TECHNOLOGY-BASED PRACTICES FOR SECONDARY STUDENTS WITH LEARNING DISABILITIES

Paula Maccini, Joseph Calvin Gagnon, and Charles A. Hughes

Abstract. The researchers conducted a comprehensive review of the literature on technology-based practices for secondary students identified as having learning disabilities (LD) involving instruction and/or assessment that measured some aspect of performance on a general education task or expectation (i.e., test). Technology-based practices included computer- or video-based interventions, multimedia programs, technology-based assessment, and verbatim audio recordings. Three practices appear promising for educating students with LD: (a) hypertext and hypermedia software programs; (b) videodisc instruction involving contextualized learning; and (c) multimedia software. Educational recommendations and directions for future research are offered based upon results.

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The use of technology is a vital and integral part of our society. Spurred by legislation, such as the Education for All Handicapped Children Act of 1986 (PL 99-457) that authorized research on the development of technological devices for individuals with special needs, technology is increasingly prevalent in our nation's schools across all levels and grades (Mathews, Pracek, & Olson, 2000). Teachers, for example, use technology as a vehicle for lesson development and implementation, and monitoring of student learning. Further, technology can be a valuable tool that promotes active student involvement in the learning process and assists students in accessing and organizing information.

Although beneficial for all students, technology has great potential for students with disabilities. Specifically, it may increase student access to the general education curriculum (U.S. Department of Education, 2000), academic achievement (Lock & Carlson, 2000), motivation (Mathews et al., 2000), and prosocial behaviors (Lock & Carlson, 2000). However, the impact of technology on secondary students with learning disabilities (LD) in the general education classroom has not been comprehensively reviewed. This analysis is crucial given that a majority of secondary students with LD are educated within the general education classroom (U.S. Department of Education, 2000), and are exposed to the curriculum of their nonhandicapped peers.

More than 80% of students with LD spend at least half of their day within general education settings (U.S. Department of Education, 2000). However, many secondary students with LD placed in the general education environment exhibit characteristics that impede their learning in such settings. For example, these students commonly experience difficulties with reading
comprehension, organizing, retaining and linking information to prior knowledge. In addition, students with LD rarely employ effective study strategies and notetaking skills, and do not take an active approach to academic tasks (Anderson-Inman, Knox-Quinn, & Horney, 1996). These students also demonstrate dismal educational and post-school outcomes. For example, 29.4% of students with LD exit school without a diploma (U.S. Department of Education, 2000). This percentage is greater than for any other disability classification, with the exception of students who are labeled with an emotional disorder (ED). Following school, students labeled LD are also less likely to attend postsecondary educational programs (25.6%), compared to youth in the general population (68.3%) (Wagner & Blackorby, 1996).

One promising approach to helping students with LD is the use of technology-based practices that include both technology-based assessment and interventions (Bender, 2001). According to Vergason and Anderegg (1997), technology-based intervention and assessment refers to using the computer or other expert systems as the medium to provide instruction and monitor student learning. Little is known about the impact of technology-based practices on the academic performance of adolescents with LD. Of specific interest is student success in meeting general education expectations (i.e., tasks and/or assessments). One related review (Hudson, Lignugaris-Kraft, & Miller, 1993) focused on all content enhancement interventions (e.g., advanced organizers, audio recordings, computer-assisted instruction) across settings for secondary students with LD up to 1991. Generally, Hudson et al. (1993) recommended a variety of content area enhancements related to effective teaching principles (i.e., activating prior knowledge, providing corrective and positive feedback) to increase student achievement. However, recent technological advancements warrant an updated analysis specifically of technology-based practices.

The purpose of this review was threefold: (a) to determine technology-based practices that appear promising for improving the performance of secondary students with LD on a general education task or assessment; (b) to review these practices relative to the instructional cycle and effective teaching variables; and (c) to provide recommendations for current practice and future research.

**METHODOLOGY**

**Criterion for Inclusion**

To be considered for inclusion in this review, studies must have met the following criteria: (a) targeted adolescents with LD (grades 6 through 12); (b) involved instruction and/or assessment that measured some aspect of performance (or at least one dependent variable) on a general education task; (c) been published in refereed journals that measured effects on students’ academic performance; and (d) included technology-based interventions or assessment formats as the independent variable.

**Search Procedures**

Search procedures consisted of three steps: (a) an electronic search in the Library Information Access System (LIAS) through the ERIC and PsychINFO systems; (b) a hand search of refereed journals published from 1970 through 2001; and (c) an ancestral search using the reference section of articles obtained through the above steps. The key descriptors for locating the articles included the following: learning disabilities, adolescents, middle school, high school, and secondary school.

Through these procedures, a total of 10 articles met the stated criteria and are included in the current review. The population and setting characteristics, study duration, and nature of intervention are described and presented in Table 1. A graduate student in special education conducted a reliability check on 100% (N = 250) of the variables coded (see Table 1); agreement was determined to be 97% (agreements divided by agreements plus disagreements, times 100).

**Effective Teaching Principles**

Each article in the current review was analyzed according to effective teaching principles, as noted in a previous review of the literature (see Hudson et al., 1993). These practices include the use of the instructional cycle and effective teaching variables. According to Hudson et al., the instructional cycle refers to “a structure for integrating effective teaching practices and content enhancement techniques in the delivery of instruction” (p. 106). As noted at the top of Table 2, these practices include the following components: (a) planning for instruction; (b) creating a learning set; (c) presenting content and guided practice; (d) providing independent student practice; and (e) assessing student knowledge. Relatedly, effective teaching variables are embedded within these phases of the instructional cycle, and a singular variable may be present in one or several phases of the instructional cycle. For example, some of the effective teaching variables associated with “assessing student knowledge” (i.e., monitoring student progress and making instructional decisions) are also present in “creating a learning set.”

**RESULTS**

In the sections that follow, technology-based practices involving computer-based interventions, assessment formats, and verbatim text recordings are described and
analyzed. The analysis within each section includes a description of the following: (a) population and setting characteristics; (b) study duration; and (c) nature of intervention procedure (e.g., videodisc, computer-assisted adaptations) involving inclusion of effective teaching variables within the instructional cycle and use of systematic instruction in technology (see Table 2). The nature of the intervention procedure also includes the effect size (ES) or magnitude of the treatment effect, Cohen’s $d = (M_1 - M_2)/SD_pooled$, where $M$ is the mean of group 1 or 2, and $SD_{pooled}$ equals the root mean squared of the two standard deviations (Cohen, 1988). The effect size (ES) is calculated to determine the “relative effectiveness” of a specific type of intervention and/or a comparison between methods (Forness, Kavale, Blum, & Lloyd, 1997, p. 4). The ES can be determined by comparing control group versus treatment group data and/or pretest and posttest comparisons. One or more ESs may be determined from a particular study, depending upon the characteristics of students, intervention variations, and number of effects investigated (Forness et al., 1997). Two studies (Higgins & Boone, 1990; Torgesen, Dahlem, & Greenstein, 1987, Experiments 1 & 2) did not include sufficient data to determine the ES.

**Population, Setting Characteristics, and Design**

A total of 389 secondary students participated in the studies targeted in the current review; 134 were labeled LD (see Table 1). The mean student age was 15.1 with a range from 12.8 to 15.5 years. Five studies did not report student age. Ten studies included high school students (grades 9-12) and one study involved both middle school and high school students (grades 7 and 10). Almost two-thirds of the participants were male ($N = 183$). Three studies did not report gender information. The number of participants per study ranged from 4 to 153. The three studies with the lowest number of participants employed a single-subject A-B-A design (Higgins & Boone, 1990), pretest-posttest design (Horton, Boone, & Lovitt, 1990), or a multi-element baseline design (Torgesen et al., 1987). Studies with larger sample sizes employed group designs to investigate treatment effects ($N = 7$) or an equivalent timesamples design ($N = 1$).

**Session Duration**

The number and duration of the instructional sessions varied among the studies (see Table 1). For example, the number of sessions ranged from two days to eight weeks and the length of sessions per day ranged from 13 minutes to 45 minutes. Over half of the lessons ($N = 7, 64\%$) lasted 30 minutes each. Three studies (Horton & Lovitt, 1994; Horton, Lovitt, & Slocum, 1988; Kelly, Carine, Gersten, & Grossen, 1986) did not report the number of sessions, and two studies (Horton et al., 1990; Torgesen et al., 1987) did not report session length.

**Nature of Intervention Procedure**

In the studies reviewed, researchers combined technology-based practices with other instructional interventions, including content enhancements, study guides, learning strategies, and various approaches to assessment. Six categories of technology-based practices are described in this section: (a) computer-assisted adaptations; (b) videodisc adaptations; (c) hypertext study guides; (d) hypermedia study guides; (e) assessment formats; and (f) verbatim text recordings.

**Computer-assisted adaptations.** In this review, computer-assisted adaptations refer to computer-based instructional tools or adaptations, such as map tutorials or study guides, that are implemented during lesson delivery to “mediate student understanding, storage, recall, and/or application of content” (Fisher, Schumaker, & Deshler, 1996, p. 132). Two studies in the present review focused on computer-assisted adaptations (Horton et al., 1988; Horton, Lovitt, Givens, & Nelson, 1989). For example, Horton et al. (1988) was the first research study to apply a computer program to teach geographic locations to secondary students with learning difficulties in the general education setting. The researchers compared the effects of a computerized map tutorial with another condition, wherein the participants used an atlas, a blank map, and a list of cities on which to focus. The study included two intact ninth-grade remedial world geography classes. The two classes consisted of 12 students with LD and 15 students considered remedial.

Each class completed a pretest that involved matching a blank map with a list of 32 cities throughout Asia. Because students experienced both interventions, the posttest for each used half of the pretest list of cities, minus the four cities most commonly answered correctly on the pretest. Following the pretest, the two interventions were implemented with the order counterbalanced between classrooms. The condition that centered on the use of an atlas required each participant to locate the 14 cities identified on a list within an atlas. Next the student was responsible for writing each city on a map and memorizing the location by covering up the city name, directing his/her attention to the point on the map where the city is located, saying the city name, and uncovering the city name to verify the verbalized answer. Participants were then allowed 15 minutes to complete the posttest in which 14 city names were matched with numbers on a blank map.

The computerized map tutorial was implemented following a pilot study in which participants used different content material to complete the same learning process. Within this intervention, participants were
Table 1
Analysis of Intervention Studies for Secondary Students with Learning Disabilities

<table>
<thead>
<tr>
<th>Study</th>
<th>N/C/G/A/GR</th>
<th>Setting and Duration</th>
<th>Research Design and Intervention</th>
<th>DV</th>
<th>Results</th>
<th>Maintenance/Generalization</th>
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<tbody>
<tr>
<td>Bottge &amp; Hasselbring, 1993</td>
<td>(36)</td>
<td>Math classes; 5 sessions, 40 min</td>
<td>Two-group design; Part 1: Videodisc computation intervention Part 2: Students assigned to contextualized problems on videodisc (CP) or instructed with series of word problems (WP)</td>
<td>Fractions computation and word problem: test (pre- and posttest). Transfer tasks: a video based contextualized problem and a text-based word problem.</td>
<td>Fractions computation test; intervention participants significantly increased scores. CP versus WP: both groups significantly improved performance on word problem posttests. CP group did significantly better than WP on the contextualized posttest and on the video transfer task.</td>
<td>M; G</td>
</tr>
<tr>
<td>Higgins &amp; Boone, 1990</td>
<td>(40)</td>
<td>Social studies classroom, computer lab; 10 sessions, 30 min</td>
<td>Three-group design; Exp. 1 Three conditions: (a) lecture; (b) lecture/computer study guide; or (c) computer study guide A-B-A design</td>
<td>Exp. 1: Multiple-choice test (pre-test, posttest, &amp; maintenance), daily quizzes.</td>
<td>Exp. 1: On posttest and retention measures, computer study guide treatment was as effective as the lecture condition for students with LD. Computer study guide treatment resulted in higher mean daily quiz scores. Mean posttest and retention scores for students with LD ranged from 47-63%.</td>
<td>M; —</td>
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<tr>
<td>Exp. 2 (5)</td>
<td></td>
<td>Computer lab; 10 sessions, 30 min</td>
<td>Exp. 2 Ten 30-minute computer study guide lessons</td>
<td>Exp. 2: Quizzes, class worksheets &amp; maps</td>
<td>Exp. 2: Students improved on posttest, but at least 80%. Retention scores variable.</td>
<td>M; —</td>
</tr>
<tr>
<td>Higgins, Boone, &amp; Lovitt, 1996</td>
<td>(25)</td>
<td>Social studies class, computer lab; 10 sessions, 30 min</td>
<td>Three-group design; Students randomly assigned to one of three groups: (a) lecture; (b) lecture/hypermedia study guide; or (c) hypermedia study guide. Each group given a 30-minute instructional period followed by a 10-minute multiple-choice quiz for 10 consecutive days</td>
<td>Daily quizzes, multiple-choice test (pretest, posttest, &amp; retention measures)</td>
<td>Students performed better on the retention test following the lecture/study guide condition than either lecture only or study guide only. Across both groups of students and conditions, students with LD obtained the highest mean percent on the retention test following the lecture/study guide condition.</td>
<td>M; —</td>
</tr>
<tr>
<td>Horton, Lovitt, &amp; Slocum, 1988</td>
<td>(27)</td>
<td>World geography classes, computer lab; —, 30 min</td>
<td>Two-group design; Two counterbalanced interventions: (a) students used an atlas to study/practice city locations; and (b) computerized map tutorial</td>
<td>Pretest: Students match location of cities with name. Posttest: Two posttests included randomly selected cities</td>
<td>For both students w/ LD and remedial classification, posttest scores (85% and 86%, respectively) favored the computerized map tutorial.</td>
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<table>
<thead>
<tr>
<th>Study Authors</th>
<th>Year</th>
<th>Methodology</th>
<th>Control Group</th>
<th>Experimental Group</th>
<th>Outcome Measures</th>
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<tr>
<td>Horton, Lovitt, Givens &amp; Nelson</td>
<td>1989</td>
<td>Three-group design</td>
<td>World geography classes, computer lab; 2 sessions, 30 min</td>
<td>Multiple-choice tests, survey of computer use, and preference of computer or text formats</td>
<td>Scores favored the computerized study guide over the notetaking condition for both students w/ LD and remedial students. Mean posttest scores for students with LD were 76% for computerized study guide and 42% for notetaking. 86% of participants preferred learning with a computer.</td>
</tr>
<tr>
<td>Horton, Boone &amp; Lovitt</td>
<td>1990</td>
<td>Pretest-posttest design; Students were seated at individual work stations and completed a hypertext study guide based on a reading passage. Following each passage and study guide, students completed a daily written test</td>
<td>Social studies class, computer lab; 3 sessions, —</td>
<td>Pretest, posttest, and retention tests, daily lesson tests</td>
<td>Significant gains for students from pretest to posttest. Significant gains also noted for maintenance measure on computerized problems.</td>
</tr>
<tr>
<td>Horton &amp; Lovitt</td>
<td>1994</td>
<td>Equivalent time-samples design;</td>
<td>MS science; MS social studies, HS social studies, computer lab (1 MS, 1 HS); —, 30 min</td>
<td>Multiple-choice tests</td>
<td>On factual questions, computer condition was favored overall; for interpretive questions no significant difference was found for the two methods.</td>
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<tr>
<td>Kelly, Camine, Gersten &amp; Grouwsen</td>
<td>1986</td>
<td>Two-group design; Thirty-minute videodisc lessons. Brief quiz (covering skills from previous lesson), lesson presentation, and a worksheet completed independently. Thirty-minute basal text lessons (i.e., introduction, teacher demonstration &amp; discussion, follow-up activities and a worksheet completed independently)</td>
<td>Math classes; —, 30 min</td>
<td>Screening tests, criterion-referenced (pretest, posttest, maintenance test), observation, independent seatwork, attitude questionnaire</td>
<td>Students receiving the videodisc curriculum scored significantly higher on both posttest and maintenance test. For both interventions, on-task behavior was above 80% and independent classwork was above 90%.</td>
</tr>
<tr>
<td>Kelly, Gersten &amp; Camine</td>
<td>1990</td>
<td>Two-group design; Instructional design curriculum: Each 45-minute lesson began w/ a brief quiz covering skills from previous lesson, lesson presentation, and 15 minutes for independent completion of a worksheet. A test was given every 5th lesson. Basal curriculum: introduction, instruction, guided practice, follow-up activities, and independent completion a worksheet. Review tests were given 2 times in the 10-day teaching unit</td>
<td>Math classes; 10 sessions, 45 min</td>
<td>Screening tests, criterion-referenced (pretest, posttest, observation, independent seatwork</td>
<td>Mean performance improved for both groups following intervention. Videodisc group scored significantly higher than the comparison group on the posttest (96% versus 82%).</td>
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Table 1 (continued)

Analysis of Intervention Studies for Secondary Students with Learning Disabilities

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| Torgesen, Dahlem, & Greenstein, 1987 | 16 LD; gr 9-12; 12M, 4F | Passage from American history, civics and/or health classes; 1 month, — | Multi-element baseline design:  
(a) read-only (i.e., students read the target text passages);  
(b) listen-only (i.e., students listened to a tape of the target passages); and  
(c) listen-read (i.e., students listened while reading the text passages) | Comprehension quiz scores | Exp. 1 | Students with LD performed better in the “read-listen” and “listen-only” conditions compared to the “read-only” condition. However, overall scores were variable among students with LD. |
| | | 6 weeks, 10 min | Exp. 2 | Students were tested following a week of text preparation on longer passages rather than after each session; treatment conditions consisted of “read and listen” and “read only” | — | — |
| | | 8 weeks, 13 min | Exp. 3 | Same as Exp. 2, plus worksheets | — | — |

Note. Dashes represent data that were not reported.

N/C/G/A/GR = number of participants, category, grade, age, gender  
gr = grade level  
MS = middle school  
HS = high school  
Duration = number of sessions, time per session  
min = minutes  
DV = dependent variable  
LD = learning disabilities  
BD = behavior disorder  
CP = computerized problems  
WP = word problems  
GO = graphic organizer  
AO = advance organizer  
sped = special education  
WISC-III = Wechsler Intelligence Scale for Children (3rd ed.)  
WAIS-R = Wechsler Adult Intelligence Scale – Revised  
WRMT-R = Woodcock Reading Mastery Tests – Revised  
DART-2 = Diagnostic Achievement Tests for Adolescents (2nd ed.)  
LASS:HS = Learning and Study Strategies Inventory (high school version)  
Exp = experiment  
M = maintenance  
G = generalization
given 30 minutes to complete the computer program as many times as possible. A four-stage sequence was maintained for each of the 14 cities: (a) a map of Asia appeared on the screen and an arrow with the name of a city on it pointed to the location of the city; (b) the arrow was removed and a box with the city name remained on the screen; (c) students moved the city name, using the mouse, to its appropriate location on the map; and (d) a correct response was indicated and the next city was listed. For incorrect responses, the sequence was repeated with the same city. Following 30 minutes of the computer tutorial, participants were given 15 minutes to complete a 14-item paper-and-pencil test. The assessment required students to match city names with the corresponding location on a map.

This four-stage sequence involved a number of effective teaching variables within the third phase of the instructional cycle, including: (a) a self-paced, sequenced approach to teaching city locations; (b) graphics (e.g., arrows and rectangles as prompts) to help focus student attention on the target locations; (c) repetition and cumulative review (i.e., each city was addressed four times within the instructional sequence); (d) corrective and positive feedback; and (e) reteaching, as necessary (e.g., repetition of the instructional sequence for incorrect responses). However, the program did not include a computerized assessment measure to monitor student progress, nor discrimination practice within the instructional set (nonexamples) to help build conceptual understanding.

For the students with LD in classes 1 and 2, a significant treatment effect was noted. These participants averaged 85% on the posttest for the computer intervention, with a mean $d$ value of 15.6. The atlas condition resulted in a mean of 19%, with a mean $d$ value of .9. Similarly, the students labeled remedial averaged 86% ($d = 6.4$) and 22% ($d = .7$) on the posttests for the two interventions, respectively. In addition, no significant difference between the two groups within each treatment condition was noted. Although the data indicated the effectiveness of the computer condition, generalization of the results was limited to similar tasks.

Another study (Horton et al., 1989) compared the effects of a computerized study guide with a notetaking intervention on the comprehension of ninth-grade students labeled either remedial or LD. Two classes of a world geography course participated in the study. The intervention group included 10 students described as remedial and nine identified as having a learning disability. The comparison group was comprised of eight students labeled remedial and nine students identified as LD.

The two experimental classes participated in both the computerized study guide and notetaking interventions, with the order of the treatments counterbalanced. The notetaking intervention consisted of a three-step process for students: (a) reading a passage as many times as possible in 15 minutes; (b) taking notes in any way they chose for 15 minutes; and (c) completing a 15-item multiple-choice test. In contrast, following an initial computer orientation, the computerized study guide condition consisted of four components: (a) reading a selected text as many times as possible for 15 minutes; (b) responding silently to study guide questions for a minimum of two times and a maximum of 15 minutes; (c) completing a 15-item multiple-choice test; and (d) receiving a hard copy of the test with teacher corrections. Although the teachers' corrections could not have affected students' scores within the study, the importance of teacher feedback within the instructional process necessitates its notation. Though the self-paced program offered many opportunities for students to respond within the third phase of the instructional cycle, the CAI program did not provide feedback (i.e., an error analysis of test questions).

No significant difference existed within the average performance of students labeled remedial and those with LD within the treatment conditions. However, within the computerized study guide intervention, both classes of participants significantly outperformed the comparison group, with a mean effect size of $d = 2.8$ for students with LD and $d = 1.2$ for remedial students. In contrast, within the notetaking intervention, only the students labeled remedial scored significantly better than the comparison group. Despite the improvements of the treatment groups, the mean posttest scores for the students with LD was 76% for the computerized study guide and 42% for the notetaking interventions. Similarly, the students considered remedial averaged 77% with the computerized study guide and 58% within the notetaking condition. Such low averages would indicate some limitations within both interventions and suggest the need to combine them with other adaptations (e.g., computer-based feedback). In addition, concerns exist due to the brevity of the study. Because each intervention occurred within only one class period, the effects of long-term implementation are unknown and therefore affect generalization of these results.

**Videodisc adaptations.** Three studies in the present review focused on videodisc adaptations (Bottge & Hasselbring, 1993; Kelly et al., 1986; Kelly, Gersten, & Carnine, 1990). Specifically, Kelly et al. (1986) compared a basal program and a videodisc program to assess the comparative effects of the latter program's instructional design features on student performance. The videodisc medium was utilized within the Mastering Fractions program (Systems Impact, 1985). The researchers noted a
previous study (Hasselbring, Sherwood, & Bransford, 1986) supporting their assertion that the features of instructional design, rather than the particular medium, directly affect student performance. Based upon this assertion, the study focused on the differing instructional design features of the basal and Mastering Fractions programs. Specifically, the comparison involved four instructional design features subsidiary to the "instructional planning" phase of the instructional cycle (review procedures, discrimination practice, example selection, explicit strategy teaching) (Kelly et al., 1986). Kelly et al. (1986) selected key activity structures when designing the fractions curriculum prior to lesson delivery. For example, the fractions videodisc program included discrimination between commonly confused concepts (e.g., adding and multiplying fractions) and the separation of potentially confusing terms (introducing numerator and denominator on different lessons). Many effective teaching variables were embedded within the phases of the instructional cycle, such as: (a) reviewing previously learned skills via a short quiz, (b) explaining the skill/concept in small steps at a brisk pace, (c) providing frequent feedback, (d) providing guided and independent practice with a wide range of examples, and (e) providing successful practice before advancing to a new skill.

Students with LD and nonlabeled students were selected from two high school math classes (i.e., remedial math, general math) and randomly assigned to either the basal program or videodisc instruction. However, the number of students with LD in the final sample was unclear. Pre-, post-, and maintenance criterion referenced tests were used to assess acquisition of skills. In addition, academic engagement and work completion were assessed through formal observation. This provided data to evaluate student success and conduct an error analysis. Additionally, a student questionnaire was used to assess student attitudes toward the math programs.

The results of the study indicated a significant difference between the pretest and both posttest (d = 1.1) and maintenance scores (d = 2.1) for the videodisc intervention. While the videodisc intervention had a significantly higher on-task rate than the basal program, for both interventions the student on-task percentage was above 80%. Similarly, success rates on independent classwork were above 90% for both interventions. An error analysis also provided support for the videodisc curriculum. For example, within the basal program, which did not couple the instruction of fractions less than one with improper fractions, the error rate for identification of diagrams representing fractions was much lower than for students who experienced the videodisc instruction.

Utilizing the Mastering Fractions program (Systems Impact, 1985), as described above, Kelly et al. (1990) investigated the effects of the instructional design principles (see Table 2) with high school students in remedial and general math classes. The participants included 17 students with LD. Similar to the previous study (Kelly et al., 1986), the researchers embedded effective teaching variables into the instructional sequence. These variables included review, teacher modeling, guided practice, feedback, independent practice, and wide range of examples.

Students were randomly assigned to the treatment condition involving curriculum design variables or to the control group consisting of basal math instruction. While the mean performance improved for both groups, students in the treatment group scored significantly higher than the comparison group, 96% versus 82% (d = 1.3), made fewer errors, such as not confusing terms (d = .6), discriminating between algorithms (d = 1.2), and solving a range of examples (d = 2.1). Thus, the curriculum program with effective design variables was significantly more successful than basal instruction.

Bottge and Hasselbring (1993) used the same videodisc program to examine its effectiveness for teaching addition and subtraction of fractions. Additionally, they investigated whether the program helped students generalize their fraction skills to contextualized word problems. The study was conducted within two remedial math classes in which approximately half of the students were labeled LD and half were described as at-risk. Within the first part of the intervention, researchers completed an error analysis of pretest scores to choose specific chapters (i.e., renaming and simplifying fractions) within the Mastering Fractions (Systems Impact, 1985) program. A fraction computation test, word problem test, and a video problem test (wherein students solved several problems based upon information embedded in an 8-minute video) were used as pre- and posttest measures for the students in the remedial classes. In addition, the assessments were administered to all other 9- to 12-grade students at the school in general and pre-algebra classes at the onset of the study.

The five-day intervention required the students to view the videodisc, respond to the information and questions verbally or in writing, and complete workbook pages. The results of the fractions computation test indicated that on calculation problems, students participating in the intervention significantly increased their level of achievement and obtained scores almost on par with the students in the comparison group. However, the pre-algebra students scored significantly higher than the students labeled remedial on the word problem test.
Following this initial five-day intervention, participants were paired by scores on the fractions computation test and randomly selected to participate in either contextualized or word problem groups. Through this process, four instructional groups were created. Over the five-day contextualized problem-solving instructional condition, participants viewed a video several times, identified the central problems and subproblems, completed worksheets, discussed approaches to solving the problems, and considered various approaches when the problems were altered slightly by the teacher. Similar to Kelly et al. (1986, 1990), the videodisc program lessons incorporated all the effective instructional principles recommended by Rosenshine and Stevens (1986): (a) review; (b) presentation of new concepts or skills; (c) guided practice and formative assessment; (d) feedback, correctives, and reteaching as needed; (e) independent practice; and (f) weekly and monthly review.

The word problem intervention maintained a consistent routine during each of the five days. A participant read aloud the problem from an overhead projector and the class identified relevant and extraneous information. After identifying the operations to be employed, each student computed the answer. Independent practice on worksheets followed. When comparing the two types of problem-solving instruction, the results of the video test indicated that students in the contextualized problem-solving instructional condition scored significantly better than those in the word problem intervention (d = 1.1). However, both groups improved significantly on the word problem test (d = .1). Further, on a maintenance measure, the students in the contextualized problem-solving instructional condition significantly outperformed the word problem students on a video problem (d = 1.1).

**Hypertext study guides.** Hypertext software is considered "a generic term for high level software which allows learners to interact with information in a non-linear fashion" (Horton et al., 1990, p. 119). Two studies in the present review focused on hypertext software involving study guides (Higgins & Boone, 1990; Horton et al., 1990). Specifically, Horton et al. investigated the effects of a hypertext software program designed to teach social studies content. Four students labeled LD enrolled in a remedial social studies class participated in the study. Each lesson included four "layers" of text. If a student answered incorrectly, the amount of extraneous information was reduced from the passage until, at the final stage, the answer was provided. In addition to providing computerized feedback and corrections, the program included the following effective teaching principles: (a) three self-paced study guide lessons; (b) access to definitions and further information via enhancements; (c) positive feedback (e.g., computer replied, "That was correct" following correct responses); and (d) numerous opportunities for student responses. Researchers determined significant treatment gains from pretest measures to the posttest on multiple-choice comprehension questions for both the computer (d = 4.3) and the control conditions (d = 1.1). Further, significant gains were noted on a maintenance measure (d = 6.1) given 30 days following the intervention with computer-presented problems, but not with "control" (noncomputerized) problems when comparing the computer versus control group scores.

Higgins and Boone (1990) also researched the effects of hypertext study guides with secondary students in social studies classes via a two-part study. In the first experiment, 40 students, including 10 students with LD, participated in one of three treatment conditions (a) lecture, (b) lecture/computer study guides, or (c) computer study guides. The hypertext software included different "layering" cues starting with a top layer of original text, and followed by subsequent layers with additional cues (e.g., definitions, tutorial strategies, and graphics). These were accessed when students clicked on highlighted words throughout the text. As Higgins and Boone noted, "The hypertext lessons provided the students with access to special enhancements within a single, familiar context. This differs from traditional CAI, which often presents lessons on isolated skills not specifically related to textbook content or the teacher's instructional style" (p. 531). The study consisted of four phases: (a) computer training; (b) a pilot study; (c) intervention with three conditions; and (d) posttest and maintenance assessments. During phase three, students from three history classes were randomly assigned to one of the treatment conditions, each of which included 30 minutes of instruction and an assessment measure. The lecture condition involved: (a) teacher lecture and student notetaking; (b) a reading passage and review worksheet; and (c) quiz (closed-book). The lecture/computer study guide condition included the same steps as the lecture condition, except students reviewed the information with hypertext software rather than the worksheet. Finally, the computer-only condition included 30 minutes of hypertext software review prior to the quiz.

Based on daily quiz scores, researchers determined that students in both the computer study guide and the lecture/computer study guide conditions performed as well as students in the teacher-instruction condition. Further, students in the computer study guide condition achieved a higher mean average on posttest and retention measures. However, the mean scores for students with LD were well below the 80% acceptability range, regardless of condition (range of 47%-63% for posttest and retention). The unit test served as a posttest
following the 10-day intervention and as a maintenance check two weeks following the intervention. Consequently, students may have been “sensitized” to the questions, resulting in “carry-over” effects.

The five lowest performing students in the first experiment (Higgins & Boone, 1990) were chosen to participate in experiment two with two additional students labeled LD. Students completed an intervention, which consisted of teacher assistance with the hypertext software. Instructional procedures and assessment measures were the same as in experiment one. Though all students performed better on posttest measures, none achieved mean percentages of at least 80%. Further, retention scores were variable.

**Hypermedia study guides.** Similar to earlier studies focused on hypertext software, Higgins, Boone, and Lovitt (1996) researched the effects of hypertext study guides. Unlike the hypertext programs, hypermedia study guides included other text enhancements, such as graphics, digital videos, and sound enhancements. They also included a “nonlinear” format so that students could “branch out” or access various computer-based resources to gather more information about the lesson (Bender, 2001). As in an earlier study (Higgins & Boone, 1990), students were randomly assigned to lecture, lecture/computer study guide, or computer study guide conditions. Two chapters of social studies were used for the study guides with 25 students, 13 of whom had a learning disability. Additional information was accessible to students, especially within the context of “presenting new material” or “independent practice” of the instructional cycle. For example, within the hypermedia presentations, students could access “enhancements” (underlined words/paragraphs) to obtain additional information or boldfaced words to obtain word replacements. The hypermedia presentations also included a control-based measure that rerouted students back to the text if the question was answered incorrectly or advanced students to the next page following a correct response. The hypertext study guides were determined to be more effective following teacher-led instruction, as a review during “guided practice” or independent practice for additional practice. The retention of information for students with LD improved when information was accessed from an “enhancement” or note. In addition, the self-paced nature of the program allowed students to work on the study guide activities as many times as needed, while providing students with positive and corrective feedback. In terms of systematic instruction in technology, the students received computer training on operating the computer and working with the hypermedia study guides during two, 1-hour workshops.

Student response to three types of questions was coded for analysis: (a) factual (explicitly stated information from the passage); (b) inferential (implicitly presented information); and (c) note information (information available from pop-up text). Assessment measures included daily quizzes, and a pretest, posttest, and retention measure developed from the daily quizzes. Students with LD performed higher on factual, inferential, and note questions in the lecture/study guide condition (79%, 73%, and 90%, respectively) compared to the other treatments. Further, remedial students achieved comparable mean scores in the lecture/hypermedia condition. Across groups and conditions, students with LD obtained the highest mean percent correct on a retention test (81%) in the lecture/study guide condition \((d = .6)\). As the authors stated, future research should include larger group sizes to aid treatment generalization, as well as determining in what situations hypermedia study guides would benefit students the most in the instructional process (i.e., before teacher lecture, following lecture, etc.).

**Computer-based assessment formats.** According to Greenwood and Rieth (1996), “Technology-based assessment generally refers to the use of electronic systems and software to assess and evaluate the progress of individual children in educational settings” (p. 279). One study in the current review used computer-based assessment (Horton & Lovitt, 1994). Specifically, two different types of group reading inventories (computer-based and paper-and-pencil format) were administered to 72 students in secondary general education science and social studies classes, including 13 students with LD. Two middle school science, two middle school social studies, and two high school social studies classes participated in the study. One class from each content area and grade level was assigned to either control \((N = 77)\) or experimental conditions. The computer-based assessment condition involved students: (a) reading textbook passages on the computer screen; (b) reviewing the passage while completing a study guide worksheet; (c) reviewing the answers on the study guide for quiz preparation; and (d) taking a computer-based quiz. The paper-and-pencil assessment involved the same steps, except the passage was presented via text format and the quiz was completed with a paper and pencil. Students in the control condition were exposed to the same procedures, with the exception of the study guide component. Researchers employed an equivalent time-samples design in which each assessment condition was randomly assigned to each experimental and control group on four occasions per assessment measure. Researchers determined that, overall, students performed better on factual-based questions via the computer condition with no differences obtained between assessment conditions on more interpretive type questions \((d = .1\) for students with LD, \(d = .2\) for normally achieving students).
However, these results should be interpreted with caution due to the variations within the two assessment methods. In order to isolate the effects of the two methods, the text format during the initial reading of the passage should be the same across conditions (i.e., text-based or computer-based).

**Verbatim Text Recordings**

Torgesen et al. (1987) conducted three experiments on the effects of verbatim text recordings or text information that was available to students in auditory format. Generally, the procedures consisted of two components: (a) presentation of text passages; and (b) assessment of overall text comprehension. In the first experiment, 16 high school students with LD were exposed to three treatment conditions over a month that covered text passages from general education history or health classes. Participants were exposed to each condition six times. The three conditions involved: (a) “read only” (i.e., students read the target text passages); (b) “listen only” (i.e., students listened to a tape of the target passages); and (c) “listen-read” (i.e., students listened while reading the text passages). After each condition, students were administered a comprehension test and awarded points for correct answers. It was determined that students with LD performed better in the “read-listen” and “listen-only” conditions than the “read-only” condition, as evidenced by higher mean comprehension scores. However, overall scores in the “read-listen” condition were variable among students with LD. Researchers also noted a high correlation (.7) between full-scale IQ and the performance in the read-listen treatment. Although students with higher IQ scores (i.e., 85 or higher) demonstrated gains similar to those of their nonhandicapped peers, the overall mean (69%) was below the stated criterion of 80%.

In Experiment 2, treatment conditions remained the same as in Experiment 1 with the following exceptions: (a) students were tested following a week of text preparation on longer passages, rather than after each session; and (b) treatment conditions consisted of “listen-read” and “read only.” Sixteen students with LD participated in the six-week intervention. Compared to the results of the previous study, the use of “listen-read” was not as effective for more extensive material over a longer period of time. However, the overall mean scores in both conditions were low (37% for the read-only, 36% for read-listen).

Treatment conditions and subjects remained the same between Experiments 2 and 3. However, in Experiment 3, worksheets (i.e., true-false, short answer, and fill-in-the-blank questions based on highlighted text) were used to determine the effects of this study aid. Similar to Experiments 1 and 2, student performance was noted as variable. However, participants in the “read-listen” and worksheet condition scored higher, with a mean of 51.4% versus 39.7% in the “read only” condition (d = .9). As noted by the researchers, however, the higher mean performance in the “read-listen” condition was still below an acceptable criterion.

In terms of effective teaching practices, the verbatim text recordings were implemented to present new content information as part of the instructional cycle in the three experiments. Further, in Experiment 3, additional supports were added to the presentation of the material, such as worksheets and texts with color-coded features or “structural signals” to highlight important content information from the passages during the presentation of the new materials within the instructional cycle. As the intervention effects were variable, the researchers cautioned that students with LD will need additional support to learn content area instruction, such as teacher-led reviews. For example, Torgesen et al. (1987) noted, “the use of auditory supplements and worksheets should be regarded as a substitute only for normal text reading activities” (p. 38). Furthermore, instruction of how to teach students to use the tapes was not given in all three experiments. Future research should examine the effectiveness of systematic instruction in teaching students to use verbatim text recordings in content area classrooms and its effectiveness as one component of the instructional cycle.

**DISCUSSION**

The purpose of this review was to extend a previous literature review (Hudson et al., 1993) focusing exclusively on technology-based instruction and assessment practices designed to improve the performance of secondary students with LD on general education tasks and/or assessments. The authors analyzed relevant literature to determine: (a) use of effective teaching practices within each study’s instructional cycle; (b) promising technology-based practices; and subsequently (c) make recommendations for current practice and future research. Many technology-based practices yielded mixed, but promising results for assisting students with LD in meeting general education expectations. Nine studies reported significant improvement for students in computer-based versus noncomputer-based interventions. Specifically, the effect sizes were mostly significant across the following categories: (a) computer-assisted instruction (range of d = 1.2 to d = 15.6); (b) videodisc instruction (range of d = .1 to d = 2.1); (c) hypertext study guides (range of d = 4.3 to d = 6.1); (d) hypermedia study guides (d = .6); and (e) verbatim text recordings (d = .9).

Further, technology-based practices were effective in increasing student comprehension, retention of
### Table 2
Effective Teaching and Curricular Design Variables

<table>
<thead>
<tr>
<th>Program Type</th>
<th>Instructional Planning</th>
<th>Learning Set</th>
<th>Presentation of New Material/GP</th>
<th>Independent Practice</th>
<th>Assessment</th>
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<td>Corresponding Effective Teaching Principles</td>
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<td>Hypermedia Study Guides</td>
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<td>Torgesen, Dahlem, &amp; Greenstein (1987)</td>
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<td>Computer-Based Assessment Forms</td>
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<td>Bottge &amp; Hasselbring</td>
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<td>Kelly, Carnine, Gersten, &amp; Grossen (1986)</td>
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<td>Kelly, Gersten, &amp; Carnine (1990)</td>
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Note: CAI = computer-assisted instruction; GP = guided practice.
important facts, calculations, and completion of word problems. Additionally, all studies (N = 5) that involved CAI, hypertext study guides, and hypermedia study guides embodied effective teaching principles, predominantly within the third phase (i.e., presentation of new material/guided practice) of the instructional cycle. Use of effective teaching principles is consistent with recommendations by Komoski (1995) and Rekruit (1999), who offered suggestions for selecting and implementing technology-based practices for students with special needs. For example, when selecting and implementing technology-based practices, such as the Internet, general recommendations for teachers include: (a) examining the instructional goals and determining Internet-based website(s) that provide both a rich source of data and an effective medium for meeting students’ instructional goals; (b) integrating technology-based lessons into the general curriculum, as appropriate; (c) linking student characteristics and needs to the technology and monitoring student difficulty (i.e., with confusing and/or complex websites, difficult vocabulary); (d) developing instructional objectives and integrating a written assignment for each Internet-based lesson or session; and (e) assisting students with sharing their research findings and with evaluating their Internet use (Komaski, 1995; Rekruit, 1999).

Overall, the results of technology-based interventions are promising. However, they must be viewed in light of four important limitations: (a) the relatively few studies reviewed; (b) the level of student proficiency following intervention; (c) the lack of maintenance checks and generalization measures; and (d) the limited number of content areas studied. Specifically, the current review was limited to published research and a small sample size (N = 10); only one study dealt with the effectiveness of technology-based assessment. Further, as the ES for computer-based assessment was only .1, more research is needed to determine if computer-based formats are more effective than traditional paper-and-pencil formats. Also, in three of the studies, students did not improve to mastery levels. For example, socially validated gains are in question when pretest lecture/computer study guide scores are 34% and posttest scores are 47% for students with LD (Higgins & Boone, 1990). In addition, methodological issues must be addressed. For example, in the present review, only 46% of the studies (N = 6) included maintenance checks. Additionally, only one study included some form of generalization measure. It is imperative that researchers consider the effectiveness of an intervention over time and across settings. Also, available information was limited related to the effectiveness of technology-based instruction across content areas. In the present review, the majority of the studies (63%, N = 7) focused on social studies content. Three other studies (27%) involved technology-based math interventions, and only one focused on science or health content. As a majority of secondary students with LD are educated within the general education classroom (U.S. Department of Education, 2000), future studies should include technology-based interventions within a variety of content areas.

Despite these limitations, several significant results were obtained, indicating that technology-based interventions are an important technique for educators of students with LD to improve student performance on general education expectations. For example, researchers determined that use of hypertext study guides (Higgins & Boone, 1990; Horton et al., 1990), hypermedia study guides (Higgins et al., 1996), and computerized study guides (Horton et al., 1989) were effective in improving student comprehension. This is an important finding given the difficulties students with LD often experience with reading comprehension and researchers’ (Hallahan, Kauffman, & Lloyd, 1985) notation that 85% of students with LD may have a reading disability. Further, all of these studies (CAI, hypertext study guides, and hypermedia study guides) embodied common effective teaching principles predominantly within the third phase of the instructional cycle, such as self-paced, sequenced computer-based lessons; enhancements or notes to obtain related information; corrective and positive feedback; numerous opportunities for student responses; and reteaching or rerouting students back to previous lessons. In addition, Botte and Hasselbring (1993) embedded mathematics concepts and skills into real-world problem-solving tasks. Students in this condition showed significant gains and also generalized to another contextualized problem-solving situation. Further, Kelly et al. (1986) determined that incorporating effective instructional design variables helped to reduce student confusion and mathematical errors with fractional concepts. However, as technology advances, more information is needed on "the integration of the hypermedia software into the instructional process ..." (Higgins et al., 1996, p. 411), particularly within other phases of the instructional cycle (i.e., independent practice, assessment).

In terms of systematic instruction in the use of the technology, 50% of the studies included some type of instruction on how to operate the computer program prior to the onset of the intervention (Higgins et al., 1996; Horton et al., 1988; Horton et al., 1989; Horton et al., 1990). For example, Higgins et al. (1996) included two training sessions on computer operation and how to "navigate" through use of the hypermedia study guides prior to intervention. However, it is of concern that half the studies did not include or describe some
type of systematic instruction on the use of technology, as "the most powerful technology is worthless if its operation cannot be mastered" (Lewis, 1998, p. 23). Thus, there is a need to include systematic instruction in technology so that students know how to use the technology as well as strategies to enhance its effectiveness (McNaughton, Hughes, & Ofishe, 1997).

**Educational Recommendations**

Based on the summary and analysis of the studies in the present review, some recommendations for instruction are emerging.

1. Implement hypermedia, hypertext, and computerized study guides to aid student comprehension of social studies text (Higgins et al., 1996; Horton et al., 1990). According to Lewis (1998), "these programs offer more opportunities than traditional, linear software for interactions between the learner and the text. This capacity for enhancing the quantity and quality of interactions may have particular value for individuals with learning disabilities, a group that has been described as passive learners" (p. 21).

2. Continue to incorporate effective instructional practices within the instructional cycle (e.g., varying cues/amounts of information per text "layer," providing immediate and corrective feedback) with hyper/multimedia and other forms of emerging technology for students labeled LD in secondary general education settings (Higgins et al., 1996; Higgins & Boone, 1990; Horton et al., 1990).

3. Program for systematic instruction in the use of technology to help students: (a) operate the technology-based system; and (b) learn to navigate through hypermedia systems.

4. Use videodisc-based instruction embedded in real-world problem-solving situations to promote generalization (Bottge & Hasselbring, 1993).

5. Incorporate effective instructional design variables within computer-based instruction to reduce student confusion and mathematical errors. For example, computer software should incorporate a wide range of examples and nonexamples for discrimination practice and generalization and pictorial representations to enhance concept development (Kelly et al., 1986; Kelly et al., 1990).

**Technological Advances and Education**

In addition to these implications, many questions remain. Future research should examine the effects of existing and state-of-the-art technologies on student achievement (Bender, 2001). For example, use of word processors has become commonplace, yet little is known about the effects this technology has on the academic achievement of secondary students with LD on general education tasks and/or assessments. In addition, there is a critical need for research on state-of-the-art technology. As laptop computers become more popular and less expensive, questions arise as to their possible benefits in assisting student organization, notetaking, and studying. Also, significant advances are occurring with graphing calculators, and teachers are expected to keep pace with the possible uses of this state-of-the-art technology (Maccini & Gagnon, 2000; NCTM, 2000). Further, as national standards (NCTM, 2000) emphasize the need to develop problem-solving skills, research in the area of problem-solving development and the use of technology may lead to better understanding of how technology can be used to assist students with LD in general education classrooms.

The effects of multimedia on the achievement of secondary students with LD in general education classrooms should also be explored. Multimedia is an extension of hypertext and hypermedia programs and includes text-enhancing features and a broad range of media programs to illustrate topics (e.g., movies, video presentations, audio playback systems, and other graphics) (Bender, 2001). Though research is limited, researchers (Bender, 2001) assert that great potential exists for students with LD, given the self-paced and high-interest characteristics of multimedia. For example, it would be interesting to determine the effects of "virtual environments" (i.e., real-world simulations via three-dimensional models) on student achievement and motivation to learn. As Mathews et al. (2000) conjectured, "imagine students being able to move around the inside of the space shuttle and the excitement they would feel as the countdown begins" (p. 346). Specifically, future investigations could include a comparison of student-directed multimedia research via Internet websites versus traditional library research, as measured by the number of research-based details in student assignments. Future research should also explore the shift toward more Internet-based activities and lessons, as opposed to computer software programs (Guptill, 2000). The Internet provides a rich data source (i.e., virtual tours, tutors on line, electronic dictionaries, movies, and music) that shows promise for improving student learning and motivation to learn.

**Conclusions**

The use of technology-based interventions shows great promise for improving the academic performance of students with LD on general education expectations. In the present review, technology-based practices with statistical and functional significance incorporated a variety of effective teaching principles within the five-stage instructional cycle to increase student acquisition and retention of tasks. Although "disabilities can impose barriers to full participation in school, at work,
and in other important areas of life, assistive technology offers ways to surmount those barriers" (Lewis, 1998, p. 17). Now, more than ever, technology is a valuable tool with great potential for assisting students labeled LD.

REFERENCES


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