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ABSTRACT

This final report discusses the outcomes of a 3-year project that studied the effectiveness of word processing tools in improving the literacy skills of students with learning disabilities in grades 4-12. In Year 1 (1994-95), four text entry strategies were compared in 132 students with learning disabilities: keyboarding instruction, alternative keyboards, word prediction, and word prediction with speech synthesizers. The Year 2 study (1995-96), investigated the effects of two types of text editing tools, such as spelling and grammar aids with and without speech synthesis, in 106 students with learning disabilities. The Year 3 study (1996-97), investigated speech synthesis under three conditions in 103 students with learning disabilities: when available at all times versus when available only during the text entry or the editing/revising stages of writing. Results of the studies found: (1) that word processing had the most impact upon the accuracy of students' writing; (2) word prediction was the most promising strategy for improving the text entry speed; (3) spell checks were effective editing tools, although grammar checkers were not, and spell checks had a more positive effect on students' writing quality and accuracy than synthesized speech. (Contains 35 references.) (CR)

FINAL REPORT

Enhancing the Writing Skills of Students with Learning Disabilities Through Technology: An Investigation of the Effects of Text Entry Tools, Editing Tools, and Speech Synthesis

Submitted to
the U. S. Department of Education,
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INTRODUCTION

Project Overview

"Enhancing the Writing Skills of Students with Learning Disabilities Through Technology: An Investigation of the Effects of Text Entry Tools, Editing Tools, and Speech Synthesis" was funded under the Research Projects That Promote Literacy competition of the Technology, Educational Media, and Materials for Individuals with Disabilities Program, Office of Special Education Programs.

The purpose of this three-year project was to study the effectiveness of one set of technologies -- word processing tools -- in improving the literacy skills of students with learning disabilities. Word processing tools include speech synthesis, text entry tools such as word prediction, and editing tools such as spelling and grammar aids. The major research question of interest was whether tools such as these increase the writing speed, quantity, quality, and accuracy of students with learning disabilities and their attitudes toward the writing process. Separate pretest-posttest control group experimental studies were conducted in each year of the project. In Year 1 (1994-1995), four text entry strategies were compared: keyboarding instruction, alternative keyboards, word prediction, and word prediction with speech synthesis. The Year 2 study, conducted in 1995-1996, investigated the effects of two types of text editing tools, spelling and grammar aids, with and without speech synthesis. The Year 3 study, conducted in 1996-1997, investigated speech synthesis under three conditions: when available at all times versus when available only during the text entry or the editing/revising stages of writing.

Organization of the Final Report

All of the goals and objectives of the Enhancing Writing Skills Project were accomplished, and the purpose of this Final Report is to present the findings of the three studies conducted during the project period. The report is divided into several sections. The first section presents an overview of the rationale underlying the project. The next three sections describe the three studies with information about the purpose and design of each study, methodology, results, and conclusions. The next major section presents overall conclusions from the three studies and recommendations for practitioners. Last

is a description of the strategies used to disseminate project activities and results.

Rationale for the Project

Students with learning disabilities are characterized by the difficulties they encounter in acquiring and applying literacy skills. In written expression, they experience problems across all stages of the writing process. These problems are typically both severe and persistent; they include low productivity, poor handwriting and spelling skills, and difficulties in planning, organizing, revising, and editing texts (Graham, Harris, MacArthur, & Schwartz, 1991; Lynch & Jones, 1989; Newcomer & Barenbaum, 1991).

At present, two major approaches are applied in an attempt to ameliorate the writing problems of students with learning disabilities. The first is modification of traditional instructional approaches to writing to include both writing as a process (D. Graves, 1983, 1985) and instruction in specific writing strategies (e.g., Englert, Raphael, Anderson, Anthony, & Stevens, 1991; Graves & Montague, 1991; MacArthur, Schwartz, & Graham, 1991; Zaragoza & Vaughn, 1992). The second major approach is word processing, and results of research generally indicate small, positive effects for word processing on some, but not all, measures of writing skills and attitudes. Although findings are not universal, many studies suggest that word processing appears to improve writing quality, quantity of writing, and accuracy in writing conventions such as spelling and written grammar for students with learning disabilities (e.g., Dalton, Winburg, & Morocco, 1990; Fais & Wanderman, 1987; Graham & MacArthur, 1988; Kerchner & Kistinger, 1984; MacArthur & Schwartz, 1990; Outhred, 1987, 1989; Yau, Ziegler, & Siegel, 1990).

However, there is need to gather further information about the effects of word processing for students with learning disabilities. Most studies to date have combined word processing with other interventions, most typically writing-as-a-process and strategy instruction (e.g., MacArthur & Schwartz, 1990; Kerchner & Kistinger, 1984). When treatments are combined, it is impossible to tease out the differential effects of each on study outcomes. In addition, most studies have treated word processing as one monolithic treatment, with little consideration of the variations that exist among word processing programs and whether they provide learners with specific word processing tools. It is also important to consider the interactions between word processing and the various

stages of the writing process. For example, the ease with which changes in text can be made with word processors may encourage students to participate more actively in the editing and revising stages of writing. On the other hand, the keyboarding skills needed for word processing may inhibit the performance of students as they attempt to create their first draft.

The three studies undertaken by the Enhancing Writing Skills Project were built upon earlier research, extending the study of word processing to specific tools that may enable students with learning disabilities to overcome the barriers inherent in the writing task and in word processing itself. Word processing tools were studied across the writing process and in configurations that allowed evaluation of the individual impact of each. Confounding of treatment variables was avoided by providing research-based writing instruction to all groups of students with learning disabilities, both those who wrote with traditional paper and pencil tools and those who used word processors.

STUDY 1: A COMPARISON OF STRATEGIES FOR IMPROVING TEXT ENTRY RATE

Purpose and Design

The major purpose of this study was to investigate the effectiveness of word processing tools for increasing the text entry speed of students with learning disabilities. Word processing was conceptualized as an addition to, not a replacement for, effective writing instruction. Thus, all students with learning disabilities received instruction based on the writing-as-a-process and learning strategies models. The major outcome variables of interest were writing speed, quality, and accuracy and attitude toward the writing process. Also of interest was whether the use of text entry strategies narrowed the achievement gap in writing performance between students with learning disabilities and their general education grade peers without disabilities.

This study employed a pretest-posttest control group design. Students with learning disabilities made up five experimental groups and the control group. In all experimental groups, students wrote using a word processor; in four of those groups, a text entry strategy was used in addition to the word processor. Those strategies were keyboarding instruction, an alternative keyboard, word prediction, and word prediction with speech. In the control group, students with learning disabilities wrote by hand. A comparison group, made up of general education students without disabilities, received no experimental treatment. Pretest and posttest data were collected to provide answers to four main research questions:

1. Are there differences in writing speed, quality, and accuracy between students with learning disabilities who write by hand, those who write using a word processor, and those who write using a word processor and a text entry tool?
2. Which text entry strategy is most effective in improving the rate of text entry for students with learning disabilities?
3. Is there a difference in attitudes toward writing between students with learning disabilities who write by hand, those who write using a word processor, and those who write using a word processor and a text entry tool?

4. Does the use of text entry tools narrow the achievement gap in writing between students with learning disabilities and their general education grade peers?

Methodology

Participants

A modified random sampling approach was used to select students with learning disabilities for participation in this study. All teachers serving this population in a 13-district special education consortium were invited to nominate students meeting four criteria: (a) identified by the district as having a specific learning disability, (b) not identified by the district as limited in English proficiency (LEP), (c) enrolled in grades 4 through 12, and (d) having one or more IEP goals in the area of written language.

Sixty-eight teachers nominated a total of 479 students, and 132 students were selected. A control group was formed by randomly selecting 22 students from the pool of students without access to computers in their special education programs. Experimental groups were formed by first randomly selecting 110 students from the pool of students with access to computers. Then students were randomly assigned to groups and groups to treatments. Some attrition took place during the year-long study, resulting in a final sample of 108 students with learning disabilities.

Sixty-eight percent of the students with learning disabilities were male; 74% received services in resource programs and the rest in special class settings. The sample was primarily white (64%) and Hispanic (24%). Students' average grade placement was 6.4 and their average age 12 years, 3 months. Students were characterized by poor writing performance (average standard score 79) despite average intellectual performance (average Full Scale IQ 98). Their IEPs most typically addressed written language skills in the areas of writing mechanics (e.g., capitalization and punctuation, 58% of students; spelling, 45%; grammar/usage, 32%), the writing process (e.g., editing, 40%), and production (e.g., writing a paragraph, 34%).

A comparison group of 132 general education students was also selected. Criteria were: (a) not identified by the district as having a disability, (b) not identified by the district as LEP, (c) enrolled in the same grade as the student with learning disabilities, and (d) being of the same gender and ethnic background as that student.

Interventions

All interventions were delivered to students with learning disabilities by their special education teachers under the supervision of project staff. All students received writing instruction using the research-based methods of teaching writing as a process and direct instruction in strategies for writing. The Traditional Group (i.e., the control group) received this type of writing instruction but wrote with paper and pencil throughout the study. The five technology groups (i.e., the experimental groups) also received this type of writing instruction but wrote using a word processor, The Writing Center (1991).

One of the five technology groups, the Word Processing Group, wrote with The Writing Center alone. The other four groups used this program as well as a text entry strategy. The Keyboarding Group wrote with The Writing Center and received systematic keyboarding instruction with the program Mavis Beacon Teaches Typing (1991). The Alternative Keyboard Group wrote with the word processor but entered text with the IntelliKeys keyboard (1994), with keys arranged in alphabetical order. The Word Prediction Group used the program Co:Writer (1992-94) in addition to the word processor, and the Word Prediction with Speech Group used Co:Writer with its synthesized speech feature activated.

Measures

At pretest and posttest, three measures were used to gather information from students with learning disabilities and general education comparison students. Three-minute speed probes were administered to determine the rate at which students were able to produce text in the draft stage of the writing process. Untimed writing samples were collected to determine the quality of students' writing and their writing accuracy. A writing attitude scale was also administered to determine students' perceptions of the writing process.

Writing quality was assessed by two analytic writing scales, the Story Quality Scale (Graves, Montague, & Wong, 1990) and the Expository Quality Scale (Graves & Fielden, 1993). A checklist was devised to evaluate accuracy of writing. This checklist was used to tally several types of writing errors: (a) mechanics errors (e.g., capitalization and punctuation), (b) spelling errors, (c) simple syntax errors (e.g., noun-verb agreement), and (d) meaning-influencing syntax errors (e.g., sentence fragments, run-on sentences, unintelligible phrases and sentences). The Writing Attitude Scale was developed by adapting

the Reading subscales of the Elementary and Secondary forms of the Estes Attitude Scales (Estes, Estes, Richards, & Roettger, 1981). Internal consistency and test-retest reliability of the adapted scale were investigated and determined to be adequate.

Information about the fidelity of treatment implementation was collected through classroom observations carried out by project staff and through analysis of weekly teaching logs maintained by participating teachers. At posttest, all teachers and a subsample of students with learning disabilities were interviewed to determine their perceptions of the interventions under study.

Procedures

At the beginning of the school year, participating teachers received training in (a) research-based methods for writing instruction, (b) strategies for integrating word processing into the writing curriculum, (c) procedures for using the word processing program and text entry tools, and (d) procedures for data collection and delivery of the interventions under study. A project staff member was assigned to each teacher to assist with and monitor all research tasks, and staff members visited classrooms on a regular basis throughout the study (on average, 9.3 visits per classroom).

As soon as pretesting was completed, treatment implementation began. The intervention phase was scheduled for 20 weeks and teachers were asked to provide students with a minimum of one hour of writing instruction per week, including computer-based writing activities. An analysis of teaching log data indicated that, on average, students received a total of 30.8 hours of instruction, which is substantially higher than the recommended minimum of 20 hours of instruction. Students in the technology groups, on average, spent 37% of their writing time in computer-based activities. Posttesting took place at the end of the school year.

Results

A repeated measures analysis of variance model was used to examine (a) differences between groups composed of students with learning disabilities and (b) differences between students with learning disabilities and general education grade peers. The variables of interest were writing speed, quality,

and accuracy and attitude toward writing. Also of interest were the views of students with learning disabilities and their special education teachers.

Writing Speed

Three-minute speed probes were used to gather data about writing speed, and the number of characters entered per minute was computed for each student at both pretest and posttest. The text entry speed of students with learning disabilities was then compared across the six groups: Traditional, Word Processing, Keyboarding, Alternative Keyboard, Word Prediction, and Word Prediction with Speech. Differences were found between intervention groups and between times of testing; in addition, there was a significant interaction between intervention groups and testing time.

Speed was higher at pretest when all students wrote by hand than at posttest when students in the five experimental groups wrote by computer. Overall, the Traditional Group showed significantly higher text input speed than all other groups, except Word Prediction. Figure 1 shows the interaction between groups and time of testing. All technology groups decreased in speed from pretest to posttest whereas the speed of the Traditional Group remained approximately the same.

This result was not unexpected. MacArthur and Graham (1987) reported that the text input speed of students with learning disabilities fell 50% when students moved from writing with paper and pencil to writing with a word processor. In the study reported here, students in four of the five technology groups achieved posttest writing speeds exceeding 50% of their pretest speeds (see Figure 2). Most notable is the Word Prediction Group with a posttest speed at 82%.

Figure 1

Pretest and Posttest Writing Speed by Intervention Group

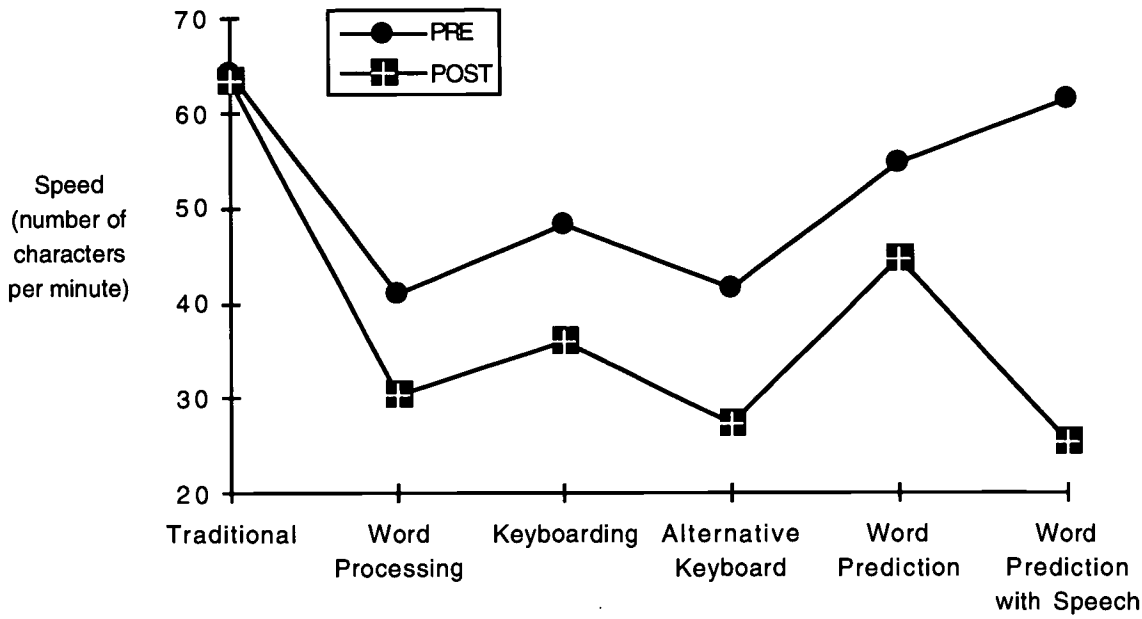
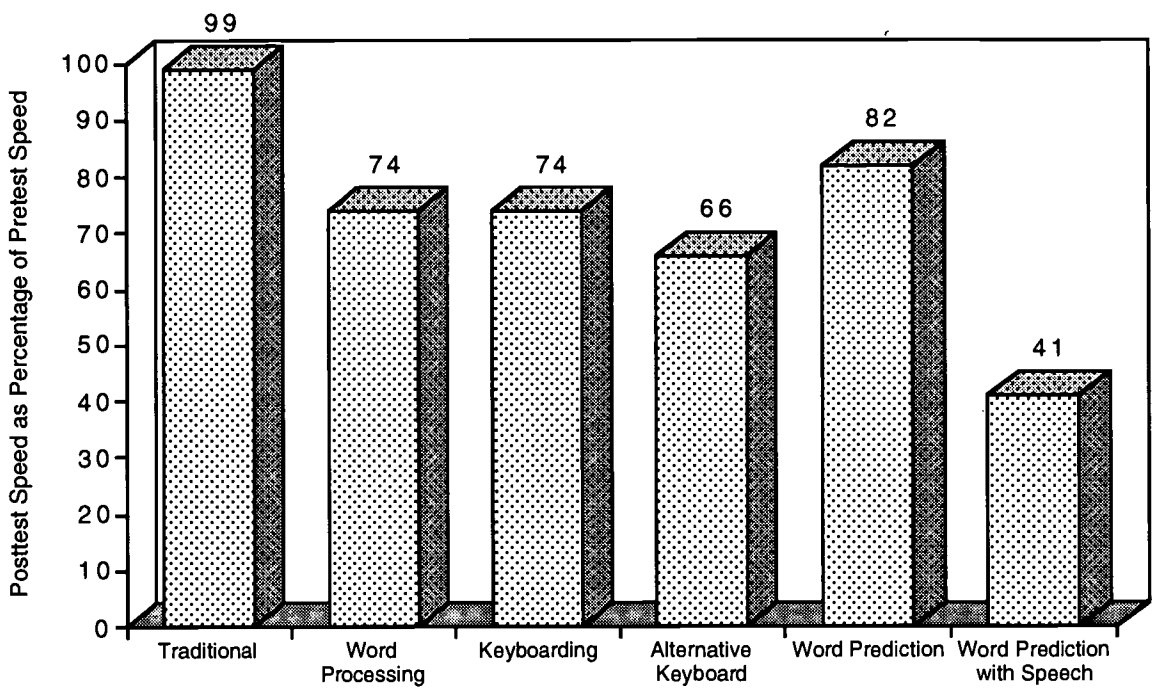


Figure 2

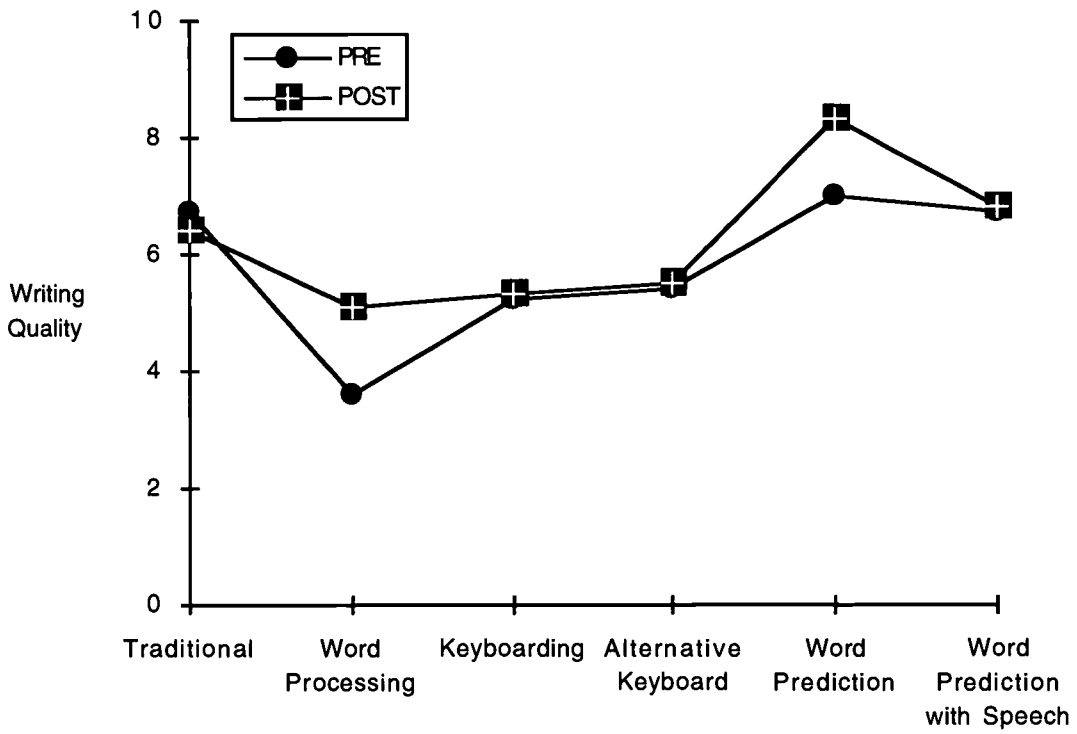
Posttest Speed as a Percentage of Pretest Speed



Writing Quality

The quality of the first drafts of students' writing samples was evaluated using analytic writing scales. A difference was found between intervention groups. The writing quality of students in the Word Prediction Group was superior to that of students in the Word Processing, Keyboarding, and Alternative Keyboard Groups. The writing quality of students in the Word Processing Group was inferior to that of students in the Traditional, Word Prediction, and Word Prediction with Speech Groups. No difference was found between times of testing and there was no interaction. As can be seen in Figure 3, students appeared to make minimal gains in writing quality over the course of the school year, although those in the Word Processing and Word Prediction Groups may have experienced some improvement.

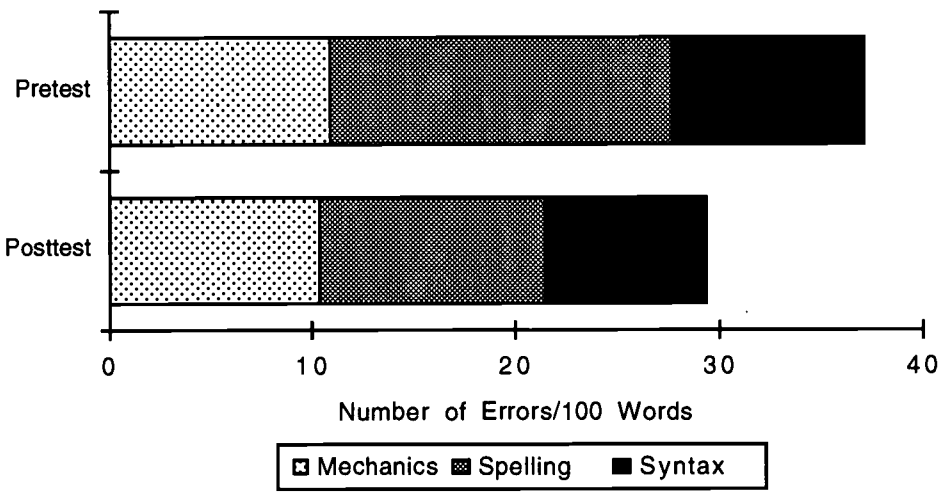
Figure 3
Pretest and Posttest Writing Quality by Treatment Group



Writing Accuracy

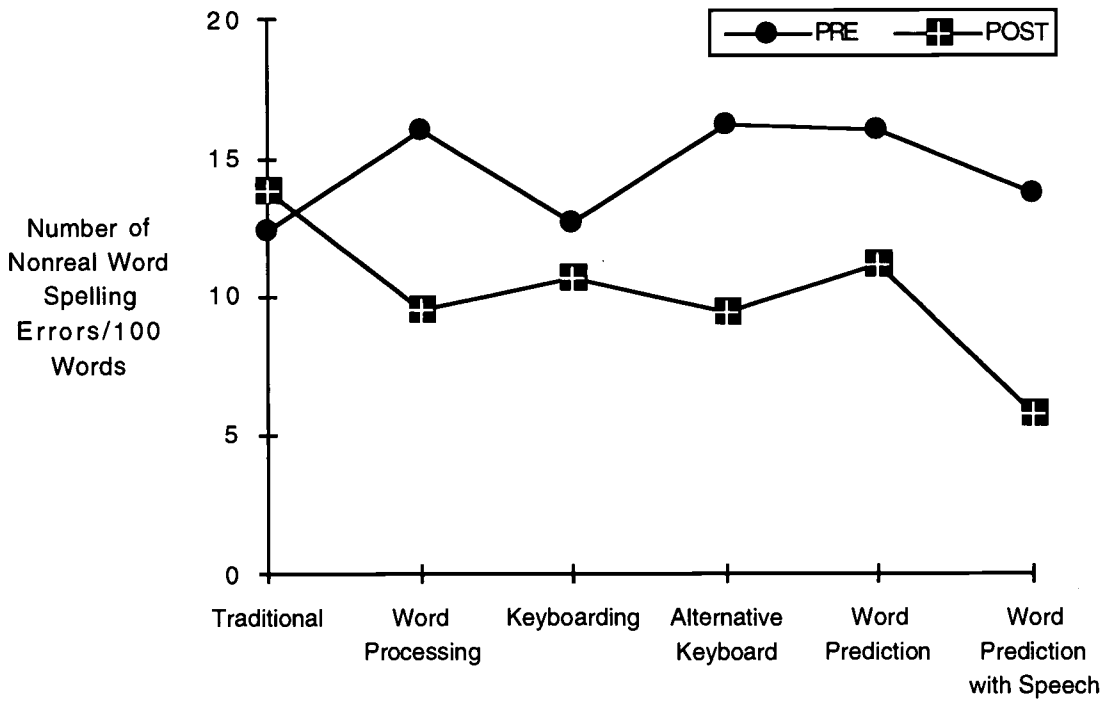
The accuracy of students' writing was evaluated by error analyses of the first drafts of their writing samples at pretest and posttest. Errors in mechanics, spelling, and syntax were identified and the number of errors per 100 words was calculated. No difference was found between intervention groups in total number of errors and there was no interaction between group and testing time. However, there was a significant difference between times of testing. As Figure 4 illustrates, students with learning disabilities made more errors at pretest (on average, 37.1 errors per 100 words) than at posttest (on average, 29.4 errors per 100 words).

Figure 4
Types of Writing Errors at Pretest and Posttest for Students with Learning Disabilities



Spelling errors were the most common. Two types of spelling errors were identified: real word errors (e.g., "to" for "two") and nonreal word errors (e.g., "thar" for "there"). Students were much more likely to make nonreal word errors, and this error type declined over time for students in the technology groups (see Figure 5). Most impressive was the improvement of students in the Word Prediction with Speech Group. At pretest, students made an average of 13.7 nonreal word spelling errors per 100 words; at posttest, they cut that number by more than half to 5.8 errors per 100 words.

Figure 5
Pretest and Posttest Nonreal Word Spelling Errors by Group



Attitude Toward Writing

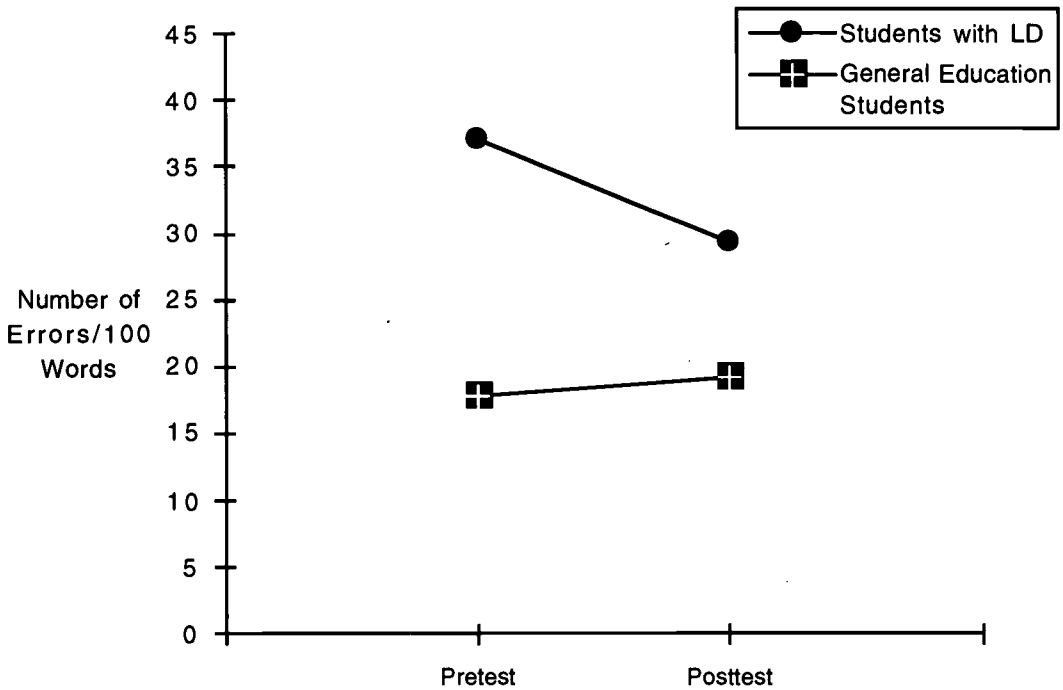
Attitude was assessed with a 15-item scale adapted from a published attitude measure. No difference was found between intervention groups or between times of testing; there was no significant interaction. Students with learning disabilities showed moderately positive attitudes toward writing at both pretest and posttest.

Comparisons with General Education Grade Peers

The performance of students with learning disabilities was compared to that of general education grade peers on writing speed, quality, accuracy, and attitude toward writing. No difference was found between students with learning disabilities and the general education comparison group in attitude toward writing. However, general education students were superior to students with learning disabilities in writing speed, quality, and accuracy. Significant interactions were found between time of testing and group for two variables: speed and accuracy. In speed, general education students showed little change over time whereas students with learning disabilities, as a group, declined in

speed from pretest to posttest. In writing accuracy, general education students experienced a slight increase in the total number of writing errors over time whereas students with learning disabilities showed a decrease (see Figure 6).

Figure 6
Total Number of Writing Errors



Views of Students with Learning Disabilities and Their Teachers

All teachers and subsamples of students with learning disabilities from each technology group were interviewed about their reactions to the word processing tools they had used. Teachers and students were generally positive about their experiences, although they were able to identify disadvantages of some of the tools. Both students and teachers criticized the number and length of the practice activities in the keyboarding program, Mavis Beacon Teaches Typing. The speed of the Co:Writer program was criticized as too slow, although this was likely due to the age of the computers used by students rather than the program itself. IntelliKeys, the alternative keyboard, was criticized as being too juvenile for older students and less desirable than the standard keyboard for younger students. When asked about whether they would recommend the

various approaches to others, 88% of teachers said they would recommend The Writing Center and Mavis Beacon Teaches Typing, 86% Co:Writer, 100% Co:Writer with speech, and 63% the IntelliKeys keyboard.

Most teachers reported that their students had made gains in their writing skills during the school year. Many teachers were also able to relate "success stories" about their students. The stories most typically reflected improvements in attitude and motivation and in overall writing quality.

Discussion

This study investigated the effectiveness of several word processing tools in enhancing the text entry speed of students with learning disabilities during the initial stage of the writing process. Writing speed was the major outcome variable of interest, although data were gathered about other written language variables including writing quality, accuracy, and attitude toward writing.

Results indicated that keyboarding was a slower mode of text entry for students with learning disabilities than handwriting. These results are consistent with those of an earlier study (MacArthur & Graham, 1987). However, in this study, all but one group of students who wrote with word processors achieved speeds higher than the expected text entry rate of 50% of handwriting speed. Most impressive was the Word Prediction Group who reached 82% of handwriting speed at posttest. In contrast, students in the Word Prediction with Speech Group experienced the sharpest decline in speed (posttest speed 41% of handwriting speed). This result must be interpreted with caution. The process of using synthesized speech to hear predicted word choices read aloud takes time, thereby slowing the text entry process. Also, the computers used by students in this study were older models on which the word prediction program ran slowly, particularly when the speech feature was activated.

Writing quality did not appear to improve over time, except for students in the Word Processing and Word Prediction Groups who made modest gains. Although the technology tools under investigation were not expected to affect overall quality of writing, it was hypothesized that all groups would show some incremental improvements. One possible explanation relates to the types of writing samples produced by students and the instruments used to assess the quality of those samples. In this study, writing topics were selected by teachers to complement their classroom writing programs. Thus, students may have written a narrative at pretest and an expository composition at posttest. These

samples would then have been evaluated using the Story Quality Scale and the Expository Quality Scale. The equivalency of these scales has not been determined and it is possible that, even if the scales were equivalent, students would show differing levels of writing skill across genres.

Writing accuracy of students with learning disabilities improved over time. On average, students decreased their total number of errors from 37.1 per 100 words at pretest to 29.4 at posttest. At pretest, spelling errors were most common, particularly errors where students wrote pseudo or nonreal words. Examples are "fanlly" for "finally," "becaise" for "because," and "borthen" for "brother." All technology groups showed decreases in the number of nonreal word spelling errors from pretest to posttest. The Word Prediction with Speech Group made the most impressive gains, decreasing their errors from 13.7 per 100 words at pretest to 5.8 at posttest.

Attitudes of students with learning disabilities toward writing were positive at both pretest and posttest. Moreover, students with learning disabilities did not differ from general education grade peers in attitude. However, the performance of students with learning disabilities was inferior to that of general education students in all other areas: writing speed, quality, and accuracy.

In one area, writing accuracy, the achievement gap did appear to narrow. Students with learning disabilities who wrote with a word processor showed a marked decrease in writing errors over time; their general education peers did not. This finding is perhaps the most important in this study because it suggests that word processors, including those augmented with tools such as word prediction, may be powerful compensatory aids to students whose writing is characterized by poor accuracy, especially in the area of spelling.

STUDY 2: THE EFFECTIVENESS OF TEXT EDITING TOOLS, WITH AND WITHOUT SPEECH SYNTHESIS

Purpose and Design

The major purpose of this study was to investigate the effectiveness of word processing tools, specifically text editing tools such as spelling and grammar checkers, for improving the written language of students with learning disabilities. As in Study 1, word processing was conceptualized as an addition to, not a replacement for, effective writing instruction. The major outcome variables of interest were writing quality, writing accuracy, and attitude toward the writing process. Also of interest was whether the use of text editing tools narrowed the achievement gap in writing performance between students with learning disabilities and their general education grade peers without disabilities.

This study employed a pretest-posttest control group design. Students with learning disabilities made up three experimental groups and the control group. In all experimental groups, students wrote using a word processor. In Group A, intervention began with a word processor only; in Group B, intervention began with the word processor and spelling checking. In the second part of the intervention period, Groups A and B used the word processor with both spelling and grammar checkers. Group C, the speech synthesis group, began intervention with spelling checking and speech; grammar checking was added in the second part of the intervention period. In the control group, students with learning disabilities wrote by hand. A comparison group, made up of general education students without disabilities, received no experimental treatment. Pretest and posttest data were collected to provide answers to four main research questions:

1. Are there differences in writing quality and accuracy between students with learning disabilities who use word processors with spelling and grammar checkers and those who write by hand?
2. Does the gradual introduction of text editing tools or the addition of speech affect writing quality and accuracy?
3. Is there a difference in attitudes toward writing between students with learning disabilities who write by hand and those who write using a word processor?

4. Does the use of text editing tools such as spelling and grammar checkers narrow the achievement gap in writing between students with learning disabilities and their general education grade peers?

Methodology

Participants

The procedures used for sample selection in Study 1 were modified in Study 2. All teachers serving students with learning disabilities in a 13-district special education consortium were invited to participate. Seventy-two teachers volunteered and two groups were selected: 24 teachers with access to computers and 7 without access. One technology teacher was forced to withdraw from the study because general educators in her full inclusion school were unwilling to assist with treatment implementation. The remaining 30 teachers were asked to nominate students meeting the identification criteria used in Study 1. A total of 300 students were nominated and 4 students were randomly selected from each teacher's list. In one case, a teacher was able to nominate only two students and both were selected. Technology teachers were then randomly assigned to groups and groups to treatments. Attrition reduced the initial sample of 118 students with learning disabilities to 106.

Sixty-eight percent of the students with learning disabilities were male; 73% received services in resource programs and the rest in special class settings. The sample was primarily white (70%), Hispanic (19%), and African American (7%). Students' average grade placement was 6.2 and their average age 12 years, 0 months. Students were characterized by poor writing performance (average standard score 74) despite average intellectual performance (average Full Scale IQ 97). Their IEPs most typically addressed written language skills in the areas of writing mechanics (e.g., capitalization and punctuation, 57% of students; spelling, 74%; grammar/usage, 36%), the writing process (e.g., editing, 31%), and production (e.g., writing a paragraph, 34%).

A comparison group of 115 general education students was also selected. One teacher in a high school setting was able to identify matches for only one of four students with learning disabilities. The identification criteria used were the same as those in Study 1.

Interventions

All interventions were delivered to students with learning disabilities by their special education teachers under the supervision of project staff. All students received writing instruction using the research-based methods of teaching writing as a process and direct instruction in strategies for writing. The Traditional group (i.e., the control group) received this type of writing instruction but wrote with paper and pencil throughout the study. The three technology groups (i.e., the experimental groups) also received this type of writing instruction but wrote using a word processor, Write This Way (1993).

Write This Way was selected for this study primarily because it was the only available Macintosh-based word processor appropriate for grades 4 through 12 that offered both spelling and grammar checkers and speech. This program allows features such as speech and spelling and grammar checkers to be turned on or off. However, one drawback of Write This Way is that the algorithm underlying the grammar checker relies on text with correctly spelled words. Thus, it was not possible investigate the effects of the grammar checker in isolation but only in conjunction with the spelling checker.

Write This Way was configured differently for the three experimental groups. Group A used Write This Way with neither checker activated during the first half of the intervention period and with both spelling and grammar checkers activated in the second half. Group B used the program with spell checking in the first half of intervention and with both checkers in the second half. Group C, the speech group, used Write This Way with speech and spell checking in the first half and with speech and both checkers in the second half. These configurations allowed study of students' performance under two conditions: speech versus no speech, and early versus later introduction of text editing tools.

Measures

At pretest and posttest, two measures were used to gather information from students with learning disabilities and general education comparison students. Writing samples were collected to determine the quality of students' writing and their writing accuracy. A writing attitude scale was also administered to determine students' perceptions of the writing process. Writing samples, both first and final drafts, were elicited using picture prompts from the Test of Written

Language-2 (Hammill & Larsen, 1988) with modified administration procedures. The attitude scale employed in Study 1 was also used in Study 2.

Final drafts of writing samples were evaluated for writing accuracy and quality. The error checklist developed for Study 1 was used in Study 2 as the accuracy measure. The quality measure was a holistic rating scale adapted from the Test of Written English (1992). In addition, the changes students made from first to final drafts at pretest and posttest were evaluated for a subsample of students. Each change was categorized using the same schema as the error checklist and then rated as positive, neutral, or negative, based on the procedures described by Stoddard and MacArthur (1993).

As in Study 1, information about the fidelity of treatment implementation was collected through classroom observations carried out by project staff and through analysis of weekly teaching logs maintained by participating teachers. At posttest, project staff carried out structured observations of all students in the experimental groups as they wrote the first and final drafts of the writing sample. In addition, all teachers and all students with learning disabilities were interviewed to determine their perceptions of the interventions under study.

Procedures

At the beginning of the school year, participating teachers received training in (a) research-based methods for writing instruction, (b) strategies for integrating word processing into the writing curriculum, (c) procedures for using the word processing program and its text editing tools, and (d) procedures for data collection and delivery of the interventions under study. In addition, technology teachers were instructed to teach students a strategy to use when the spelling checker identified a word as incorrect but was unable to suggest an alternative. In the SpellCHECK strategy, students check the beginning sound of the word, hunt for correct consonants, examine the vowels, consult changes in the word list for hints, and keep repeating each of the steps (Ashton, 1997). As a last resort, students should consult a dictionary, a children's dictionary, a "my words" list, a peer, or a teacher. As in Study 1, a project staff member was assigned to each teacher to assist with and monitor all research tasks, and staff members visited classrooms on a regular basis throughout the study (on average, 11.5 visits per classroom).

As soon as pretesting was completed, treatment implementation began. The intervention phase was scheduled for two 8-week periods, a total of 16

weeks. Teachers were asked to provide students with a minimum of one hour of writing instruction per week, including computer-based writing activities. An analysis of teaching log data indicated that, on average, students received a total of 38.2 hours of instruction, which is more than double the recommended minimum of 16 hours of instruction. Students in the technology groups, on average, spent 46% of their writing time in computer-based activities. Posttesting took place at the end of the school year.

Results

A repeated measures analysis of variance model was used to examine (a) differences between groups composed of students with learning disabilities and (b) differences between students with learning disabilities and general education grade peers. The variables of interest in these quantitative analyses were writing quality and accuracy and attitude toward writing. Also of interest were the qualitative data collected regarding the editing skills of students with learning disabilities and the views of students and their special education teachers.

Writing Quality

The quality of the final drafts of students' pretest and posttest writing samples was evaluated using a holistic rating scale. There was no difference between intervention groups although posttest quality scores were significantly higher than pretest scores. The interaction between groups and time of testing approached but did not reach significance. As can be seen in Figure 7, all groups showed improvements in writing quality over time.

Writing Accuracy

The accuracy of students' writing was evaluated by error analyses of the final drafts of their writing samples at pretest and posttest. Errors in mechanics (including spelling) and syntax were identified and the number of errors per 100 words was calculated. No difference was found between intervention groups in total number of errors and there was no interaction between group and testing time. However, there was a significant difference between times of testing. As Figure 8 illustrates, students with learning disabilities improved their writing accuracy over time.

Figure 7
Pretest and Posttest Writing Quality by Treatment Group

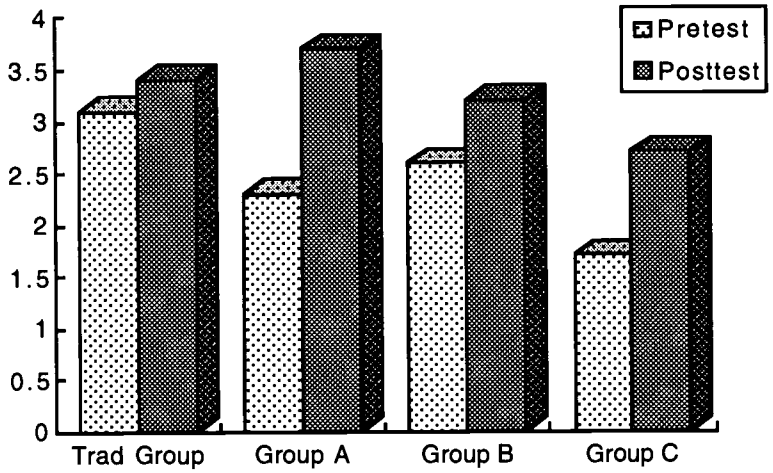
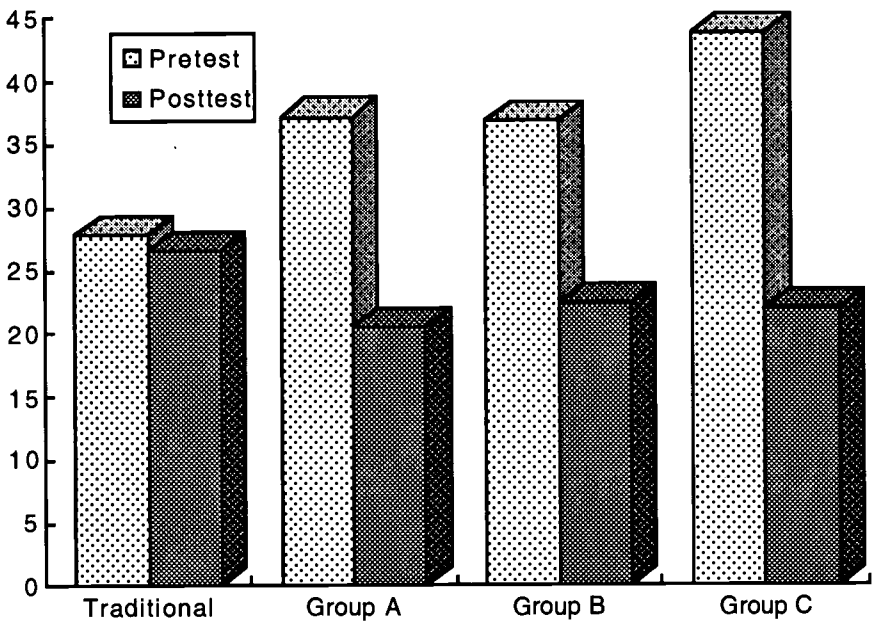


Figure 8
Total Number of Writing Errors at Pretest and Posttest, by Group



Students with learning disabilities were more likely to make errors in mechanics than in syntax, and spelling errors were the most common type of mechanics errors. As in Study 1, two types of spelling errors were identified: real word errors (e.g., "to" for "two") and nonreal word errors (e.g., "thar" for "there"). Students were much more likely to make nonreal word errors, and this error type declined over time for students in the technology groups (see Table 1). Students in the Traditional Group showed a slight decline in nonreal word errors from pretest to posttest (16.2 errors per 100 words at pretest to 15.3 at posttest). In contrast, the error rate for students in the three technology groups fell from 19.4 at pretest to 10.8 at posttest.

Table 1
Number of Spelling Errors per 100 Words, by Error Type

	Traditional Group		Technology Groups	
Type of Error	Pretest	Posttest	Pretest	Posttest
Real Word	2.7	2.9	3.1	3.3
Nonreal Word	16.2	15.3	19.4	10.8

Editing Skills of Students with Learning Disabilities

Changes from first to final drafts of pretest and posttest writing samples were analyzed for a subsample of study participants: students with learning disabilities in the Traditional Group (n = 4), students with learning disabilities in the three technology groups (n = 11), and general education grade peers (n = 13). As Table 2 illustrates, students in the three groups made about the same number of changes at pretest but, at posttest, that number declined for students with learning disabilities in the technology groups. However, at posttest, technology groups improved their rate of positive changes, that is, changes which resulted in corrections of errors. Their success rate increased from 36.3% at pretest to 65.9% at posttest, the highest rate for any group. Traditional Group students with learning disabilities and general education students showed little change from pretest to posttest.

Table 2
Average Number of Changes and
Percentage of Positive Changes at Pretest and Posttest

	Number of Changes		Percentage of Positive Changes	
Group	Pretest	Posttest	Pretest	Posttest
Traditional	27.5	21.3	48.4%	41.9%
Technology	20.6	14.0	36.3%	65.9%
General Education	23.0	26.6	45.6%	46.9%

At both pretest and posttest, the most common changes students made related to spelling and syntax. In syntax, the most typical changes were categorized as Syntax II (meaning related) as opposed to Syntax I (sentence elements). Technology group students showed impressive improvements in the percentage of positive changes in both spelling and syntax, as Table 3 shows. In spelling, their success rate rose from 28.6% at pretest to 70.4% at posttest and, in syntax, it rose from 39.3% to 73.3%. In contrast, Traditional Group students and general education grade peers showed decreases in the percentage of positive changes or only slight increases.

Table 3
Percentage of Positive Changes in Spelling
and Syntax II at Pretest and Posttest

	Percentage of Positive Spelling Changes		Percentage of Positive Syntax II Changes	
Group	Pretest	Posttest	Pretest	Posttest
Traditional	34.7%	16.7%	47.9%	32.0%
Technology	28.6%	70.4%	39.3%	73.3%
General Education	47.4%	34.6%	49.6%	51.4%

All students with learning disabilities in the three technology groups were observed during posttesting to determine their facility with the text editing tools of the word processors. The first step in editing with Write This Way is activation of the Proof feature to detect spelling and grammar errors; 89% of students used this feature to locate errors in their first draft. After proofing, students can ask the program for help with the errors detected. Ninety-six percent of the students with spelling errors identified by the program asked for spelling help; 49% of students with grammar errors asked for grammar help.

Data were collected on the first two errors (both spelling and grammar) that each student attempted to correct. In spelling, the word processor was able to suggest the correct option for 50% of misspelled words. The spell checker's accuracy rate becomes more understandable when students' errors are considered; examples are *elftnas, elner, lufis,* and *elfets* for *elephant* or *elephants*. When the correct option was suggested, students selected it 94% of the time. Students were also able to make appropriate corrections 27% of the time when the correct option was not suggested. This occurred most frequently (53% of the time) in Group C, the speech synthesis group. Observational data indicated that several of these students continued to make changes in misspelled words until the program suggested the correct option. Group C students used speech when seeking help for 61% of their spelling errors.

In grammar, 22% of the errors identified by the program were not errors; in most cases, the incorrect grammar error flags appeared in sentences with spelling errors. The word processor was able to provide accurate error messages for 46% of true grammar errors; students were able to correct 78% of these errors. Group C students used speech when seeking help for 29% of their grammar errors.

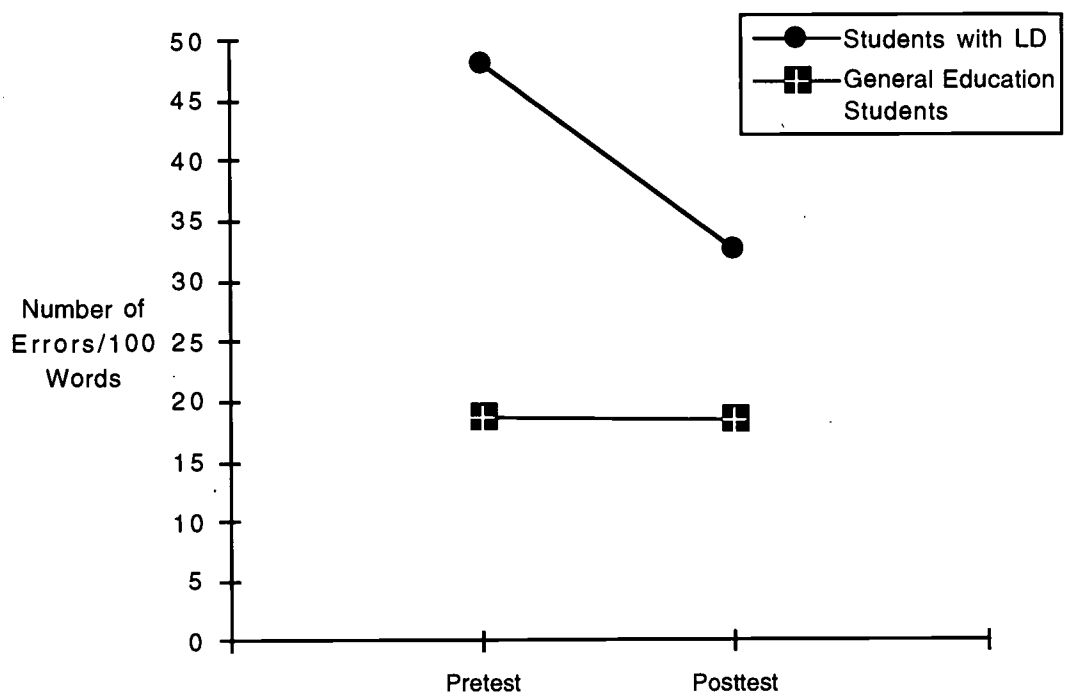
Attitude Toward Writing

Attitude was assessed with a 15-item scale adapted from a published attitude measure. No difference was found between intervention groups and there was no significant interaction between group and testing time. A difference was found between pretest and posttest scores. Students with learning disabilities showed a small decline from pretest to posttest, although scores at both times showed moderately positive attitudes toward writing.

Comparisons with General Education Grade Peers

The performance of students with learning disabilities was compared to that of general education grade peers on writing quality, accuracy, and attitude toward writing. General education students were superior to students with learning disabilities in all three areas. In quality and accuracy, posttest performance was superior to pretest performance; no difference was found in attitude over time. A significant interaction between time of testing and group was found for one variable: accuracy. As Figure 9 shows, students with learning disabilities experienced a sizable decrease in the number of writing errors from pretest to posttest whereas general education students showed minimal change.

Figure 9
Interaction between Group and Time of Testing
on Total Number of Errors



Views of Students with Learning Disabilities and Their Teachers

All teachers and technology group students were interviewed about their reactions to the word processing program they had used. Teachers and students were generally positive about their experiences; 78% of teachers said

they would recommend Write This Way to others and 79% of students made positive comments about the program. In general, teachers and students were much more critical of the grammar checker than the spelling checker. The grammar checker was criticized because of its inability to provide meaningful help messages when errors were detected; the most common complaint about the spelling checker was its inability to suggest the correct option for some misspelled words. Speech was considered a valuable feature by 79% of the students in the speech group (Group C) and 100% of their teachers.

Eighty-six percent of students agreed that Write This Way was a helpful tool for writing. Teachers were able to relate "success stories" about their students. The stories most typically reflected improvements in attitude and motivation and in writing skills.

Discussion

This study investigated the effectiveness of text editing tools such as spelling and grammar checkers in enhancing the writing performance of students with learning disabilities during the editing/revising stages of the writing process. The major outcome variables of interest were writing quality, writing accuracy, and attitude toward writing.

Results indicated that writing quality and accuracy improved for students with learning disabilities from pretest to posttest. There was no significant interaction between intervention groups and time of testing, as would be expected if there were a differential effect related to technology use. In the area of accuracy, Traditional Group students made 5.5 fewer errors per 100 words at posttest than at pretest, and students in technology Groups A, B, and C made 16.0, 17.7, and 23.5 fewer errors respectively. In spelling, students in the technology groups appeared to be more successful than Traditional Group students in decreasing their rate of spelling errors over time.

Qualitative analyses of the changes students made when revising the first drafts of their writing samples produced some of the most intriguing findings of this investigation. Although this portion of the study involved only a small subsample, results suggest clear differences between students who used technology and those who did not. At pretest, all groups of students, including general education matches, made about the same number of changes from first to final drafts; in no group did the percentage of positive changes reach 50%. At posttest, students in the technology groups made fewer changes than at pretest.

However, at posttest, technology group students achieved the highest rates of all groups in percentage of total positive changes (66%), positive spelling changes (70%), and positive syntax changes (73%).

Results of posttest observations of technology group students with learning disabilities indicated that most students used the proofing feature of the word processor to check their work, although some students did not. Those who proofed their work were more likely to attempt to correct spelling errors than grammar errors. This may be because students were instructed to correct spelling mistakes first (to increase the probability that the program would be able to detect grammar errors accurately) or because, as students and teachers reported, the grammar checker was often unable to provide helpful assistance. The spelling checker appeared to be a useful tool. It provided correct suggestions for 50% of misspelled words, a rate equivalent to that reported by other researchers (MacArthur, Graham, Haynes, & DeLaPaz, 1996), and students were able to select the correct spelling 94% of the time. Speech was also identified as a valuable feature by both students and teachers.

Attitudes of students with learning disabilities toward writing were moderately positive, although they declined over time. When compared to general education grade peers, students with learning disabilities showed inferior performance in all areas under study: writing quality, accuracy, and attitude toward writing. As in Study 1, the achievement gap appeared to narrow in one area, writing accuracy. Students with learning disabilities who wrote with a word processor showed a marked decrease in writing errors over time; their general education peers did not.

STUDY 3: THE EFFECTS OF SPEECH SYNTHESIS ON TEXT ENTRY, EDITING, AND REVISION

Purpose and Design

The major purpose of this study was to investigate the effectiveness of speech synthesis for improving the written language of students with learning disabilities. As in Study 1 and Study 2, word processing was conceptualized as an addition to, not a replacement for, effective writing instruction. The major outcome variables of interest were writing quality, writing accuracy, and attitude toward the writing process. Also of interest was whether the use of speech synthesis narrowed the achievement gap in writing performance between students with learning disabilities and their general education grade peers without disabilities.

This study employed a pretest-posttest control group design. Students with learning disabilities made up three experimental groups and the control group. In all experimental groups, students wrote with a word processor with a built-in spelling checker; in the first part of the intervention period, speech synthesis was not activated. One experimental group, Group A, used speech in the text entry stage of writing during the second part of the intervention period. Group B used speech in the editing/revising stages of writing and Group C used speech throughout the writing process. In the control group, students with learning disabilities wrote by hand. A comparison group, made up of general education students without disabilities, received no experimental treatment. Data were collected to provide answers to five main research questions:

1. Are there differences in writing quality and accuracy between students with learning disabilities who use word processors with spelling checkers and those who write by hand?
2. Does the introduction of speech synthesis affect writing quality and accuracy?
3. Are there differences in writing quality and accuracy between students with learning disabilities who use speech during text entry, those who use speech during editing/revising, and those who use speech throughout the writing process?
4. Is there a difference in attitudes toward writing between students with learning disabilities who write by hand and those who write using a word processor?

5. Does the use of speech synthesis narrow the achievement gap in writing between students with learning disabilities and their general education grade peers?

Methodology

Participants

Study 3 used the same procedures for sample selection as Study 2. All teachers serving students with learning disabilities in a 13-district special education consortium were invited to participate. Ninety-two teachers volunteered and two groups were selected: 24 teachers with access to computers and 8 without access. One Traditional Group teacher was forced to withdraw from the study when she took a new position; one technology group teacher was dropped part way through the study because of failure to comply with the treatment protocol. The remaining 30 teachers nominated a total of 266 students meeting the identification criteria used in Study 1, and 4 students were randomly selected from each teacher's list. Technology teachers were then randomly assigned to groups and groups to treatments. Attrition reduced the initial sample of 120 students with learning disabilities to 103.

Fifty-nine percent of the students with learning disabilities were male; 75% received services in resource programs and the rest in special class settings. The sample was primarily white (66%), Hispanic (18%), and African American (12%). Students' average grade placement was 5.7 and their average age 11 years, 4 months. Students were characterized by poor writing performance (average standard score 76) despite average intellectual performance (average Full Scale IQ 95). Their IEPs most typically addressed written language skills in the areas of writing mechanics (e.g., capitalization and punctuation, 65% of students; spelling, 66%; grammar/usage, 27%), the writing process (e.g., editing, 42%), and production (e.g., writing a paragraph, 37%).

A comparison group of 120 general education students was also selected. The identification criteria used were the same as those in Study 1.

Interventions

All interventions were delivered to students with learning disabilities by their special education teachers under the supervision of project staff. All students received writing instruction using the research-based methods of teaching writing as a process and direct instruction in strategies for writing. The

Traditional Group (i.e., the control group) received this type of writing instruction but wrote with paper and pencil throughout the study. The three technology groups (i.e., the experimental groups) also received this type of writing instruction but wrote using a word processor, Write:OutLoud (1993-94).

Write:OutLoud was selected for this study because it contains both a spelling checker and speech synthesis. The speech synthesis feature can be activated for a portion of the writing process (either text entry or editing/revising) or for the entire writing process; speech can also be turned off.

In the first half of the intervention period, students in the three experimental groups used Write:OutLoud with speech synthesis off. This allowed study of the effects of the word processor and spell checker alone (without speech) versus when speech was added. In the second half of the intervention period, all students used speech but Write:OutLoud was configured differently for the three groups. Group A used Write:OutLoud with speech activated during the text entry stage of writing. Group B used the program with speech activated during the revising/editing stage. Group C used the program with speech activated throughout the writing process. These configurations allowed study of the effects of speech synthesis in all stages of writing.

Measures

At pretest and posttest, two measures were used to gather information from students with learning disabilities and general education comparison students. Writing samples were collected to determine the quality of students' writing and their writing accuracy. A writing attitude scale was administered to determined students' perceptions of the writing process. Writing samples were also collected from students with learning disabilities at midyear (in addition to those collected at pretest and posttest).

As in Study 2, pretest and posttest writing samples, both first and final drafts, were elicited using picture prompts from the Test of Written Language-2 (Hammill & Larsen, 1988) with modified administration procedures. A picture prompt similar to those in the TOWL-2 was developed for use in midyear collection of writing samples. The attitude scale employed in Study 1 and Study 2 was also used in Study 3.

Final drafts of writing samples were evaluated for writing accuracy and quality. The error checklist developed for Study 1 was used in Study 3 as the

accuracy measure. As in Study 2, the quality measure was a holistic rating scale adapted from the Test of Written English (1992).

As in Study 1 and Study 2, information about the fidelity of treatment implementation was collected through classroom observations carried out by project staff and through analysis of weekly teaching logs maintained by participating teachers. At midyear and posttest, project staff carried out structured observations of all students in the experimental groups as they wrote the first and final drafts of the writing sample. In addition, all teachers and all students with learning disabilities were interviewed at posttest to determine their perceptions of the interventions under study.

Procedures

At the beginning of the school year, participating teachers received training in (a) research-based methods for writing instruction, (b) strategies for integrating word processing into the writing curriculum, (c) procedures for using the word processing program and speech synthesis, and (d) procedures for data collection and delivery of the interventions under study. As in previous studies, a project staff member was assigned to each teacher to assist with and monitor all research tasks, and staff members visited classrooms on a regular basis throughout the study (on average, 11.2 visits per classroom).

As soon as pretesting was completed, treatment implementation began. The intervention phase was scheduled for two 8-week periods, a total of 16 weeks. Midyear writing samples were collected from students with learning disabilities prior to the start of the second 8-week intervention period. Teachers were asked to provide students with a minimum of one hour of writing instruction per week, including computer-based writing activities. An analysis of teaching log data indicated that, on average, students received a total of 35.8 hours of instruction, which is more than double the recommended minimum of 16 hours of instruction. Students in the technology groups, on average, spent 49% of their writing time in computer-based activities. Posttesting took place at the end of the school year.

Results

A repeated measures analysis of variance model was used to examine (a) differences between groups composed of students with learning disabilities and (b) differences between students with learning disabilities and general

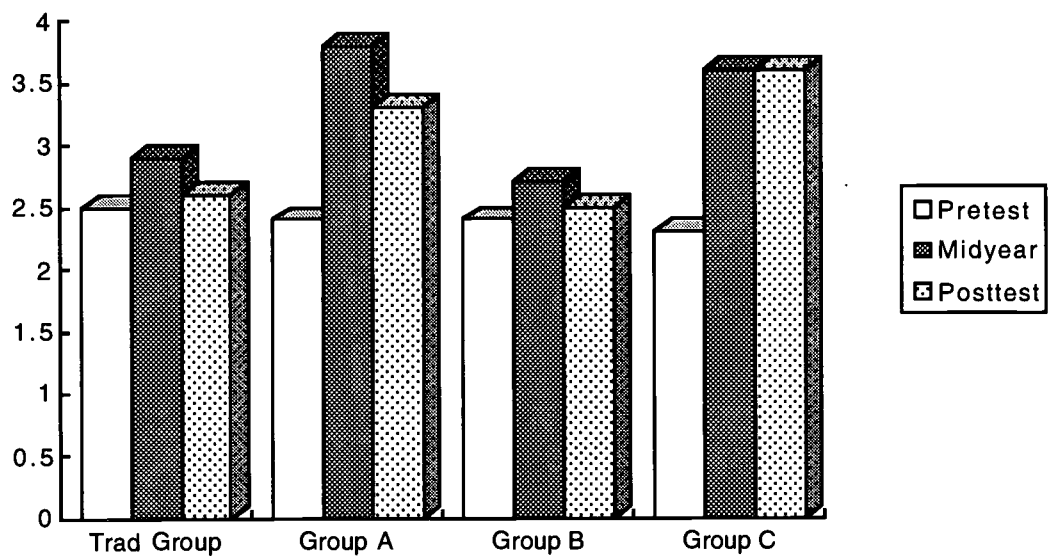
education grade peers. The variables of interest in these quantitative analyses were writing quality and accuracy and attitude toward writing. Also of interest were the qualitative data collected regarding the use of word processing tools by students with learning disabilities and the views of students and their special education teachers.

Writing Quality

The quality of the final drafts of the pretest, midyear, and posttest writing samples of students with learning disabilities was evaluated using a holistic rating scale. No difference was found between groups in quality. However, a significant difference was detected in time of testing and there was a significant interaction between testing time and group (see Figure 10). Quality improved over time, although it appears that students in Groups A and C made more substantial gains than students in Group B and the Traditional Group. However, the largest gains appear to have occurred from pretest to midyear. From midyear to posttest, all groups appeared to show decreases or no change in quality.

Figure 10

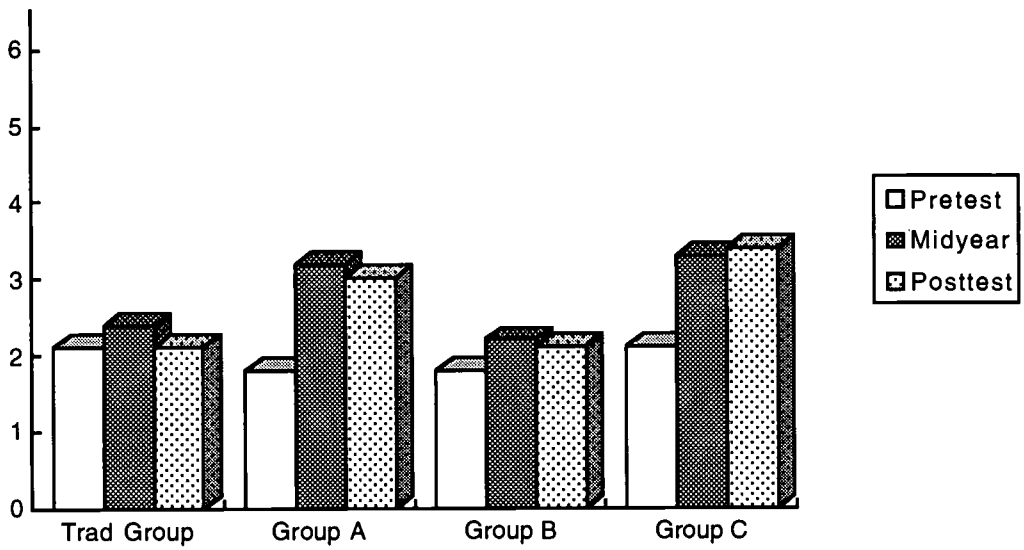
Pretest, Midyear, and Posttest Writing Quality by Treatment Group



Further analyses were done in an attempt to discover reasons for these results. Because it was hypothesized that age may be a contributing factor, the

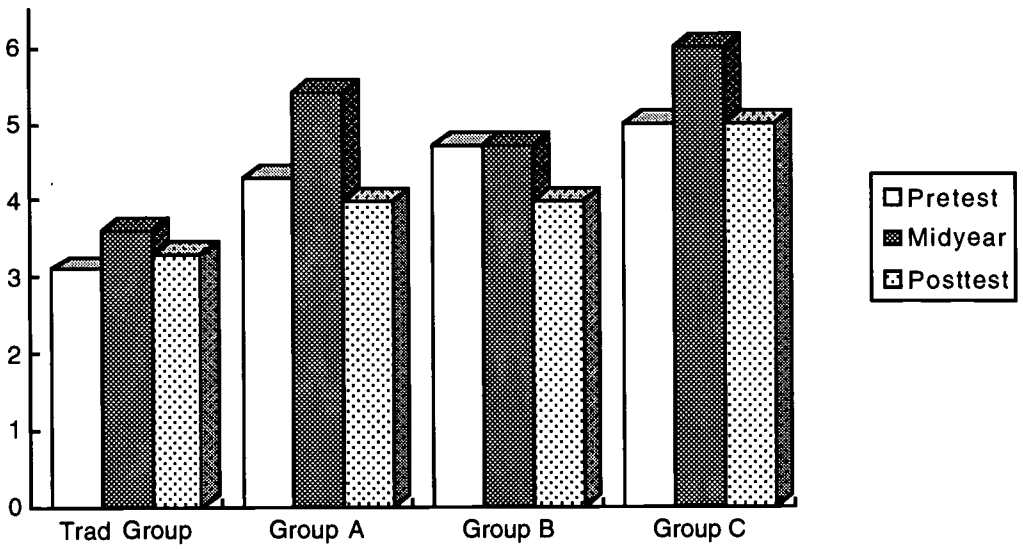
sample was divided into students in the elementary grades (n = 82) and those in the secondary grades (n = 21). Statistical analyses of quality data for elementary students yielded the same results as those for the sample as a whole; the interaction between testing time and group is shown in Figure 11.

Figure 11
Elementary Students Only: Pretest, Midyear, and Posttest Writing Quality by Treatment Group



Statistical analyses of the secondary data were not possible because of the lower number of students included in this portion of the sample. However, as Figure 12 shows, secondary students with learning disabilities appeared to improve in writing quality from pretest to midyear (with the exception of Group B, which showed no change). In contrast, the writing quality of these students appeared to decline from midyear to posttest, particularly for students in the three technology groups. This finding suggests that speech synthesis may not be a useful feature for older writers with learning disabilities with respect to quality of writing.

Figure 12
Secondary Students Only: Pretest, Midyear, and Posttest Writing Quality by Treatment Group



Writing Accuracy

The accuracy of students' writing was evaluated by error analyses of the final drafts of their writing samples at pretest, midyear, posttest. Errors in mechanics (including spelling) and syntax were identified and the number of errors per 100 words was calculated. No difference was found between intervention groups in total number of errors and there was no interaction between group and testing time. However, there was a significant difference between times of testing. As Figure 13 illustrates, students with learning disabilities improved their writing accuracy over time.

Data were again analyzed by age groups. Results for elementary students were the same as those for the sample as a whole; elementary students showed a decrease in errors over time. In contrast, secondary students in the three technology groups appeared to increase the number of errors they made from midyear to posttest (see Figure 14). This finding suggests that speech synthesis may have a negative effect on the writing accuracy of older students with learning disabilities.

Figure 13
Total Number of Writing Errors per 100 Words
at Pretest, Midyear, and Posttest, by Group

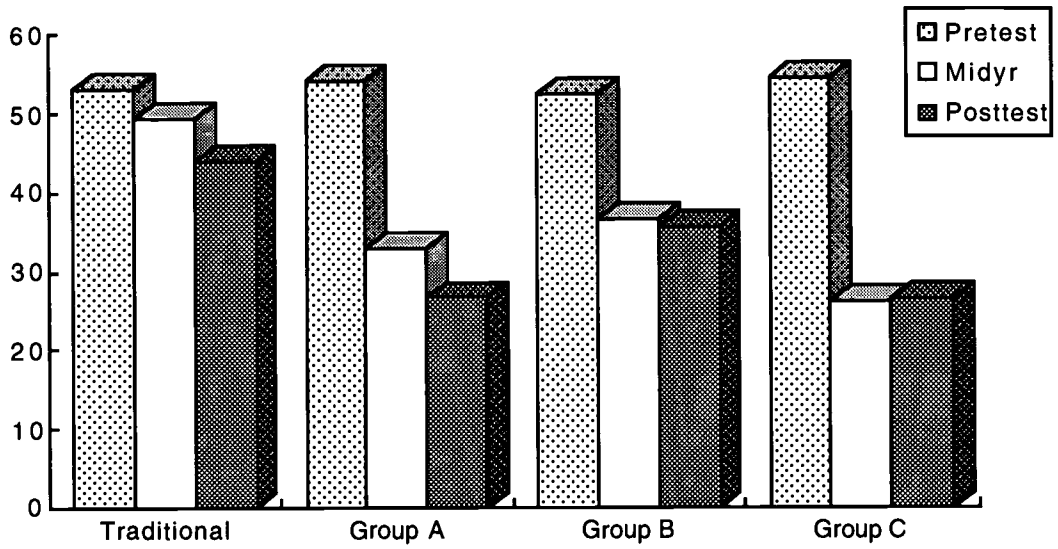
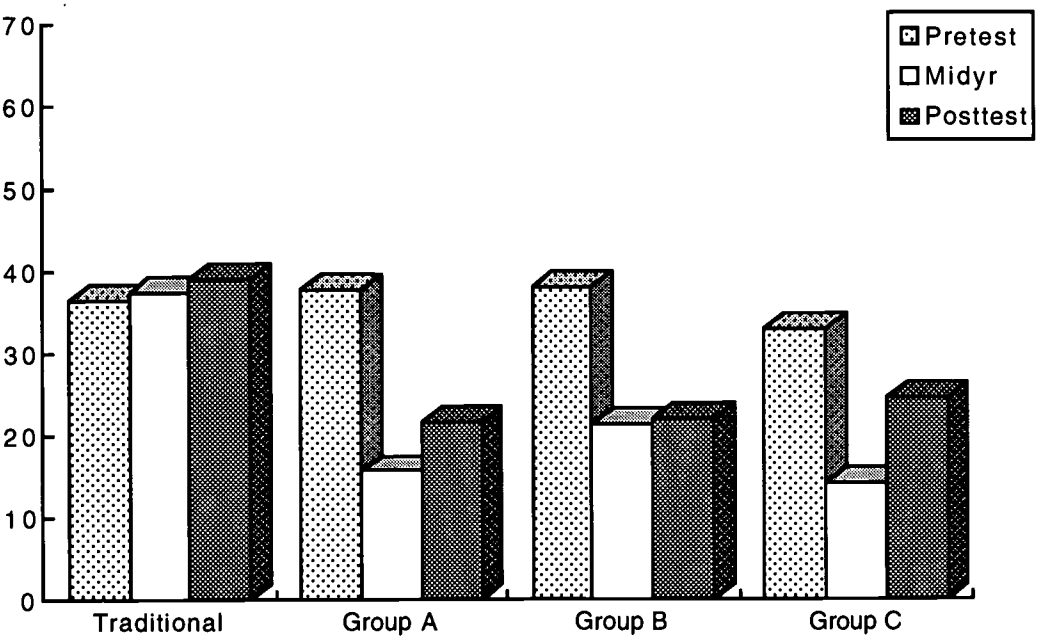
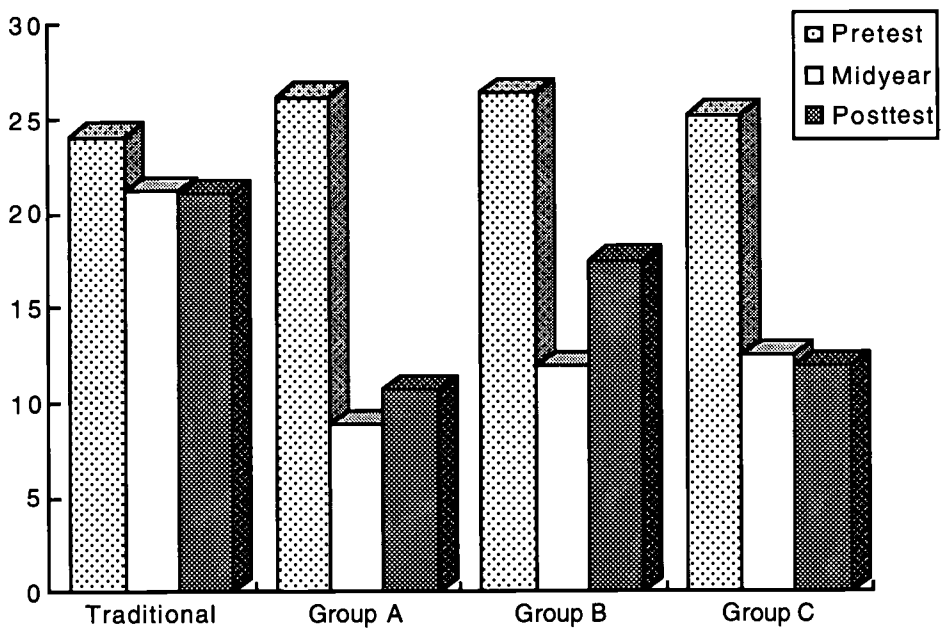


Figure 14
Secondary Students Only: Total Number of Writing Errors per 100 words
at Pretest, Midyear, and Posttest, by Group



Students with learning disabilities were most likely to make errors in spelling, followed by other types of mechanics errors. No difference was found between intervention groups in number of spelling errors. There was a significant difference between times of testing and a significant interaction between testing time and group. As Figure 15 illustrates, students with learning disabilities improved their spelling accuracy over time. However, although students in the three technology groups decreased the number of spelling errors from pretest to midyear, their errors increased or declined only slightly from midyear to posttest. Results for elementary students were the same as those for the sample as a whole. Secondary students showed a similar pattern except that, in all three technology groups, spelling errors appeared to increase from midyear to posttest.

Figure 15
Number of Spelling Errors per 100 Words
at Pretest, Midyear, and Posttest, by Group



Use of Word Processing Tools by Students with Learning Disabilities

All students with learning disabilities in the three technology groups were observed during data collection at midyear and posttest to determine their facility with the word processing tools in Write:OutLoud. At midyear, almost all students (99%) used the spelling checker built into the word processor as they prepared their final draft. The spelling checker was able to suggest the correct option for misspelled words 70% of the time, a rate substantially higher than that of Write This Way, the program investigated in Study 2. When the correct spelling was suggested, students selected that spelling 76% of the time.

At posttest, almost all (93%) students used speech, although a smaller percentage (88%) used speech in accordance with their assigned treatment protocol. Speech was used during text input by 90% of students in Groups A (speech during text input only) and C (speech at all times). Students in Groups B (speech during editing/revising only) and C (speech at all times) used speech at different rates for various editing tasks: 77% used speech with the spelling checker, 60% to read their first draft aloud, and 37% to read their second draft aloud.

The spelling checker was used by almost all students (99%) at posttest. Again, the spelling checker proved to be quite accurate. It was able to suggest the correct option for misspelled words 69% of the time and, when the correct spelling was suggested, students selected that spelling 82% of the time. When students used speech and were given the correct option, they chose that option 80% of the time. Students also made accurate corrections when the spell checker did not offer the correct spelling: 13% of the time overall, and 18% of the time when speech was used.

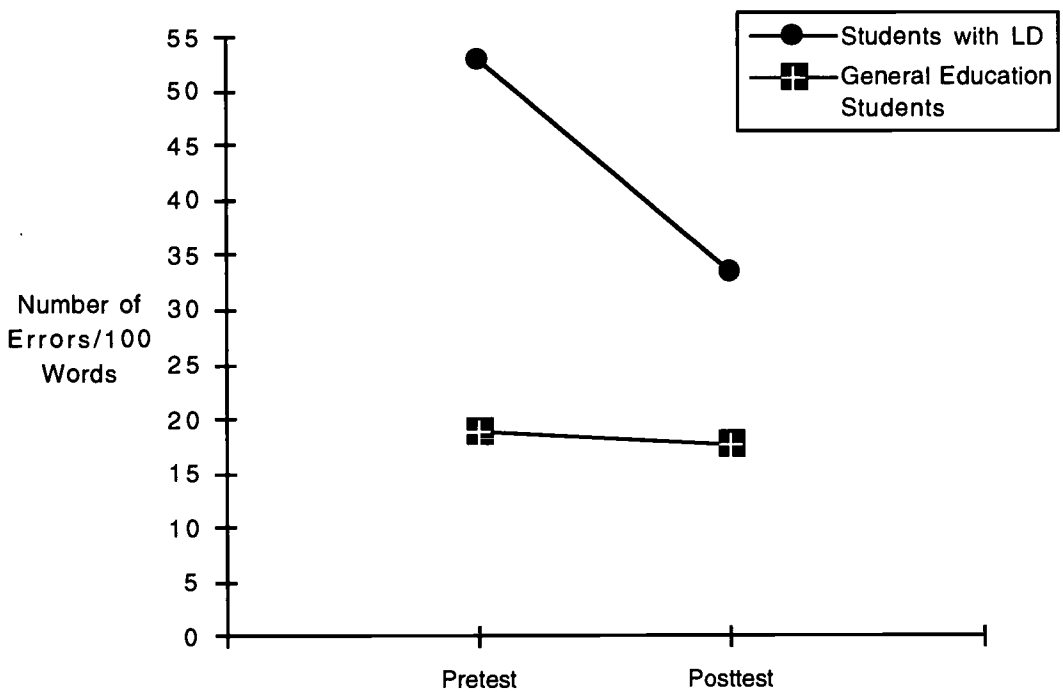
Attitude Toward Writing

Attitude was assessed with a 15-item scale adapted from a published attitude measure. No difference was found between intervention groups or between times of testing; there was no significant interaction between group and testing time. All groups of students with learning disabilities showed moderately positive attitudes toward writing at both pretest and posttest.

Comparisons with General Education Grade Peers

The performance of students with learning disabilities was compared to that of general education grade peers on writing quality, accuracy, and attitude toward writing. In all three areas, general education students were superior to students with learning disabilities and posttest performance was superior to pretest performance. Significant interactions were found between group and time of testing for two variables: attitude and accuracy. In attitude toward writing, students with learning disabilities showed a slight decrease over time whereas general education students showed a slight increase. In accuracy (see Figure 16), the decrease in total number of errors over time was much sharper for students with learning disabilities than for their general education peers.

Figure 16
Interaction between Group and Time of Testing
on Total Number of Errors



Views of Students with Learning Disabilities and Their Teachers

All teachers and technology group students were interviewed about their reactions to the word processing program they had used. Teachers and students were generally positive about their experiences; 87% of teachers said

they would recommend Write:OutLoud to others and 91% of students made positive comments about the program. Of the 6 negative comments about this program, 4 were made by secondary students; the comments of the other 11 secondary students were positive.

Both teachers and students saw the advantages of Write:OutLoud to be its speech and spelling checker. The major disadvantages both related to speed: the program ran slowly and speech slowed students down. When asked whether the speech feature was helpful, 88% of the teachers in Group A (speech during text entry), 63% of those in Group B (speech during editing/revising), and 100% of those in Group C (speech at all times) said yes. Students were asked to comment on the value of speech at different stages of the writing process. Seventy-one percent felt that speech during text entry was helpful (Groups A and C), 90% said it was useful to hear their story read aloud (Groups B and C), and 83% said it was helpful to use speech with the spelling checker (Groups B and C).

Most teachers reported that their students had made gains in their writing skills during the school year, and 96% of students agreed that Write:OutLoud was a helpful tool for writing. Teachers were able to relate "success stories" about their students. The stories most typically reflected improvements in attitude and motivation, in writing skills, and in fluency.

Discussion

This study investigated the effectiveness of speech synthesis in enhancing the performance of students with learning disabilities across the writing process. In addition, the study design allowed evaluation of the effects of a word processor with spell checker without speech and when speech synthesis was added. The major outcome variables of interest were writing quality, writing accuracy, and attitude toward writing.

Results indicated that writing quality improved for students with learning disabilities over time but that there was a significant interaction between time and treatment group. Students in the three technology groups showed improvement in quality from pretest to midyear, the period during which the word processor and spelling checker were used without speech. However, when speech was introduced (from midyear to posttest), writing quality declined for two of the groups and showed no change in the other. This effect was even more pronounced for secondary students: quality declined for secondary

students in all three technology groups. Thus, it appears that the addition of synthesized speech does not enhance the writing quality of students with learning disabilities.

Results were quite similar in the area of writing accuracy. Overall accuracy improved over time; the total number of errors per 100 words decreased. In the area of spelling, accuracy also improved over time and there was a significant interaction between testing time and group. The largest decreases in spelling errors were made from pretest to midyear, and two of the three technology groups showed increases in spelling errors from midyear to posttest. For secondary students, all technology groups increased their error rate under the speech condition. Thus, it seems possible that synthesized speech may have a negative effect on the writing accuracy of students with learning disabilities, particularly those in the secondary grades.

Results of midyear and posttest observations of technology group students with learning disabilities indicated that, while most students used the spelling checker and speech synthesis according to their treatment protocols, some students did not. Other researchers (Anderson-Inman, Knox-Quinn, & Horney, 1996; MacArthur & Haynes, 1995; Wise & Olson, 1994) have also reported students' failure to take advantage of software features; Anderson-Inman and her colleagues call these students "Reluctant Users."

The spelling checker in Write:OutLoud appears more accurate than that of the word processor used in Study 2 and those described by other researchers (MacArthur et al., 1996). The spelling checker suggested correct options for misspelled words 70% of the time at midyear and 69% of the time at posttest. Students were able to select the correct spelling 76% of the time at midyear and 82% of the time at posttest. At posttest, speech was used most often during text input (Groups A and C), with the spelling checker (Groups B and C), and to read first drafts aloud (Groups B and C).

Attitudes of students with learning disabilities toward writing were moderately positive, although they declined over time. When compared to general education grade peers, students with learning disabilities showed inferior performance in all areas under study: writing quality, accuracy, and attitude toward writing. As in both Study 1 and Study 2, the achievement gap appeared to narrow in writing accuracy. Students with learning disabilities who wrote with a word processor showed a marked decrease in writing errors over time; their general education peers did not.

CONCLUSIONS AND RECOMMENDATIONS

Although the three studies conducted in the Enhancing Writing Skills Project each focused on different types of word processing tools, it is possible to draw some overall conclusions from this body of research and to offer at least tentative recommendations to practitioners. This section of the Final Report presents conclusions based on the findings of the three investigations and provides suggestions for educators to consider when making decisions about the use of word processing programs and tools for students with learning disabilities.

Conclusions

The major conclusion arising from this body of research is that word processing programs and tools enhance some, but not all, aspects of the written language performance of students with learning disabilities. In general, word processing has the most impact upon the accuracy of students' writing, allowing students with poor handwriting and spelling skills to improve the appearance of their work and to decrease the frequency with which misspelled words appear. There are also important differences among the various word processing tools in their effectiveness in aiding students and in their acceptability to both students and teachers. The sections that follow discuss these conclusions along with others emanating from the individual studies and the project as a whole.

Characteristics of Study Participants

The more than 300 students who participated in the three studies were each identified as having specific learning disabilities by their school districts. These students were characterized by severe deficits in writing performance despite average intellectual performance. It is important to note that the writing problems that these students faced were not minor. Across the three studies, students' average standard scores on individually administered measures of writing performance ranged from 74 to 79; average Full Scale IQ scores ranged from 95 to 98. Students were enrolled in grades 4 through 12, although the majority of participants across the studies were in the elementary grades. As is the case in the national population, boys with learning disabilities outnumbered girls, and about three-fourths of the students were served in resource programs rather than special classes.

Strategies for Increasing Writing Speed

Word prediction appears to be the most promising strategy for improving the text entry speed of students with learning disabilities as they make the transition from writing by hand to writing on the computer. When used for a 20-week period, word prediction allowed students to achieve a typing speed equal to 82% of their handwriting speed. In previous research (MacArthur & Graham, 1987), students transitioning to keyboarding achieved a keyboarding speed only half that of their handwriting speed.

The issue of whether to teach keyboarding skills to students with learning disabilities is an important one. It can be argued that, although it takes time for students to learn a systematic method of interacting with the standard keyboard, efforts will eventually pay off because students will have a quick, efficient strategy for text input. The results of Study 1 suggest that efficient keyboarding skills cannot be acquired in one school year, at least using the interventions we employed. After 20 weeks, students who did not receive keyboarding instruction achieved the same speed (in relation to their initial handwriting rate) as those who did. It is possible that practice with keyboarding may be as beneficial as systematic keyboarding instruction, at least in the short term.

There are a number of considerations in selecting instructional approaches for students with learning disabilities. One is the acceptability of an approach to teachers and students. Teachers appear more willing to adopt instructional strategies, including word processing programs and tools, when they are easy to learn and, once learned, easy to use. Students are also concerned about ease of use and they hold definite opinions about the acceptability of various text entry strategies. For example, older students were critical of the IntelliKeys alternative keyboard because they viewed its appearance as juvenile and different from the standard keyboard.

Another important consideration are the tradeoffs that must be made in the selection of an instructional approach. The focus of Study 1 was text entry speed, and the strategy with which students fared the worse in terms of speed was word prediction with speech. However, that strategy appeared to produce the most impressive gains in students' ability to avoid making the most common type of spelling error (writing pseudo or nonreal words). Before making a final decision about the most appropriate strategy for any student, it is necessary to consider both the advantages and disadvantages of the available options.

It is interesting to note that, in Study 1, all groups of students with learning disabilities who wrote with a word processor showed a decrease in nonreal word spelling errors; students with learning disabilities who continued to write with paper and pencil did not. These results are based on students' first drafts, written by hand at pretest and written without the aid of a spelling checker at posttest. One explanation relates to the poor handwriting that many students with learning disabilities exhibit. It may be that students are better able to detect and correct spelling errors when they view legible text on the screen than when they must read their own handwriting.

Spelling and Grammar Checkers as Editing/Revising Tools

Spelling checkers appear to be effective editing tools for students with learning disabilities, although grammar checkers do not. However, it is difficult to draw conclusions about the value of grammar checking tools for this population for two reasons. First, grammar checkers are rarely included as a feature in word processing programs designed for students in grades 4 through 12, the target population in this project. Second, in the one word processor meeting requirements for Study 2, the algorithms underlying the grammar checker rely upon text with correctly spelled words. Students with learning disabilities are unlikely to write text that is free of misspelled words.

When students with learning disabilities use editing/revising tools such as spelling and grammar checkers, they make fewer changes in their original drafts. However, the changes that they do make are more likely to be positive changes, resulting in error corrections. For example, students with learning disabilities who used word processors with spelling and grammar checkers made successful corrections about two-thirds of the time. Students with learning disabilities who wrote by hand and students without disabilities were able to make successful corrections less than half the time.

Spelling checkers vary in their levels of effectiveness. In Study 2, the spelling checker in the word processor Write This Way was able to offer correct suggestions for misspelled words 50% of the time. This result was consistent with previous research (MacArthur et al., 1996) in which spelling checkers gave correct suggestions 50% to 65% of the time. In Study 3, the spelling checker in the word processor Write:OutLoud was more effective; it provided correct suggestions 70% of the time at midyear and 69% of the time at posttest.

Another important finding is that students with learning disabilities appear able to select the correct option when it is suggested by spelling checkers. In Study 2, students chose the correct option 94% of the time. In Study 3, students chose the correct option 76% of the time at midyear and 82% of the time at posttest. Although unable to recall the correct spelling of words that they are writing, students with learning disabilities appear able to recognize the correct spelling when it is presented in a list of suggested options.

Speech Synthesis

The findings relative to the addition of synthesized speech to word processors are contradictory and difficult to explain. In Study 1, students who used word prediction with speech were the most successful in decreasing the most common type of spelling error. In Study 2, students who used spelling checkers with speech were the most successful in making corrections in misspelled words when the spelling checker was unable to suggest the correct option; similar results were obtained in Study 3. However, in Study 3, spelling checkers appeared to have a much more positive effect on students' writing quality and accuracy than synthesized speech. When the speech feature of Write:OutLoud was activated, little change was seen in the performance of elementary grade students. Students in the secondary grades also did not improve and, although it is difficult to draw firm conclusions from the small number of secondary students included in the sample, they appeared to experience declines in performance. One possible explanation is that speech acts as a distraction to older students, drawing their attention away from the conceptual aspects of the writing task.

One of the issues with speech synthesis is that listening to speech takes time. In Study 1, the students who used speech had the slowest text entry speed; it takes time for the word prediction program to read the list of suggested options aloud. In Study 3, the writing samples were collected from students under timed conditions. It is possible that the use of speech slowed the editing/revising process, causing students to make fewer changes as they prepared their final drafts. Further analyses will be carried out on the Year 3 data to determine if this was the case.

Narrowing the Achievement Gap with General Education Students

A clear result from all three studies is that the achievement gap between students with learning disabilities and their general education grade peers narrowed over time in writing accuracy. This is a very important finding. Students with learning disabilities who used technology saw sharp drops in writing errors over time, and these declines moved their level of performance closer to that of their grade peers. Students with learning disabilities become more likely to be able to succeed in general education classrooms as their skills in written language approach those of their grade peers.

The question remains as to the cause or causes of this increase in writing accuracy. In Study 1, students wrote with a word processor and various text entry tools; first drafts completed without the aid of a spell checker were analyzed for accuracy. In Study 2 and Study 3, students wrote with a word processor and spelling checker; final drafts were analyzed for accuracy. It is possible that word processing alone contributes to increases in writing accuracy and that the addition of spell checking further enhances performance.

Success Stories

Students with learning disabilities and their special education teachers who participated in the three studies were generally positive about the word processing programs and tools they used. Noteworthy exceptions were the alternative keyboard in Study 1 and the grammar checker in Study 2. Both teachers and students complained about programs that ran slowly and problems with computers such as slow operation and freezing. In most cases, it is likely that the hardware was at fault, rather than the software, given the age of the computers available to students in special education programs.

At the conclusion of each school year, teachers were asked to share success stories about students who had participated in the project. The most typical areas of improvement teachers noted were attitude and motivation, writing skills, fluency, and form. Examples of these stories appear in Table 4.

Table 4
Success Stories

Type of Improvement	Examples
Improved Attitude, Increased Motivation	• All of them have developed a better attitude -- participating more, writing more in journals. One student would throw desk, books, even run out of room when writing mentioned -- now writing a lot in journal, wants to read what he wrote aloud. Writes little notes to mom, grandma on computer. • Student X at the beginning of the year when given a writing assignment would shake, even cry, and would have tremendous difficulty with spelling errors. He now writes, is comfortable at the computer, and can do it. • One student hated to and refused to revise. This year he doesn't even complain. He's into it, does the spell checker. The regular ed. students asked the regular ed. teacher if they could come to RSP [Resource Specialist Program] because it must be for really smart people because of their computer use and knowledge. My kids know more about the computer than some of their teachers. • Student X feels much better about himself. Will stay after school to do assignments on computer, and actually turns them in. • Students quit saying 'I can't.' • Learning how to write a report on the computer was a biggy. Increased their confidence a LOT! • Student X feels much better about himself. Will stay after school to do assignments on computer, and actually turns them in.
Skill Improvement	• Student won a writing contest through Sammy's Pizza and won $50. • Student X was off the charts in improvement.

	• Student X -- he hates to write. He writes so poorly and it has really improved. When he is on the computer, his final draft is so much more intelligible (grammar, spelling, quality, and quantity). • Two of my students were chosen for the "Authors' Tea." • Student X went from a 0 to a 3 (0-6 rubric) on district writing prompt.
Increased Fluency	• Student X at the beginning would hardly write two sentences. His volume has quadrupled and he takes much less time. Spell check has improved his spelling. He recognized correct words. • Student used to write one sentence with prodding, now writes complete stories. • Student has quadrupled his output. • Student X couldn't get his ideas down on paper. Now has been freed, knows he has the abilities now. • Student X has come from writing nothing to writing stories.
Improved Form	• Student has made it to a simple three paragraph story. Has more of a concept of paragraphs. • Student's Beowulf essay -- very good job. Five paragraph essay, prewrite through final draft. • One student who never got past basic sentence writing is now capable of seeing the big picture of beginning/middle/end and is writing multi-paragraph stories with imagination.

Recommendations for Practitioners

Research results must always be viewed as tentative until they are confirmed by other investigators. However, it is also important to translate research results into guidelines that can inform practice. To that end, this set of tentative recommendations is offered.

1. Combine good writing instruction with word processor use. Use the writing-as-a-process model and teach students strategies for planning, editing, and revising. Also teach strategies for using the word processor and its features such as spelling checkers.
2. When selecting a word processing program or tool, consider these factors:
   - *Ease of use.* The student's skill levels must be the first concern in evaluating ease of use. However, it is also important to consider the demands placed on the teacher. An approach that requires a great deal of teacher time and effort is not likely to be used with any regularity.
   - *Capabilities of the computer.* Determine whether the computer has sufficient power and memory to run the program quickly and efficiently.
   - *Acceptability to the student.* Like any other instructional material, software programs and computer devices should be age-appropriate. The best judges of this are students themselves; they are the experts who must determine if something is too juvenile or too different to fit within their comfort zone.
3. Consider a word prediction program such as Co:Writer to increase text entry speed. This program is not a word processor; it is used in addition to a word processor. When the student types the first letter of a word, programs like Co:Writer attempt to predict the word being entered and list several alternatives. If the correct word is not displayed, the student types the second letter to see a second array of choices. The process continues until the correct word is available for selection.
4. Choose a word processor with a spelling checker. Select a program such as Write:OutLoud that has been found effective with students with learning disabilities. If no information is available about a program, use samples of students' work to evaluate the effectiveness of the spell checker.

5. Remember that spelling checkers are not perfect.
   - Spelling checkers don't recognize "personal" words. Choose a program that lets you add to the spelling dictionary. Add students' and teachers' names, the name of the school and its teams, and other words as needed.
   - Spelling checkers don't recognize "real word" errors. The biggest problems are homonyms and careless errors (e.g., "the" for "they").
   - Spelling checkers suggest alternatives but the correct word isn't always there. Encourage students to use a strategy such as SpellCHECK to systematically change the spelling of the word so that the spelling checker can recognize it.
   - Some students can't read the words that spelling checkers suggest. Consider a word processor with speech.
   - Spelling checkers are an aid to spelling, not a replacement for spelling instruction.
6. Be wary of grammar checkers. Before using a word processor with a grammar checker, evaluate the checker carefully to determine if it detects errors accurately and provides help messages that will be intelligible and useful to students.
7. Speech synthesis is more likely to be helpful to younger students than to older students. When using a word processor with speech, carefully evaluate the effects it is having on students' writing performance.
8. Balance concerns about writing speed with other benefits. Word processing increases legibility, a potentially important benefit even if speed decreases. Tradeoffs may be necessary. Approaches that offer improved writing accuracy and quality do not always improve writing speed.
9. Think about combining approaches. For example, some students may benefit from using word prediction with a program that offers a powerful spelling checker.
10. Whatever approach is selected, monitor the student's progress and re-evaluate, as necessary. As with any other instructional intervention, ongoing assessment of the student's progress provides information about the effectiveness of the intervention and alerts the teacher to the need for change if the student is not experiencing success.

DISSEMINATION EFFORTS

Activities and research findings of the Enhancing Writing Skills Project have been disseminated in two ways: through presentations at professional conferences and in publications. By the end of academic year 1997-98, project staff will have made more than a dozen conference presentations. These presentations have targeted a variety of audiences including special education teachers, teacher educators, and researchers (e.g., Council for Exceptional Children Conference), special education technology practitioners (e.g., the Closing the Gap and California State University, Northridge Conferences), and parents of individuals with learning disabilities (Learning Disabilities Association Conference). Reports of project findings have been or will be disseminated in a variety of publications including proceedings of the annual California State University, Northridge Conference, *Closing the Gap,* and *Learning Disabilities Research and Practice.* Additional manuscripts have been submitted for review and a manuscript reporting the results of Study 3 is in preparation. It is also anticipated that at least one manuscript will be written summarizing the results of all studies and offering recommendations to practitioners.

The dissemination efforts of the Enhancing Writing Skills Project to date appear in the list that follows. That list is organized first by study and then by type of dissemination activity.

Study 1: Text Entry Tools

Conference Presentations

Lewis, R. B., & Ashton, T. (1995, October). *Optimizing word processing for persons with learning disabilities: Choosing the best text entry mode.* Paper presented at the 1995 Closing the Gap Conference, Minneapolis, MN.

Lewis, R. B., Ashton, T., & Kieley, C. (1996, March). *Word processing and individuals with learning disabilities: Overcoming the keyboard barrier.* Paper presented at the 1996 CSUN Technology and Persons with Disabilities Conference, Los Angeles, CA.

Lewis, R. B., Graves, A., Ashton, T., & Kieley, C. (1996, April). *Enhancing writing skills of students with learning disabilities through instruction and*

technology. Paper presented at the 1996 Council for Exceptional Children Conference, Orlando, FL.

Lewis, R. B., Graves, A., Ashton, T., & Kieley, C. (1996, April). *Text entry strategies for improving writing fluency of students with learning disabilities.* Poster session presented at the 1996 Council for Exceptional Children Conference, Orlando, FL.

Graves, A. (1996, April). *Word processing and individuals with learning disabilities: Overcoming the keyboard barrier.* Paper presented at the American Educational Research Association Conference, New York, NY.

Ashton, T. M. (1996, November). *Optimizing word processing for persons with learning disabilities: Choosing the best text entry mode.* Paper presented at the 1996 West Coast Special Education Conference, Anaheim, CA.

Publications

Lewis, R. B., Ashton, T., & Kieley, C. (1996). Word processing and individuals with learning disabilities: Overcoming the keyboard barrier. In *Eleventh Annual Conference of Technology for People with Disabilities, California State University, Northridge, submitted papers, 1996* [computer software]. Newport Beach, CA: Rapidtext.

Ashton, T. (1996). Students with learning disabilities are using computers in San Diego County schools. *The Journal of the California State Federation-Council for Exceptional Children, 47*(1), 11-12.

Lewis, R. B., Graves, A. W., Ashton, T. M., & Kieley, C. L. (in press). Word processing tools for students with learning disabilities: A comparison of strategies to increase text entry speed. *Learning Disabilities Research & Practice, 13*(2), 105-118.

Study 2: Editing Tools

Conference Presentations

Lewis, R. B., & Ashton, T. (1996, July). *Enhancing Writing Skills Project: Software tools for evaluating writing samples.* Poster session presented at the 1996 Office of Special Education Programs Project Directors' Conference, Washington, D.C.

Lewis, R., Ashton, T., & Kieley, C. (1996, October). *Word processing for persons with learning disabilities: Choosing effective tools for revising and editing.* Paper presented at the 1996 Closing the Gap Conference, Minneapolis, MN.

Ashton, T. M., & Kieley, C. (1996, November). *Help for struggling writers through technology.* Paper presented at the 1996 San Diego Computer Using Educator's Technology Fair, San Diego, CA.

Lewis, R. B., Ashton, T., Kieley, C., & Debol, M. (1997, February). *Using word processing to enhance the writing skills of students with learning disabilities.* Paper presented at the 1977 International Technology and Media Division Conference, San Jose, CA.

Lewis, R. B., & Ashton, T. (1997, February). *Computer-assisted writing: Using word processing to improve the writing skills of individuals with learning disabilities.* Paper presented at the 1997 Learning Disabilities Association Conference, Chicago, IL.

Lewis, R., Ashton, T., Haapa, B., & Fielden, C. (1997, March). *Word processing tools for editing and revising: Improving the writing skills of persons with learning disabilities.* Paper presented at the 1997 CSUN Technology and Persons with Disabilities Conference, Los Angeles, CA.

Ashton, T. M. (1997, May). *A qualitative analysis of the influence of word processing on the editing and revising strategies of students with learning disabilities.* Paper presented at the 1997 California State University Research Competition, San Luis Obispo, CA.

Lewis, R. B., & Ashton, T. (1997, July). *Enhancing the writing skills of students with learning disabilities through technology: An investigation of the effects of text entry tools, editing tools, and speech synthesis.* Poster session presented at the 1996 Office of Special Education Programs Project Directors' Conference, Washington, D.C.

Ashton, T. M. (1997, July). *Word processing for students with written language deficits: Choosing effective tools for text entry, revising, and editing.* Paper presented at the 1997 Pi Lambda Theta Leadership Conference and Biennial Council, San Diego, CA.

Publications

Lewis, R., Ashton, T., Haapa, B., & Fielden, C. (1997). Word processing tools for editing and revising: Improving the writing skills of persons with learning disabilities. In *Twelfth Annual Conference of Technology for People with Disabilities, California State University, Northridge, submitted papers, 1997* [computer software]. Newport Beach, CA: Rapidtext.

Lewis, R. B., Ashton, T. M., Haapa, B., Kieley, C. L., & Fielden C. (manuscript submitted for review). Improving the Writing Skills of Students with

Learning Disabilities: Are Word Processors with Spelling and Grammar Checkers Useful?

Ashton, T. M. (manuscript submitted for review). Making technology work in the inclusive classroom: A spell CHECKing strategy for students with learning disabilities.

Study 3: Synthesized Speech

Conference Presentations

Lewis, R. B., Ashton, T., Kieley, C., & Debol, M. (1998, March). *Talking word processors: Do they assist individuals with learning disabilities in the writing process?* Paper presented at the 1998 Learning Disabilities Association Conference, Washington, DC.

Lewis, R. B., & Ashton, T. (1998, April). *Benefits of talking word processors for students with learning disabilities.* Paper presented at the 1998 Council for Exceptional Children Conference, Minneapolis, MN.

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Lewis, R., & Ashton, T. (1998, February/March). Talking word processors: Useful tools for person with learning disabilities. *Closing the Gap, 16*(6), pp. 8-9.

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