Zecker, Bradlow, and Kraus (2012) explored the possibility that a compensatory assistive device can, in fact, not only support students' classroom work, but also ameliorate the underlying cause of the disability. The study was of a between-subjects matched-control design. Participants were thirty-eight students at a private school in the Midwestern United States for children with severe learning disabilities. Participants were between the ages of eight and fourteen, and all had dyslexia with no hearing impairment. Nineteen students wore a personal FM system in class throughout the school day over the course of one academic year. They did not wear the FM systems during free time or periods requiring physical activity (e.g. physical education), and they did not wear them during testing. The other nineteen students did not wear the devices.

Results indicated that the FM system may be an effective compensatory assistive device in that it allowed children with dyslexia to increase the signal to noise ratio as well as enhanced "signal quality" (Hornickel et al. 2012, p. 16732) and provided "greater interactions with the meaningful words of teachers" (Hornickel et al. 2012, p. 16732). Students in the intervention group improved significantly on phonological awareness and reading as measured by pre- and post-tests with the Comprehensive Test of Phonological Processing and the Woodcock Johnson III test of basic reading. The nineteen students in the control group did not improve on either of these measures over the course of the study despite attending the same schools and the same classes as the intervention group. In addition, the authors found that "after children used the FM system for one year, their auditory brainstem responses to speech became more consistent" (Hornickel et al. 2012, p.16732), and that this effect did not diminish over time. Consistent response to speech sounds is a foundation of phonological processing. Thus, according to Hornickel et al. individual FM systems worn during instructional periods throughout the school day may have not only improved response to the instruction itself, but had lasting neurological benefits.

Igo, Riccomini, Bruning, and Pope (2006) studied a variety of strategies for a computer generated note taking framework for taking notes from online sources. Specifically the authors compared the effects of the strategies on the retention of students with SLD. On the basis of studies indicating that notes that are hand written and involve summarizing or paraphrasing seem to result in better encoding for typically developing students, authors hypothesized that notes typed or written into a web-based template would best foster encoding of information. In their sequential mixed-methods study, they explored "the encoding function of Web-based note taking for middle school students with LD" (Igo, et al. 2006, p. 91). In the quantitative phase, students took notes by copying and pasting into a web-based note taking tool, by writing notes into the same template, and by typing notes into the web-based tool. They were tested right after taking notes, and then again four days later to establish the extent to which information had been encoded. In the qualitative phase, students were interviewed to ascertain their reactions to the three methods, and their notes were analyzed to understand their note taking strategies, their learning, and their mental processing.

Results of the study indicated that students performed better on the tests after using the computer based copying and pasting tool. Authors surmised that this result indicated that students with SLD did not engage in "deep processing" (Igo, et al. 2006 p. 95) while taking notes using any of the three strategies. Qualitative data indicated that in the writing and typing conditions, students tried to copy notes verbatim rather than paraphrasing or summarizing, while in the copying and pasting condition, students thought more about the material in order to decide which passages to copy. In addition, when trying to write or type notes, students often made errors, so that the notes that had been copied and pasted were of better quality, affording students more accurate information when they reviewed their notes. A third benefit of the copy and paste tool was that students overwhelmingly preferred it to the other methods because it relieved anxiety about taking correct notes.

In 2006, Boon et al. explored the effects of computer based cognitive organizers on students' learning in social studies class in two quasi experimental studies—one pilot study and a second systematic replication which supported the findings of the pilot. Both studies compared instruction using Inspiration 6, a visual mapping and outlining software, to traditional textbook instruction in a group of students made up of students with SLD, students with diagnosed emotional disorders and students with no special education eligibility. Both studies were between subjects pre-test post-test design and involved a similar number of students (forty-four in the original study and forty-nine in the replication study).

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Students were those assigned to two inclusive general education social studies classes in a high school in the U.S. In the original study one classroom served as the control (textbook) condition while the second served as the intervention (computer-based graphic organizer), and in the second study the first classroom served as intervention and the second as the control.

In both studies, both classrooms were team taught the same chapter from their history textbook by one general education teacher and two special education teachers. Teachers followed lesson plans which stipulated proven “teacher effectiveness strategies” including “daily review,” “statement of purpose,” “guided practice,” and “formative evaluation” (Boon et al. 2006a, p.7), and both sets of students took identical pre- and post-tests. In the intervention classroom, the general education teacher lectured about social studies information while the special education teacher completed a cognitive organizer on the overhead projector (modeling effective note-taking) and students filled out a paper and pencil template of the organizer. The following day, teachers reviewed the information, and students met in the computer lab to input the notes from their paper and pencil organizers into the Inspiration 6 organizer. On the last day they reviewed their computer-generated organizers independently and in pairs; the teacher reviewed the material, and students took a post-test identical to the pre-test.

In the control classroom, the teacher lectured on the content in the chapter, the class then participated in a Socratic exchange with the teacher, in discussion sessions with peers, and in independent reading and in cooperative learning activities. They also watched a video and filled out worksheets. On the last day the teacher reviewed the information, and students took the post-test.

In both studies, students who learned the material using the computer-based cognitive organizer performed better on the post-test and improved more between pre-test and post-test than the students who learned the material using the traditional textbook method. Authors found that the original study “demonstrated that the use of cognitive organizers has the potential to significantly improve content area learning for both students with and without disabilities” (Boon et al. 2006a, p. 9), and that the second study strengthened this finding.

Unzueta and Barbetta extended the findings of Boon et al. in a 2012 study in which they explored how using computer based graphic organizers affect Hispanic middle schoolers’ persuasive writing. In their single-subject multiple baseline study, four Hispanic, U.S. seventh and eighth graders with SLD used Inspiration 8 to help compose persuasive writing pieces. Before the baseline phase of the study, students had regular classroom instruction in persuasive writing. Investigators reviewed the important elements of this instruction before beginning the study. In the baseline phase, students planned, wrote and revised a persuasive essay on laptops in their classroom in response to a prompt. Times for each stage were recorded before students moved on to the next stage.

In the intervention stage, investigators taught students how to use the Inspiration 8 software to create, expand and link main idea “clusters” and supporting idea “clusters.” They were also taught how to command the software to generate an outline from the graphic organizer they had created, and, finally, to transfer the outline to Microsoft Word 2007. After this training, students wrote another persuasive piece under conditions that were identical to the baseline phase except that the planning was done using Inspiration 8.

Results indicated that during the intervention phase students’ composition of persuasive writing improved in each of five areas. Students increased the number of words they wrote; they increased the total amount of time they spent planning; they increased the number of supporting details in their compositions; their compositions scored higher on a measure of organization, and they showed greater syntactical maturity. Authors found that computer-based graphic organizers improved the ability of Hispanic students with SLD to write persuasively, and that teachers should consider introducing them “after instruction in the persuasive writing genre” (Unzueta and Barbetta, 2012, p. 28).

Lancaster et al. explored the use of a computer based tutorial to teach secondary students effective strategies for taking standardized tests. The study included fifty-two middle school students and sixty high school students all of whom had been identified as having SLD. In each setting (middle school and high school) students made up four class sections.

Sections were randomly assigned to intervention or control conditions. All students took a pretest of strategy use, strategy knowledge and metacognitive awareness. Students in the intervention group then completed the computer based program, called the *Test Taking Strategy CD*. This program was a multi-media presentation based on a program of test taking strategies that had been previously proven to be effective in increasing standardized test scores. The program involved about sixty to ninety minutes of instruction, practice and video. After students watched the *Test Taking Strategy CD*, teachers checked for understanding, provided feedback, and directed students to repeat parts of the program if necessary. After completing the program students took post tests and completed a satisfaction questionnaire and interview. Students in the control group spent the same amount of time completing a computer-based program on self-advocacy.

Results indicated that in high school and middle school groups there was no difference in performance on pre-tests between control and intervention groups, but that there were significant differences in post-test performance. Students who had undergone the intervention scored higher on all three post-tests than those in the control groups. Responses on satisfaction questionnaire in both intervention groups ranged from “satisfied” to “very satisfied” and interviews indicated that most students “were happy with the program as it was” (Lancaster et al. 2009, p. 175). The authors found that “the *Test Taking Strategy CD* was an effective tool for teaching junior- and senior- high school students with LD a complex test-taking strategy” (Lancaster et al. 2009, p. 179). Authors emphasized that while the *Test Taking Strategy CD* is a self-contained program, including all information and activities needed to teach the strategies, “teachers play a critical role in helping students master the strategy” (Lancaster et al. 2009, p. 172).

Acknowledging that “Self-perception such as students’ academic perceived competence, is a good predictor of academic success” (Chiang and Jacobs, 2009, p. 106), Chiang and Jacobs (2009) asked whether use of Computer Based Instruction significantly increased the academic self-perception of high school students with SLD in a quasi-experimental study. Participants were 50 students, all of whom qualified for special education. Students had already been assigned to one of two classrooms before the beginning of the study. The twenty-five students in the experimental group were taught to use K-3000, an educational software that provides reading, writing and study strategy support. They then used K-3000 to do homework and or coursework for twenty to thirty minutes a day, three to five times a week for ten weeks. The control group did not use K-3000 and did homework and course work with paper and pencil. Both groups completed a SPPA and SPPLD, measures of self-perception, before and after the experimental period. Students were also compared on the basis of performance on a functional task (filling out a job application) but this was not related to academic performance and no connection was made in the study between performance on the functional task and students’ academic self-perception.

Results indicated that students with SLD scored higher on measures of self-perceived reading competence and self-perceived general intelligence after using the K-3000 software program. Students who had more severe SLD made more progress than those with less severe SLD, and, while there was no general trend indicating that more time spent using the software translate into higher scores on the measures of self-perception, those who scored highest on the measures had spent the most time using the software. Overall, the authors found that K-3000 software program may improve the academic self-perception of students with SLD, with greatest benefit accruing to students who used the software most and students with the most severe disabilities.

Conway and Amberson (2011) reported on the affective effects of widespread laptop use on students with SLD and their peers without disabilities in Ireland. The *Laptops Initiative* was an effort by the Irish government to provide laptops to students in several schools to establish best uses and practices for laptops to support students with dyslexia in inclusive environments in Irish schools. Thirty-one schools were provided with computers, and they used them in three ways: floating (laptops accessed only when needed), fixed (laptops present in classrooms and shared by students), and fostered deployment (each student had access to his or her “own” computer for the duration of the project). Students with disabilities and students without disabilities had equal access to the laptops. Data were collected through student focus groups, teacher and administrator interviews, school case studies, classroom observations, collection of student work, and surveys.

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Authors found that use of the laptops promoted student agency, responsibility and engagement when the laptops were included in structured, meaningful educational activities. Students took care of their laptops and were responsible with their use, and they focused greater attention on the learning activities as well as on activities specific to technology use, like choosing and setting backgrounds, etc. However, these benefits evaporated when the “laptops were used in a carrot and stick method by granting access to laptops in the classroom in an ad hoc way or as an occasional treat or reward” (Conway & Amberson, 2011, p. 178). The authors also found that use of laptops encouraged and increased commitment to student-centered and community based learning where students were seen as experts of the subject and of the computer technology. Particularly in schools with the fixed model, collaborative work, learning communities and peer review processes increased. Prior to the initiative, the most common approach to educating students with SLD was to pull them out of the general education classroom to receive instruction in a resource room. However, when everyone had equal access to laptops, special services for student with disabilities could be provided less conspicuously. As the authors observe:

Students may be asked to collect their laptop from the school library or some such location and bring it to a withdrawal (pull-out) support lesson, or the mainstream classroom; equally a number of laptops may be introduced to a large classroom for all students, either complementing or replacing withdrawal methods. In the latter situation the student with the specific literacy difficulties is wholly included in the lesson and becomes part of a community of learners. (Conway and Amberson, 2011, p. 179)

Overall, Conway and Amberson’s study of Ireland’s *Laptop Initiative* found that general distribution of laptops in schools—to students with and without disabilities alike—created no disruptions to the special instruction of students with SLD and increased the agency and learning opportunities of students with SLD as well as integrating them in the general community of learners.

Stetter and Hughes (2011) explored the extent to which a computer-based story mapping presentation was effective in improving reading comprehension for high school students. Nine students in a large urban high school in the United States participated in a single-subject, multiple-baseline study in which they were taught to use computer-based story maps to help them understand and remember class texts. All nine students were identified as having SLD in reading. During the baseline phase, students read stories and answered comprehension questions on computers. During the intervention stage they were taught to complete story maps which involved drop down menus indicating important story elements.

Results showed “little or no growth in students’ comprehension” (Setter & Hughes, 2001). Authors posited that the failure of the computer-based story map intervention may have been due to lack of motivation and attention on the part of the students, or to the fact that comprehension requires multiple strategies rather than just the one provided by the intervention in this study. They pointed out that “ultimately, it is the teacher who introduces and directs learning activities, increasing success for the student. The study at hand may have lacked sufficient teacher-led instruction in the reading comprehension strategy itself (Setter & Hughes, 2011, p. 96). The authors further considered the possibility that “the activity on the computer in the study at hand was too passive for the students, in that they only had to select the answer from a multiple-choice drop-down menu...the students in this study needed more interactions with the text and material.” (Setter & Hughes, 2011, p. 96). Overall, this study found that computer based story mapping was not an effective intervention for increasing reading comprehension.

Finally, Schmitt, McCallum, Rubinic, and Hawkins (2011) tested the effectiveness of reading pen technology in increasing comprehension in students with SLD. Participants were three high school students with SLD. The study was conducted in ten sessions across ten school days. During the control condition, students read passages and answered questions without using the reading pen. Investigators then explained the reading pen functions and checked for understanding. There were two intervention sessions. In the first, students used the reading pen with the definition function turned off so that students could use the reading pen only for help decoding words.

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In the second intervention session students used the reading pen with both the decoding and definition functions active so that students could use the pen both to help with decoding and to get the definitions of unfamiliar words. In each intervention session the students answered comprehension questions after reading the passage. Investigators measured the time spent reading the passage and the number of times reading pen functions were accessed as well as comprehension accuracy and comprehension rate in all three conditions.

Results indicated that students' comprehension accuracy and rates were lowest in the third intervention condition where students used both functions of the reading pen. Comparison between students' reading accuracy and rates in the first intervention condition, where students used the reading pen for decoding only, varied among participants indicating that both conditions were equally effective. Overall, authors found that "the comprehension accuracy and rates of the high school students in this study were generally negatively affected by access to reading pen accommodations" (Schmitt et al., 2011, p. 238). Authors posited that use of the reading pen distracted students from the text and disrupted reading fluency, and, consequently, interfered with comprehension.

Table 1
Summary of Study Findings

Cita- tion	Study design	Partici- pants	Age/ grade	Diagnosis	Interven- tion	Setting	Finding
Stetter & Hughes 2011	Multiple baseline single subject	9 students at large urban US high school	14-15 years	SLD reading	Computer Story Mapping	Pull-out in Com- puter Lab	Computer based story map was ineffective in increasing comprehen-sion

Table 1 Continued

Cita- tion	Study design	Partici- pants	Age/ grade	Diagnosis	Interven- tion	Setting	Finding
Hor- nickel et al. 2012	Between subjects matched control	38 stu- dents at private school for severe LD in US	8-14 years	SLD reading and/or writing	Personal FM System	Regular class- room	Individual FM systems improved phonological awareness and reading achievement

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Con-way & Amber-son 2011	Quali-tative observa-tion case study	840 stu-dents in 31 schools in Ireland	Grade 6-12	21% dyslexia 79% other reading Or writing difficul-ties	Laptop computers	Regular class-room and com-puter lab	General distribution of laptop computers increased agency, learning opportunity and integration
Igo et al. 2006	Explana-tory, sequential, mixed meth-ods	15 US middle school stu-dents	12-14 years	SLD (11), OHI (2) ED (2)	Web-based note taking tool	Regular class-room	Copy and pasting notes into computer generated framework was more effective than paraphrasing or writing
Schmitt et al. 2011	Within-subjects, alternating treatments	3 US high school Stu-dents	16-17 years	SLD	Reading-pen Advanced Edition (2006)	Quiet inner office con-ference room	Reading-pen's decoding function had no effect; decoding and vocabulary functions together decreased compehen-sion

Table 1 Continued

Citation	Study design	Partici-pants	Age/grade	Diag-nosis	Inter-vention	Setting	Finding
Unzue-ta & Barbeta 2012	Within subjects multiple baseline	4 US middle school stu-dents	12-13 years	SLD	Inspiration 8 (computer based graphic organizer)	Regular English Class-room	Computer based graphic organizer improved subjects writing in each of four categories
Boon et al.	Pre-test post-test	44 US high	Grade 10	27%SLD 13%ED	Inspira-tion 6	Regular social studies class-	Cognitive organizers improved performance

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2006	between subjects	school stu-dents		60% no diagnosis		room and com-puter lab	compared with control between pre-test and post- test and on post test
Boon etal. 2006	Pre-test post-test between subjects	49 US high school stu-dents	Grade 10	27% SLD 14% ED 59% no diagnosis	Inspira-tion 6	Regular social studies class-room and com-puter lab	Cognitive organizers improved performance compared with control between pre-test and post- test and on post test
Chiang & Jacobs 2009	Quasi-experimen-tal between subjects	50 US high school stu-dents	15 years	SLD	K-3000	Regular class-room and home	CBI might improve functional performance and self-perception

Table 1 Continued

Cita-tion	Study design	Partici-pants	Age/grade	Diag-nosis	Inter-vention	Setting	Finding
Lancas-ter et al. 2009	Between subjects pre-test/post-test	52 US middle school stu-dents and 60 US high school stu-dents	12-18 years	SLD	Test taking cd.	Com-puter lab	Computeriz-ed program is effective in teaching test taking strategy in a large group.

Discussion

Considering the wide range and large number of computer based products advertised as effective aids for students struggling with SLD, it is surprising that this search yielded only ten studies in the last ten years measuring the extent to which these products actually help students. In addition, most of the studies examined for this review have relatively few participants. One study (ten percent of total) had 840 participants, but all others had fewer than sixty, and three (thirty percent of total) had fewer than ten. However, the studies discussed in this review explore the effects of a wide variety of technologies. One study focused on reading pens, one on personal FM systems; one on laptops; one on web-based note taking tools; one on a computer based program for teaching test taking skills, one on a software with multiple applications for reading and writing support, and three on computer-based graphic organizers. Studies are about evenly split between participants in middle and high school and between male and female participants.

Articles examined for this review of literature indicate uneven effectiveness of technological interventions for students with SLD in reading and writing. Individual FM systems were found to be effective in helping students gain access to instruction without direct mediation by teachers. Computer-based cognitive organizers and a computer-based program to teach test taking skills were found to be effective in the studies that examined them when accompanied by significant teacher involvement. Laptops distributed to all students (those in general ed. as well as those in special ed.) and the K-3000 software were found to increase affective aspects of academic experiences such as self-perception and engagement. Findings of other technologies ranged from effective in certain contexts or with some reservations, to not effective at all over the course of the study, to actually decreasing student learning. Overall, the findings of these studies indicate that technology can be effective in enhancing the learning of students with reading and writing disabilities, but only in conjunction with teacher involvement and genuine student engagement. According to these studies, technology seems to be most effective in helping students organize thoughts for writing, in helping students learn some discrete skills, and in improving students' affective experience of academic study.

Five studies found that the technologies they examined increased academic success of students with SLD. Of these, one study (ten percent of total) was found to achieve this increase on its own, without teacher mediation of the technology, by making it possible for students to gain access to and process the instruction normally offered in the classroom. In a study of students in a private school for children with severe reading disabilities, Hornickle et al. found that wearing individual FM systems during instructional time improved signal to noise ratios for students. Consequently students improved scores on phonological processing and reading achievement.

Authors of the remaining studies in this successful group (four studies, forty percent of total) emphasized that technology increased success only with significant teacher involvement. Unzueta and Barbetta (2012) found that a computer based graphic organizer improved the students' persuasive writing and Boon et al. (2006a and 2006b) found that graphic organizers improved students' absorption and retention of information. In all three studies, the use of graphic organizers involved teacher involvement in training students how to use the organizers and how to choose and structure the information organized. Similarly, Lancaster et al. (2009) found that the *Test Taking Strategy CD* raised students' scores on simulated standardized tests and on tests of knowledge of the strategies presented and of metacognitive understanding, but only with significant teacher involvement.

Two studies (twenty percent of total) found that the technologies they studied improved students' subjective experience with school and academic work. Conway and Amberson (2011) found that giving all students (those with disabilities and those without) laptop computers enhanced the school and learning experiences of students with dyslexia.

This was the result of laptops' tendency to increase peer tutoring and collaborative learning as well as to make students with disabilities feel that they were typical members of the class—accessing technology as part of a group experience and not just because of their disability. Results of this study indicated that laptops allowed students with disabilities access to teachers' lessons in a way that makes students with disabilities feel included in the general curriculum. Students with SLD in Chiang and Jacobs's study indicated improved academic self-perception after completing school and class work using a learning support software.

One study (ten percent of total) found that the technology it focused on was effective only when used in such a way that it did not get in the way of the intended instruction. Igo et al. (2013) found that a web-based note taking tool was most effective when middle school students with learning disabilities took notes by cutting and pasting from a web page than when they typed notes or took notes by hand. Authors posited that this was the case because when students took notes by typing or writing by hand, rather than engaging with the text, they simply tried to copy notes verbatim from the source. When copying and pasting, students actually engaged more with the text by deciding what to copy. Also, later, when they revisited the notes, they had a better record of what the source had actually said.

Two studies (twenty percent of total) found technology to have neutral or detrimental effects on students' learning. Schmitt et al. (2011) found that a reading pen was ineffective in increasing high-school students' reading comprehension. With its most basic function (decoding) active, students using the pen scored about the same as they did without it on a measure of comprehension, and with the reading pen's more advanced function (decoding and defining) students scored lower on the comprehension measure than they scored without the reading pen. Authors suggested that the reason was that the definition function decreased student engagement with the text by making the student wait for the definition and shift attention from the train of thought followed by the text. Stetter and Hughes (2001) found that a story mapping software was no more effective than the control condition—that of reading the text online. Authors' explanation was that the computer story mapping was too passive and that it lacked the benefits of good teaching. Those benefits include a teacher's ability to motivate students and to engage students in the text they are reading and the subject they are studying. These last three studies emphasize the risk of applying technological solutions without ensuring that they are supported by effective, engaged teachers.

Limitations

Several limitations must be considered when considering the implications of this review. First, the review's scope of only ten studies might be too small to support sweeping conclusions with regard to the effectiveness of technology in the education of adolescents with SLD. Second, many of the studies themselves are small, most with fifty or fewer participants and several with fewer than ten. Finally, the studies represent a wide variety of study designs, some of which may not produce reliable results.

Implications for Practice

This review indicates that some technologies can have a positive effect on secondary students' academic performance. Teachers and parents of students with SLD (as well as the students themselves) can find empirical evidence in the literature of increase in students' knowledge, understanding and skills attributable to technology. In particular, personal FM systems gave students access to meaningful communications from their teachers; graphic organizers were effective in helping students apprehend and organize information presented in class and they helped students improve their persuasive writing, and computer based programs targeting specific skills helped students learn those skill. However, those seeking technological help for SLD's must be aware of a caveat also indicated by this review. Only one technology (personal FM systems) was effective on its own. The other successful technologies improved students' academic lives only in conjunction with significant teacher involvement.

For parents, teachers and students who are searching for products to improve students' affective experience of secondary school this study indicates that technology might provide an effective support.

Two multifaceted technologies (Laptops and Kurzweil-3000) improved students' engagement and academic self-perception. This suggests that technological solutions may confer a subjective benefit independent of increases in learning or performance.

This review also indicates a caveat for those searching for technological support for secondary students with SLD. Thirty percent of the studies found mixed results of the technology in question or indicated no benefit or negative effects. In light of these results, teachers, parents and students looking for support for students with SLD should be encouraged to seek out technological solutions. However, they should choose with caution, remembering that there is no silver bullet, technological or otherwise, for SLD and that most technological solutions are much more effective with teacher involvement.

Considerations for Future Research

In light of the burgeoning body of technology which purports to help students with SLD, much more research is needed to establish the extent to which specific products and general classes of technology are effective. Most of the products advertised as improving academic performance for students with SLD are relatively expensive, and it is important that families and school districts have empirical evidence based information to inform decisions to invest in them.

In addition, studies with more participants and more robust study designs are needed to strengthen results and findings. Larger studies would increase generalizability as well as validity and reliability of results. Small studies like many of those included in this review suffer not only from uncertainty regarding the extent to which they are representative, but also tend to lack diversity among participants. Randomized control studies clearly delineating the effects of the technologies in question would sharpen the edges between confounding and causal variables.

The need for studies that explore the relationship between technology, engagement/inclusion, self-perception and success for students with SLD is also indicated by this review. The two studies that focused on affective benefits of technology for students with SLD did so without exploring the more objective effects of the technology, for instance the extent to which it improved students' academic grades or scores on measures of academic achievement.

Finally, future studies might also take into account the rapidly increasing body of research into the neurological/biological bases of reading and writing disorders and address questions of how and why technologies succeed or fail based on the structural causes of the disorders. This approach might help consumers to identify products that most closely match their needs. In addition this approach would lend credence and specificity to results.

Conclusion

While the articles discussed in this review give a glimpse into the benefits and limitations of technology for students with SLD in reading and writing, they are disappointingly few in comparison to the hundreds of technological products aimed at helping students with SLD survive in the general education classroom. That said, these articles indicate that while technology holds promise for making it possible for students with SLD to learn, participate and feel comfortable and competent in the general education classroom, it does so in conjunction with good teaching, not independent of it.

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