Using Technology to Enhance the Writing Processes of Students with Learning Disabilities

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Abstract

This article reviews the ways that computers can support writing by students with learning disabilities, with an emphasis on applications that go beyond word processing. Following an overview of research on word processing is a discussion of software that assists with the basic processes of transcription and sentence generation, including spelling checkers, speech synthesis, word prediction, and grammar and style checkers. Next, applications that support the cognitive processes of planning are reviewed, including prompting programs, outlining and semantic mapping software, and multimedia applications. Finally, the use of computer networks to support collaboration and communication with diverse audiences is addressed.

Mark, a sixth-grade student with a severe reading disability, enjoys talking about his interests in class. However, on writing tasks, his spelling is often so unusual that even he cannot read what he has written. Consequently, Mark is extremely reluctant to write. In school, he uses a word processor that provides speech synthesis and a personalized word bank. He discusses his topic individually with the teacher, who adds key words from this discussion to his word bank. As he writes, Mark can select many of the words he needs from the word bank, rather than having to spell them. The speech synthesizer provides a check on the accuracy of his writing and supports his reading as he prepares to share his writing orally with his peers.

Each month a flurry of activity breaks out in Mrs. Adams's class as the deadline for the class magazine approaches. Students rush to complete and edit their best writing. The editors for the month collaborate on layout and production. Desktop publishing software enables them to produce a professional-looking product, with headlines, graphics, and neat columns of text. This regular publishing project has had a dramatic impact on the amount and quality of writing produced by this class. Parents and peers who read the magazine cannot tell from the product that the writers are all students with learning disabilities (LD).

As these examples illustrate, computers are flexible writing tools that can enhance writing processes in many ways. They can support the basic skill of being able to produce legible text with correct mechanics, as well as the more complex cognitive processes of planning, writing, and revising text and the social processes of collaboration and communication with an audience.

The support provided by computers may be especially beneficial for students with LD, who often find writing frustrating. Students with LD perform less well than their peers on a variety of written language tasks (Englert, Raphael, Anderson, Gregg, & Anthony, 1989; Graham, Harris, MacArthur, & Schwartz, 1991). They often have difficulty with the physical demands and conventions of writing and with fluent production of sentences. Many students with LD have difficulty coordinating the complex cognitive processes of setting goals, generating content, organizing their writing, and evaluating and revising their text. However, recent research demonstrates that instructional programs that provide (a) a supportive social context for writing in the classroom, (b) meaningful writing tasks, and (c) instruction in writing processes can improve the writing achievement of students with LD (Englert, Raphael, Anderson, Anthony, & Stevens, 1991; MacArthur, Graham, & Schwartz, 1993).

The purpose of this article is to review specific ways in which computers can support the writing processes of, and enhance writing instruction for, students with LD. Because word processing is now quite common in schools (Becker, 1993) and published research reviews on word processing are available (Bangert-Drowns, 1993; Cochran-Smith, 1991; MacArthur, 1988), the present review starts with a brief overview of that research. The major focus of the article is on com-

puter applications that go beyond word processing. Following the overview of word processing is a discussion of computer tools that can assist with the basic processes of transcription and sentence generation. Next, applications that support the cognitive processes of planning are reviewed. Finally, the use of computer networks to support collaborative writing and communication with diverse audiences is addressed. It is important to note that many of these applications, particularly the more recent advances, have little or no research support. Because development generally precedes research in this field, this article is not limited to research-supported techniques; however, the discussions clarify the extent to which the techniques are supported by research.

Word Processing

Word processors have several capabilities that may influence the writing process. First, the editing features of the word processor allow writers to make frequent revisions without tedious recopying. Consequently, writers may make more revisions, and it is possible that this ease of revision will encourage students to concentrate on content while writing a first draft and edit for mechanics later (Daiute, 1986a). The potential impact of word processing on revising is significant, as revision is an important aspect of the composing process that distinguishes expert writers from younger and less skilled writers (Fitzgerald, 1987). Students with LD, in particular, have a limited conception of revising as being an opportunity to correct errors, and their revisions are restricted primarily to minor changes that do not affect the overall meaning or quality of writing (MacArthur, Graham, & Schwartz, 1991).

Simply having access to word processing has little impact on the revising behaviors of students with LD; for example, MacArthur and Graham (1987) found no differences in the number or type of revisions such students made using paper and pencil compared to using word processing. Furthermore, the final drafts of papers written on a word processor did not differ from those written by hand on any of the measures used in the study, including overall quality; length; story structure; vocabulary; syntactic complexity; or errors in spelling, capitalization, and punctuation. Only two minor differences were found between handwriting and word processing: More deletions were made with the former; and word processing resulted in more revisions during writing of the first draft, whereas nearly all revisions with handwriting were made while writing the second draft.

However, instruction in revision in combination with word processing can significantly increase the amount and quality of revision by students with LD (Graham & MacArthur, 1988; MacArthur, Schwartz, & Graham, 1991; Stoddard & MacArthur, 1993). Graham and MacArthur taught elementary-school students with LD a strategy for revising opinion essays. The strategy focused on substantive revisions, such as stating the thesis clearly, giving and supporting reasons, increasing the coherence of text, and closing with a summary statement. MacArthur and his colleagues (MacArthur, Schwartz, & Graham, 1991; Stoddard & MacArthur, 1993) provided instruction in a peer revising strategy in which pairs of students with LD learned to help each other revise papers written on a word processor. In all three studies, strategy instruction in combination with word processing resulted in increases in substantive revisions and improvement in overall quality of compositions.

Second, word processors give students the power to produce neat, printed work and to correct errors without messy erasures. The literature on process approaches to writing and whole language places considerable emphasis on the value of publishing students' writing (Calkins, 1991). The motivation provided by printed published work may be especially important for students who struggle with handwriting and mechanics. Computers make it possible to publish in a wide range of professional-looking formats. Desktop publishing programs make it easy to produce newsletters, illustrated books, big books, business letters, signs and posters, and many other forms of work.

A third feature of word processors that is mentioned less often is the visibility of the text on the screen (MacArthur, 1988). This visibility, together with the use of typing rather than handwriting, can facilitate collaborative writing among peers and scaffolded interactions between teacher and student. Peers can work together, sharing responsibility for generating ideas, typing, and revising in flexible ways, as both partners can see and read the text easily and typing does not identify separate contributions. Daiute (1986b) studied pairs of low-achieving elementary-school students working on a series of collaborative writing tasks. Through careful analysis of student talk and the resulting written products, she documented ways in which the students learned writing techniques from each other.

In addition to facilitating peer collaboration, word processing can enhance scaffolded interactions between teachers and students. The visibility of the text on the screen enables teachers to more easily observe students' writing processes and intervene when appropriate (Morocco & Neuman, 1986). Teachers can scaffold students' writing by sharing writing tasks and providing appropriate coaching (Cochran-Smith, 1991). The visibility of text on the screen can also support teacher-directed group lessons. Using a large monitor or projection panel, teachers can model writing processes and discuss strategies for planning and revising. As with the other features of word processing, the impact of greater collaboration depends on the instruc-

tional program and the skill of the teacher.

Finally, typing is substantially different from handwriting. Typing is probably inherently easier than handwriting, especially for students with handwriting problems. On the other hand, typing can also be a barrier, as it is not a standard part of curricula. Students need some typing instruction if they are to use word processors regularly (MacArthur et al., 1993).

A relatively large number of studies have investigated the use of word processing with nondisabled populations. A recent meta-analysis by Bangert-Drowns (1993) found that use of word processing in writing instruction programs had a positive, though relatively modest, impact on students' writing. Cochran-Smith (1991) concluded that students have positive attitudes toward word processing but that the impact of computers on the quality of students' writing and writing processes depends on teachers' strategies for using word processing, and on the social organization of the classroom. MacArthur (1988) discussed the potential benefits and problems associated with using word processing with students with LD and reviewed the limited and inconclusive research with that population. More recent studies (MacArthur et al., 1993; Morocco, Dalton, & Tivnan, 1990) have indicated that word processing combined with effective writing instruction can enhance the writing of students with LD.

A growing number of writing support tools are available that go beyond word processing. The next section focuses on computer tools that support the basic writing processes involved in transcription and sentence generation.

Sentence Generation and Transcription

For competent adult writers, the basic processes of formulating grammatically correct sentences and transcribing them into written language are relatively automatic. In fact, evidence from studies comparing dictation and handwriting suggests that for normally achieving students, the mechanics of writing cease to be a limiting factor by the end of elementary school. The dictated stories of primary-grade children are superior to their written stories (King & Rentel, 1981), but by fifth or sixth grade, dictated compositions, although longer, are not qualitatively better than handwritten ones (Hidi & Hildyard, 1983; Scardamalia, Bereiter, & Goelman, 1982). In contrast, the dictated compositions of students with LD have been reported to be substantially longer and qualitatively superior to their compositions written via handwriting or word processing (Graham, 1990; MacArthur & Graham, 1987). The difficulties of students with LD with transcription processes—spelling, capitalization, punctuation, and usage—are well documented (Graham et al., 1991). The dictation studies suggest that these difficulties interfere with the overall composing process. This interference may take a number of forms (e.g., students may avoid using words they cannot spell). The effort devoted to mechanical issues may reduce the cognitive capacity available for planning and revising processes. Students may also write less because of the effort involved or because of low self-confidence.

These sentence-generation and transcription processes are important throughout the stages of writing. Consequently, this section discusses computer tools designed for use during both initial drafting and revising.

Spelling Checkers

The most widespread and generally useful tools to support transcription are spelling checkers. Nearly all word processors designed for adults, and most recent versions targeted at schools, include an integrated spelling checker that can be accessed without leaving the word processor. Spelling checkers perform two functions: They identify misspelled words, and they suggest correct spellings.

Although clearly useful, spelling checkers do have limitations, especially for students with serious spelling problems (Dalton, Winbury, & Morocco, 1990). Two of those limitations pertain to the identification of misspellings. First, spelling checkers flag proper nouns and special terms as errors. Second, and more important, they fail to flag misspelled words that are other words correctly spelled, including homonyms and "other correct words" (e.g., *back* for *bake* or *whet* for *went*). In two recent studies, MacArthur, Graham, and De La Paz (in press) found that about 26% to 38% of spelling errors made by fourth- through eighth-grade students with LD fit into this second category. Dalton (1988) reported that approximately 40% of spelling errors made by fourth-grade students with LD were not identified by spelling checkers. Similar results have been reported for nondisabled students (Mitton, 1987). This problem might be ameliorated by smaller or adjustable-size dictionaries having fewer uncommon words.

Two potential limitations pertain to suggesting correct spellings. First, spelling checkers fail to suggest the correct spelling for many words, especially severe misspellings. Different checkers vary in their ability to suggest the correct word; for example, MacArthur, Graham, and De La Paz (1994) reported that eight spelling checkers found the correct spelling for 46% to 66% of the words the checkers flagged as misspelled. Second, even when the spelling checker suggests the correct word, students with LD may not be able to identify the correct word from the list. Spelling checkers convert the writer's task from producing the correct spelling to recognizing it from among a list of similar words. This recognition task can be difficult for poor spellers, especially if the list is long. Of course, a trade-off exists between the length of the list and inclusion of the correct word. Two soft-

ware design strategies are available to help with this issue: synthesized speech to pronounce the words in the list, and definitions of words in the list.

A recent study of middle school students with LD who had moderate to severe spelling problems provided data on the overall usefulness of spelling checkers (MacArthur, Haynes, & Graham, 1994). Twenty-six students wrote stories and revised their spelling using a spelling checker. They misspelled 4% to 35% of their words. The spelling checker flagged 63% of their errors, missing 37% that were homonyms or other correct words. The correct spelling was suggested for 58% of the flagged words, or 36% of all errors. Students were able to correct 82% of the errors with correct suggestions and 23% of the errors when the correct suggestion was not offered. Overall, students corrected 36% of their errors using the spelling checker.

A final issue about spelling checkers is whether they can be used to promote greater spelling skill as well as to directly compensate for poor spelling. One instructional technique is to have students attempt to locate misspelled words and circle them on a printout prior to using the spelling checker. Handheld spelling checkers, which require students to identify potentially misspelled words and type them on the checker, may encourage this strategy. Another approach is to teach students to use their knowledge to try alternate spellings prior to relying on the computer-generated list of suggestions. These strategies have the potential to transfer to editing spelling errors without a computer.

Speech Synthesis

Speech synthesis software (or hardware) translates text into speech. It is not as natural-sounding as digitized speech, which is recorded, but its advantage is that it can be used to speak any text. Word processors with speech synthesis enable students to hear what they have written and to read what others have written; this capability may support writing by allowing students with writing problems to use their general language sense to monitor the adequacy of their writing (Rosegrant, 1986). For example, students may notice incomplete or awkward sentences, misspelled words, or errors of meaning. In an instructional context that focuses on meaningful communication, talking word processors may help bridge the gap between what children want to express and what they have the skills to read and write. Speech synthesis can scaffold both reading and writing, for example, by helping students read language-experience stories and the writings of their peers.

Research investigating the potential of speech synthesis to improve writing among elementary-school children is limited. Borgh and Dickson (1992) compared word processing with and without speech synthesis with nondisabled second- and fifth-grade students. Both versions of the word processor incorporated a special prompting feature: Each time a period was typed, signaling the end of a sentence, a prompt appeared on the screen reminding the student to reread the sentence and consider revising it. Students did more revising after each sentence with the speech synthesis and less revising at the end of the story. No differences were found in length or quality of writing.

Research on and adoption of speech synthesis have been slowed by problems with the quality of the speech. High-quality speech synthesis, using expensive hardware (e.g., DECtalk, no date), is nearly as comprehensible as recorded speech, but less expensive hardware has been found to have serious comprehensibility problems (Mirenda & Beukelman, 1987). The quality of less expensive software-only speech synthesizers has been improving, though they still do not rival the comprehensibility of digitized (recorded) speech.

Currently, a number of word processors and related writing tools that have speech synthesis are available. The Talking Textwriter (no date) word processing software has been available for some time for both Apple II and IBM; however, it uses the relatively poor Echo speech synthesizer. My Words (1993) provides a straightforward word processor with a variety of text-to-speech options; it will read letters, words, sentences, or the full text. Write:Outloud (1993) provides speech synthesis with similar options for reading letters, words, sentences, or the full text. In addition, it provides spell checking.

Word Prediction and Word Banks

Word prediction was originally developed for individuals with physical disabilities to reduce the number of keystrokes required to type words and sentences. However, it may have potential for students with serious problems with spelling, punctuation, and syntax, as well. A brief description of one word prediction program will provide information about the basic functions (see Figure 1). Co:Writer (1992) is a commercially available program for Macintosh computers that supports word prediction for any word processor. The user types in a window on top of the word processor. As each letter is typed, the software predicts the intended word (offering a list of adjustable length). If the intended word is in the list, the user can type the number of the word or point and click with the mouse to insert the word in the sentence. If the correct word is not present, the user continues to type the next letter and so on. Predictions are based on spelling, syntax, and the words previously used by particular users. Speech synthesis is available to read the words in the list of suggestions, as well as the completed sentence. When the sentence is complete, it is transferred into the word processor.

A related type of software is word processors that include word banks.

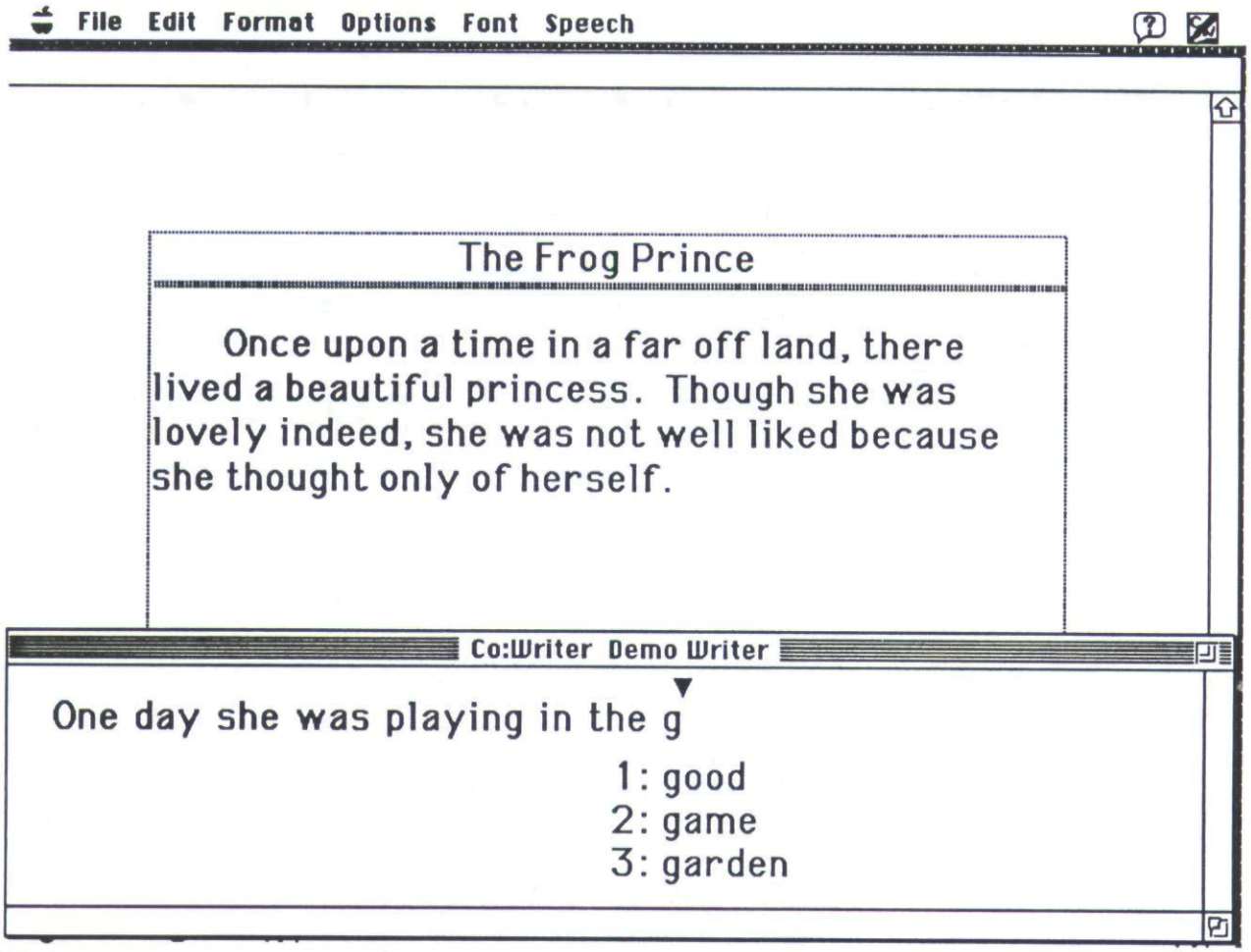

FIGURE 1. Co:Writer word prediction software with a word processor in the background. (The user has just typed "g" and the software has suggested three possible words.)

My Words (1993), for example, is a word processor with speech synthesis and a word bank (see Figure 2). In the default operation, all words typed in the word processor are collected in an alphabetized list of words at the side of the screen. This list can also be edited and locked separately from the writing. As a user types, the list automatically scrolls to find words beginning with the letters typed. For example, as the student types a *t*, the list scrolls to the first word starting with *t*. The student can continue to type or select a word from the list by clicking with the mouse. Such programs provide a limited version of word prediction in a format that may be less intrusive than word prediction programs designed for individuals with physical disabilities.

Another approach to providing vocabulary support for young children is the use of word and picture banks, as in Kid Works 2 (1992). This program includes "boxes" of nouns, verbs, and adjectives. Each word is accompanied by a picture and can be pronounced by speech synthesis. Students can incorporate these words into stories as pictures to create rebus stories, or can translate them into words.

For students with LD, word prediction software and word processors with word banks assist transcription during the process of writing, rather than during revision. They have the potential to support spelling, capitalization, and sentence formation. This potential is untested; I am not aware of any empirical research on word prediction with students with LD. Our research group has conducted preliminary studies with word prediction and word bank software, but no results are available at this time.

Grammar and Style Checkers

Grammar and style checking software goes beyond spelling to check syntax, sentence structure, punctuation and capitalization, and writing style. Several sophisticated style checkers are on the market for college and adult writers, but reviewers seem to disagree on whether the advice they

provide is helpful. In any case, they appear to be of limited value for elementary-school students or poor writers. They successfully identify relatively minor grammatical and stylistic problems, but often do not interpret serious grammatical and mechanical errors correctly. One program, Write This Way (Emerson & Stern Assoc., 1992), was designed specifically to meet the needs of students with LD. It consists of a basic word processor with speech synthesis, spell checking, and grammar checking. Unfortunately, the grammar checker does not appear to be successful at identifying errors in the writing of students with or without LD. In an informal review (MacArthur, 1994), the checker was used to proof 10 writing samples written by elementary-school students with LD and those same papers with spelling, punctuation, and grammatical errors corrected. It did not flag the majority of grammatical errors in the uncorrected writing versions, and it incorrectly flagged many errors in the corrected versions. When it did locate an error, its diagnoses were often difficult to comprehend. In summary, at this time I am not aware of any useful grammar-checking software for students with LD.

Planning Processes

Experienced writers typically devote a substantial portion of writing time to planning activities. They set goals in terms of the intended audience, generate content through memory search and information gathering, and organize their material carefully (Flower & Hayes, 1981). Students with LD may have difficulty with all of these component processes (Englert et al., 1989; Graham et al., 1991). Typically, they begin writing after devoting minimal time to planning. They often have problems generating sufficient appropriate content and thus produce short compositions with limited information. They typically lack awareness of common text structures that could help them in organizing material and in generating more content. In addition, limited background knowledge may interfere with both their reading comprehension and their

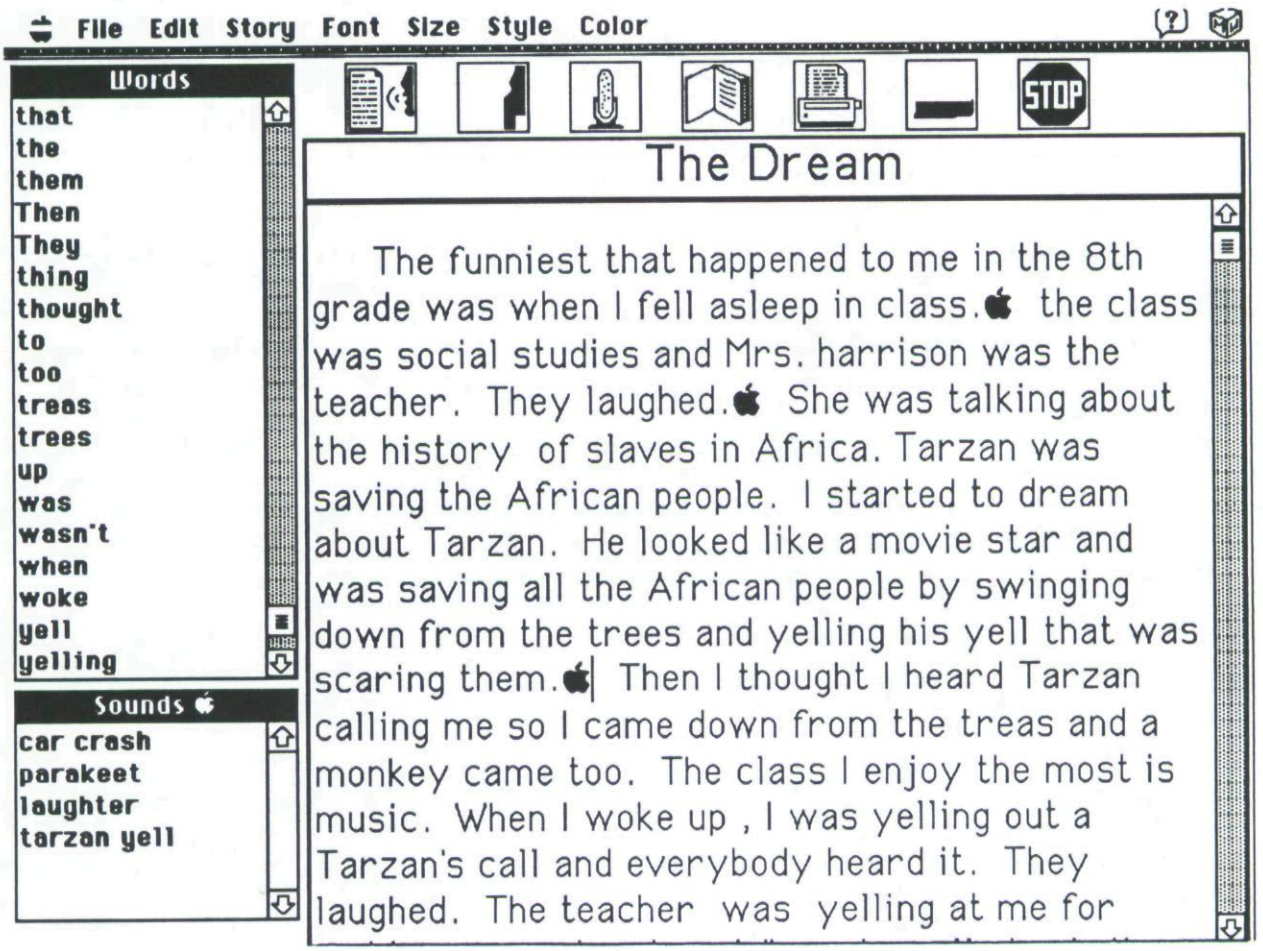

FIGURE 2. My Words, a word processor with speech synthesis and a word bank.

writing (Garner, Alexander, & Hare, 1991).

This section considers several types of software that have the potential to support these students' planning processes and facilitate their access to background knowledge. Revising processes, which also present problems for poor writers, were discussed earlier, in the sections on word processing and transcription support.

Prompting

The interactive capabilities of computers can be used to develop programs that prompt writers to engage in planning processes, by asking them a series of questions or presenting reminders. The most common prompting software presents a series of questions designed to help writers generate ideas prior to writing. These questions can be designed around particular text structures. For example, for a news article, a program might prompt students with "who, where, why, and when" questions; for a story, it might prompt them with questions about characters, problem, action, and resolution. Writer's Helper (1990) contains a large collection of interactive planning programs, including programs that support brainstorming, freewriting, and categorizing, as well as structured questions. At a somewhat lower level of interactivity, several word processors permit teachers to enter series of questions that can be locked. Students write their answers between the questions.

I am not aware of any research on the impact of using such planning programs. However, some research indicates that simple text-structure prompts may enhance the writing of students with LD (Montague, Graves, & Leavell, 1991). Prompting programs might also be used in conjunction with strategy instruction based on text structures (Graham et al., 1991).

Research has been conducted on software programs that provide prompts during the composing process to remind students to engage in planning or revising strategies. Salomon (1992) developed a special writing program that provided guidance (in the form of questions) before, during, and after writing. For example, questions before writing concerned audience, purpose, and content; questions during writing addressed elaboration, organization, explicitness; and questions after writing posed evaluation issues. Salomon reported that the quality of writing produced by students using this prompting program improved, and that those gains generalized to writing with paper and pencil. Daiute (1986a) found that a program that prompted students to revise during composing was effective in increasing the amount of revision.

Outlining and Semantic Webbing

Outlining and semantic webbing are common practices for organizing ideas prior to writing, both in school and among experienced writers. Many sophisticated adult word processors include outlining capabilities. Early programs for semantic mapping were restricted by screen size and limited graphics capabilities. A sophisticated program for semantic webbing, Inspiration (1994), is available for Macintosh computers (see Figure 3). The program permits the creation of semantic webs on the screen with elements that can be easily rearranged for experimentation with different arrangements of ideas. Hidden notes can be attached to the main ideas in the web. The entire web, including notes, can be automatically converted into an outline prior to writing. Most of the semantic webbing activities that teachers use on paper can be carried out on the computer using this program. For example, teachers can create blank webs that model particular text structures (e.g., compare/contrast, description). Whether the advantages of flexible rearrangement of ideas and neatness outweigh the simplicity of webbing on paper is an open question and probably depends on a number of student, task, and instructional factors. I am not aware of any research on the use of computers to support semantic webbing.

Multimedia

The potential of multimedia software to enhance writing processes is just beginning to be explored as new software tools are developed. Although multimedia can also serve as a new means of publication and help to compensate for weak basic skills, it is discussed in this section on planning processes because it has the potential to promote the generation of ideas and provide background knowledge for planning. For the purposes of this review, *multimedia* includes programs that integrate drawing tools with writing as well as programs that include video and sound.

For young children, "writing" often consists primarily of drawing pictures. Children learn how to tell stories, describe their experiences, and explore what they know by drawing and talking about their drawings. Some of the most popular programs for home markets are drawing and writing programs for children, such as Kid Pix (1992) and Kid Works 2 (1992). Kid Pix has a wide variety of fanciful drawing tools but limited text capabilities; Kid Works 2 permits children to create pictures using a palette of drawing tools and to write stories to accompany their pictures; it will then play back the story, displaying the pictures and reading the story with synthesized speech. With other software, children can create visual environments that serve as backgrounds for story writing. For example, Storybook Weaver (1992) provides background scenes, objects, and animated figures for children to use in creating pictures. As they write the stories to go with the pictures, they can rely on a large picture dictionary for words they do not know how to spell. Sounds

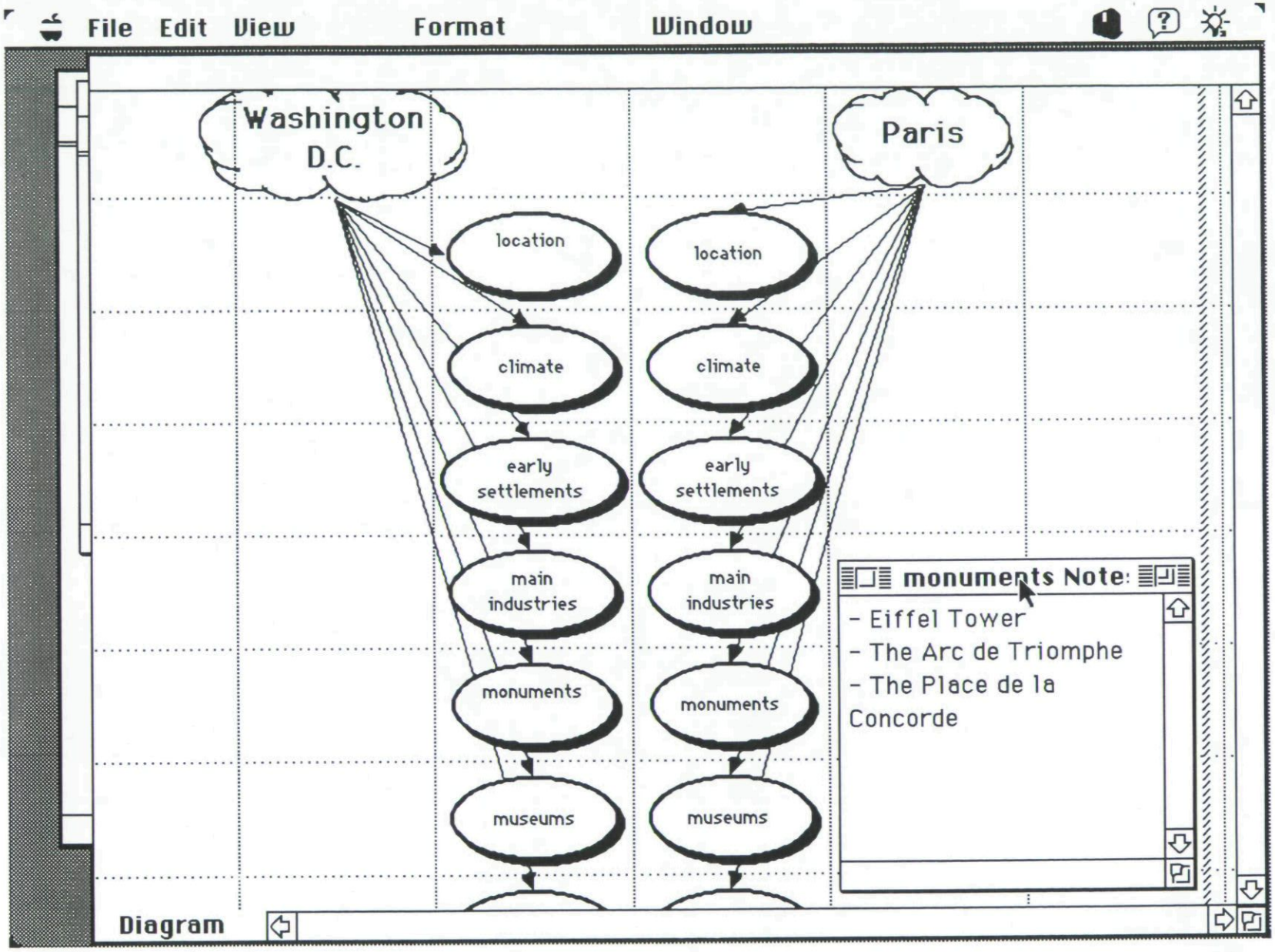

FIGURE 3. Inspiration, a semantic mapping and outlining program. (This example is a map for a compare/contrast paper. The notes for Paris monuments are shown.)

and music can be added to their stories. The Explore-a-Science series (1993) includes science topics (e.g., *whales*) for expository writing.

Older students are generally expected to convey their ideas via writing without the support of drawing. However, students at any age benefit from the use of visuals and other media in preparation for writing. This benefit may be especially important for students with more limited literacy skills or prior knowledge in a particular area, due to an educational disability or a different cultural and linguistic background (Daiute, 1992). Daiute reported on a multimedia project with students with poor writing skills from diverse cultural backgrounds. Students collected visuals and sounds that had personal meaning to them (e.g., snapshots, music), wrote about these images and sounds, and used simple multimedia software to combine them with their text. This descriptive study provided anecdotal evidence that multimedia can motivate students to write more and help them find new ways to express themselves.

Although multimedia has the potential to enhance writing, there are drawbacks as well. The addition of graphics and sounds to compositions may result in reduced focus on text—the text becomes relatively less important in carrying the meaning. Creating graphics and sounds also requires time and attention, which may detract from attention to the written text. Bahr, Nelson, and Van Meter (1994) investigated the effect of using graphics-based writing software on the writing of fourth- through eighth-grade students with LD. The software allowed students to create scenes and then type stories about those scenes. The authors conceptualized the graphics features as an aide to planning what to write, and compared this software to text-based planning software that presented questions based on story grammar. Students typed answers to these questions and used their responses as plans for their stories. The stories produced using the two types of software were compared on narrative maturity (a measure of overall quality) and several quantitative indicators related to length (e.g., number of words and T-units). No significant differences were found between the two conditions; however, these results should be interpreted with caution, as only 9 students participated. Clearly, further research is needed on the addition of graphics features to writing software.

Multimedia may have the potential to enhance reading and writing in content-area tasks as well. Multimedia can be used to extend background knowledge and to encourage students to explore their ideas prior to writing. Research on anchored instruction, which uses video to provide a meaningful, shared context for learning, has demonstrated the potential of multimedia materials to make information more usable for problem solving by connecting new learning to background knowledge (Cognition and Technology Group, 1993). In one project, researchers at Vanderbilt developed a multimedia composing tool that uses video to provide background information on a particular topic as a basis for writing activities for individuals with reading and writing disabilities (Hasselbring & Goin, 1991). After viewing a video segment, students receive graduated supports in reading and writing about the topic presented in the video; they can return to the video at any time to explore the content further. Another project at Vanderbilt (Kinzer, Hasselbring, Schmidt, & Meltzer, 1990) explored the use of video news reports to teach text structures and how to use the structures in reading and writing. Students learned about the typical structure of news reports (i.e., "who, what, when, where, why, and how" questions) and how to use that structure in note taking, brainstorming, and revising. Students' comprehension of television and oral news reports improved, and they included more structural elements in their written news reports.

Collaborative Writing and Publishing with Networks

As mentioned earlier in the section on word processing, computers can change the social context for writing by supporting publishing and collaborative writing in the classroom. Formats for publishing can be further extended with multimedia software. In addition, networks (both local area networks within a school and telecommunications networks) can offer expanded opportunities for collaborative writing and communication with diverse audiences.

In one early educational application of telecommunications, Riel (1985) developed an electronic newswire that involved students from geographically diverse cultures in collaborative production of a newspaper. Because the students from California and Alaska did not share the same cultural knowledge, they had to struggle to communicate clearly. Using a similar network with seventh-grade students from Israel, Cohen and Riel (1989) conducted a study to explore the effects of writing for authentic audiences of peers from different cultural backgrounds. They reported that essays written by students for distant peers were superior to essays written to be graded by their teachers, because the former were more explicit and detailed. Telecommunication networks for use by schools are supported by a number of state and national organizations.

Local area networks can also be used to support communication in writing. Peyton and Batson (1986) used a network within a classroom to teach writing to students with hearing impairment whereby all discussion and interaction were conducted in writing. Students viewed the ongoing conversation on their computer screens and participated by typing their remarks. For students with hearing impairment, the network provided an immersion approach to mastering English. Students with LD may also benefit from writing on such a net-

work. The network interaction can change the social context for writing by providing a connection between conversation and formal writing.

Concluding Comments

As the capabilities of computers have increased in the past decade, a variety of exciting new tools have been developed that have the potential to enhance the writing of students with LD. Basic tools, such as spelling checkers, have become common even on simple word processors. Printing features and desktop publishing have become more powerful and easier to use. The quality of speech synthesis has improved, and the variety of programs providing speech has expanded. Word prediction software has become available to support access to writing and reading. Telecommunications networks are accessible to schools willing to invest in modems and a phone line. Multimedia programs that integrate drawing and writing are widely available, and programs that integrate photographs, video, and sound with writing will become increasingly available in the next few years.

The challenge for special educators is twofold: First, existing research on word processing makes it clear that simply providing technology to teachers and students will not result in improvements in students' writing. Effective instructional methods must be developed that make use of the power provided by these tools to enhance the writing of students with LD. Second, as this review reveals, research on computers and writing has been limited primarily to studies of the effects of basic word processing. Researchers need to go beyond word processing to investigate the effects of instruction using a range of technological tools to support writing. This review has attempted to provide a framework for both the development of instructional methods using technology and research on their effectiveness. Teachers, administrators, teacher educators, and researchers need to collaborate in this effort to transform the potential of technology into reality.

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