SUPPORTING STRUGGLING WRITERS USING TECHNOLOGY: EVIDENCE-BASED INSTRUCTION AND DECISION-MAKING

November 2007

George R. Peterson-Karlan
Howard P. Parette
Special Education Assistive Technology Center
Department of Special Education
Illinois State University

Special Education Assistive Technology
seat center
Illinois State University

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WRITING MATTERS—BUT ACHIEVEMENT LAGS

Writing matters. Along with reading comprehension, writing proficiency predicts academic success (Graham & Perin, 2007), develops higher-order thinking skills (National Writing Project & Nagin, 2006), is an essential "threshold skill" for hiring and promotion (National Commission on Writing, 2004), and is a basic requirement for participation in civic life and a global economy (Graham & Perin, 2007; National Commission on Writing, 2003). However, writing achievement is not where it is expected to be and not where it needs to be. State governments report that, despite the high level of educational attainment of state employees compared with that of the general public, approximately 30% of professional employees fail to meet state writing expectations (National Commission on Writing, 2006). Nearly one-third of students who intend to enter higher education have not attained the readiness benchmarks for college-level English composition courses (ACT, 2005). According to the National Assessment of Educational Progress (NAEP) (Persky, Daane, & Ying, 2002), many students (51%–58%) are at a *basic* level of writing, which is below the desired *proficient* level. Those 16%–22% of students below even the basic level of writing reported by the NAEP are *struggling writers*, called *low-achieving writers* by Graham and Perin (2007). They include students who have been identified as learning disabled (LD) as well as others with academic and learning difficulties whose writing skills are not adequate to meet classroom demands (Graham & Perin, 2007).

If writing matters, writing instruction needs to improve (Graham & Perin, 2007; National Commission on Writing, 2006; National Writing Project & Nagin, 2006). The research-based models and methods for teaching good writing are known (National Commission on Writing, 2006; National Writing Project & Nagin, 2006). Good writers use three primary, recursive processes: planning (generating ideas, setting goals, and organizing, referred to in this paper as "planning"), translating (turning plans into written language, referred to here as "transcription"), and reviewing (referred to here as "editing and revising") (National Writing Project & Nagin, 2006). These processes are represented in instruction as *writing strategies* in which students are provided models, some direct instruction, some kind of *scaffolding* (an explicit framework or sequence of steps) that gives them an organizational scheme, and guidelines for using inquiry strategies (e.g., imagining a situation from a perspective different than one's own, comparing and contrasting cases, explaining how evidence supports a claim) (National Writing Project & Nagin, 2006). Despite agreement about what constitutes good writing instruction, it is not being used (National Commission on Writing, 2003, 2006). To bring about reform in writing instruction, the National Commission on Writing (2003) presented four challenges: (1) increase the amount of time that students spend writing, (2) improve the assessment of writing, (3) apply emerging writing technologies, and (4) provide professional development for all teachers.

Among national organizations considering writing outcomes, there is widespread acceptance that writing has moved from a paper and pen activity to one that is technology driven. Technologies are recognized as having potential both to support writing and the teaching of writing (National Commission on Writing, 2003; National Writing Project & Nagin, 2006) and to represent new venues for writing itself (*National Council of Teachers of English, 2004*). Three approaches to technology have emerged from this discussion: *technology-supported writing*, *technology-enabled writing*, and *multimedia writing*. Technology-supported writing can advance all phases of writing—planning, transcribing, and editing and revising. But technology also enables writing in new ways. Technology provides new sources for and means of obtaining information (e.g., the Internet, search engines) and enables sharing, editing, and collaboration among writers, teachers, and peers. Additionally, the ability to work from remote locations permits students to gauge the quality of their writing and their level of skill against those of peers elsewhere (National Commission on Writing, 2003, 2006; National Writing Project & Nagin, 2006). Finally, technology transforms writing by introducing new electronic genres and multimedia forms in which composing involves a combination of media, including print, still images, video, and sound (National Council of Teachers of English, 2004).

TECHNOLOGY AND STRUGGLING WRITERS

There has been a sustained interest in using technology to support struggling writers, especially those with learning and academic disabilities. These technologies include word processors, spell checkers, word prediction, speech recognition (SR), and text-to-speech screen review (Berninger & Amtmann, 2003; MacArthur, 1996, 1999a, 2000). This report examines and summarizes the research base for the full range of *technologies to support writing*. These technologies are not meant to replace good writing-as-process instruction. Instead, they provide scaffolding (National Writing Project & Nagin, 2006) for basic writing skills, especially for students who struggle. Technological scaffolding provides a compensatory function in that it permits students to perform at higher levels of proficiency (Peterson-Karlan & Parette, in press). Technology that provides such a compensatory function is called *assistive technology* when used by students with disabilities to enhance their functioning on writing tasks (Peterson-Karlan & Parette, in press), especially when instructional or remedial approaches have failed to develop the required skills (Edyburn, 2002). This report provides guidance on choosing and implementing technologies to support writing and writing instruction. It also serves as a framework for including technologies (software and devices) in www.TechMatrix.org, an online database of technologies reviewed for assistive and accessibility features maintained by the National Center for Technology Innovation (NCTI). The report is organized into a background section followed by three sections addressing each of the three main writing processes: planning, transcription, and editing and revising. Each section presents research findings and strategies to guide technology implementation.

BACKGROUND

Synthesizing Research-Based Findings

This report uses research-based findings to examine the effectiveness of technology in supporting writing by students with LD and academic disabilities. Both No Child Left Behind (NCLB) and the Individuals with Disabilities Education Improvement Act of 2004 (IDEA 2004) require teachers to use evidence-based practices to ensure that students receive the highest quality instruction. NCLB defines "scientifically based research" as research that applies rigorous, systematic, and objective procedures to obtain valid knowledge and that has been accepted by a peer-reviewed journal or approved by a panel of independent experts through a rigorous scientific review (Weatherly, 2006). This summary of research on technology to support writing is based on articles in peer-reviewed journals.

To identify published articles related to technology that supports writing by students with LDs and academic disabilities, multiple searches were completed using the ERIC-OVID (search period 1994–2004) and PsycINFO (search period 2004–2006) electronic databases. Each search was refined with a three-phase process whereby initial search terms were modified, with each subsequent search using keyword and title descriptors identified from the previous search. In addition, a hand search was conducted of 15 journals known to publish articles on the topic. For each article identified, ancestor searches of the references cited in the article were also completed. If authors appeared to have multiple publications in the search area of interest, additional author searches were conducted, using ERIC-OVID and PsycINFO to identify any appropriate systematic lines of research. The resulting database contained more than 200 articles, including discussion articles, meta-analyses, research articles, and national reports. Only articles reporting research were used in the analysis of technology effectiveness. Citations and abstracts for these articles are cataloged on www.TechMatrix.org. Discussion articles, meta-analyses, and national reports provided a conceptual framework for each major section examining technology effectiveness related to a specific writing process.

Successful and Struggling Developing Writers—The Evidence Base 1980–1990

Newcomer and Barenbaum (1991) summarized 41 studies conducted between 1980–1990 that build an evidence base related to the written composition problems of children with LD and strategies for remediating these problems. Generally, the available literature indicates that students exhibit problems in one or more areas of (a) planning, (b) transcription, and (c) editing and revising (Englert & Raphael, 1989; Raphael & Englert, 1990).

During the writing process (i.e., drafting, transcription, or text production), students with LD frequently (Newcomer and Barenbaum; 1991):

- lack a clear understanding of the purpose of the composition (i.e., the writing task, such as free writing, narrative, and expository writing);
- fail to have a plan for composition, spend less time writing, and use an immature and ineffective "knowledge telling" strategy when writing (i.e., each written thought or idea generates the next);
- lack strategies or procedures for generating and organizing ideas and either do not use or do not know about text structures to plan the composition (i.e., how a comparison essay and a book review are structured differently); and
- over-rely on narrative or descriptive text structures (Englert & Raphael, 1989; Raphael & Englert, 1990).

When the written compositions of these students are compared with those of typical peers, the products show the following characteristics:

- More mechanical errors, including spelling, punctuation, and capitalization (fourth grade through college), with spelling the most pronounced
- More subject/predicate agreement (syntax) errors
- Fewer words and sentences, less variety of words, fewer adjectives and adverbs, fewer novel words, and fewer words with at least seven letters
- Less-complex sentences lacking subordinate clauses and fewer words in main clauses

In the area of editing and revising, the evidence base between 1980 and 1990 indicates that students with LD do not have or do not sustain a plan for revising the composition and that they tend to revise only mechanical errors. They do not revise content such as ideas, organization, and cohesion.

TECHNOLOGIES TO SUPPORT PLANNING AND ORGANIZING

Two basic approaches to supporting the planning and organizing components of writing have been identified: (a) *procedural facilitation*, or instructional scaffolding, a remedial approach that allows students to "emulate the performance of mature writers, in spite of their less advanced developmental levels" (Englert, Raphael, Anderson, Anthony, & Stevens, 1991, p. 340) and (b) *substantive facilitation*, or interactive teaching. Examples of each follow:

1. ***Procedural facilitation*** may be a series of graduated questions that teachers give students during planning to cue strategy use, or they may be cueing cards (Graves, Montague, & Wong, 1990) or "think sheets" for specific text structures and strategies provided prior to writing (Englert & Raphael, 1989; Raphael & Englert, 1990). Such cognitive scaffolding tools in the form of paper or electronic guides to planning have been the basis for a number of research approaches to improving prewriting planning (Bahr, Nelson, & Van Meter, 1996).
2. ***Substantive facilitation*** (Graves & Montague, 1991) is instruction in which the teacher actively interacts with the student who is engaged writing by providing context-sensitive information and

directing or by modeling the processes, procedures, and strategies for writing (Graham & Harris, 1989; Hallenbeck, 1996; Zipprich, 1995).

Research shows that explicit and systematic instruction in the use of text structure and strategy-based tools enhances writing outcomes when used as an adjunct to, or in tandem with, process-based writing instruction (Englert & Raphael, 1989; Englert, Raphael, Anderson, Anthony, & Stevens, 1991; Graham & Harris, 1989; Graves et al., 1990; Raphael & Englert, 1990). Genre-specific planning tools increase the number of elements that students include in the specific compositional form (e.g., story, opinion essay, descriptive writing), which is associated with increased holistic quality scores for writing. Using both genre-specific supports and general case procedural supports produce compositions with better content (ideas and variety of words) and organization. These tools do not, however, consistently increase the length of compositions or increase their conventional accuracy (spelling, punctuation, capitalization). Planning time also increases, but given that planning time spent by students with LD is almost nonexistent (often less than 1 minute) (Graham, 1990), any time spent planning would be an increase.

Only a small body of literature has examined the “compensatory” use of tools for planning and organizing compositions by students with LD. Three studies examined digital tools (Bahr, Nelson, & Van Meter, 1996; Englert, Wu, & Zhao, 2005; Sturm & Rankin-Erickson, 2002), and another examined a paper-and-pencil tool (Zipprich, 1995). However, in these studies, several key features of planning tools can be identified (see Table 1), including specific plan components, content prompts, procedural prompts, visual-graphic mapping, and other features (e.g., print version of the plan, digital file version that may be easily modified, text-to-speech support in digital or computer-based tools). Instructional strategies that students need to understand and effectively operate the tool are presented in Table 2. Instruction in the use of planning tools should not replace instruction in the process of writing, including knowledge of the text structures associated with each genre.

Table 1. Features of Comprehensive Planning Tools and Elements of Instruction in Tool Use

TOOL FEATURES
Explicit plan components (components needed in the plan, including the purpose of the composition, intended audience, topic, and content) are made visible and concrete.
Content prompts identify the important components needed in a complete composition: general case (e.g., introductory sentence, supporting details, concluding sentence) or genre-specific (e.g., five elements of a story).
Procedural prompts are present for generating, selecting, and organizing the component elements and ideas within the plan: instructions for how to proceed or questions that the students can use to self-direct or guide the plan development. The questions can be general case or genre-specific.
Visual-graphic mapping organizes and groups information in spatially meaningful ways (e.g., outline, chart, web) to enhance the representation of the logical sequencing of information (e.g., listing, comparison) or ordinate relationships (e.g., main idea-supporting ideas).
Other features may include a print version of the plan, a digital file version that may be easily modified, and text-to-speech support in digital or computer-based tools.

Table 2. Elements of Tool Instruction

Explanation of the tool, including the problems generated by not planning before writing (why), which may include reviewing the student's own writing samples, what the tool does, and how it enhances the planning and organizing part of the writing process
Modeling by the teacher of how to use the tool to plan a target composition, with input from the student regarding topics, ideas, details, and so on
Guided practice with the student using the tool to plan and organize a target composition, with teacher interaction and assistance (substantive facilitation)
Independent use by the student, with the teacher reviewing the finished plan before the student begins to draft the composition
Note: Group instruction may be used for explanations and modeling, but individual instruction in tool use is recommended.

What to Do—Planning and Organization

- Use planning and organization technology as an adjunct to, or in tandem with, process-based instruction in writing to improve prewriting planning and organization.
- Match a student's strengths and weaknesses with tools by their planning and organization features and applications.
- Use electronic outlining tools and draft templates, especially those that are genre-specific and contain embedded content prompts and procedure cues.
- Directly instruct the student in how to use the tool and how to apply the tool to the writing tasks.
- Search the www.TechMatrix.org for tools that support writing through planning and organizing as well as the other writing processes discussed below.

TECHNOLOGIES TO SUPPORT TEXT TRANSCRIPTION

After planning and organizing, drafting is the next step in the writing process (Englert & Raphael, 1989; Raphael & Englert, 1990). Preparing a draft requires the writer to produce text that is based on the previously developed writing plan. Theoretically, text production is composed of two separate processes: *text generation*, that is, the translation of ideas into language representation as sentences in memory, and *text transcription*, that is, the translation of language representation into written words (Berninger, 1999). Text transcription requires the writer to apply two concurrent skills: word production (typically achieved through handwriting) and spelling. Although the planning and organizing activities of prewriting can assist the writer during drafting, it is still necessary for the writer to both create ideas in sentence form (generate text) and transcribe them onto paper in one combined cognitive activity. This has been described as a juggling act (Berninger, 1999) in which the writer must juggle (a) planning what to say and how to say it, (b) selecting words and sentence and discourse structures, (c) producing text, and (d) monitoring what has been written with what is about to be written while revising. Berninger proposes that handwriting and spelling skills exert limits on the ability of beginning, developing, and struggling writers to translate oral language in memory (text generation) into written language on paper (text production).

This view has been generally supported in discussions of the compositional abilities of students with LD (Graham, 1990). As students become overly involved in the difficulties of producing legible handwriting and properly spelled words, they eliminate other processes that generate the ideas, logical sequences, and details (Graham, 1990), qualities that are present in their dictated versions of stories and explanations (Graham & Harris, 2000). In addition, poor transcription skills among students with LD have an impact on:

- readability (Isaacson & Gleason, 1997);
- adult perceptions of the quality (content) of the compositions (Graham, 1990); and
- completion time on tasks such as timed essay tests or classroom note-taking (Graham & Harris, 2000; Weintraub & Graham, 1998).

Intermediate-grade students with LD not only had slower rates of transcription than their peers but could not make equivalent increases in their handwriting speed to meet task demands (Weintraub & Graham, 1998).

Several categories of technologies address the challenges presented by the transcription process, including word processors, word prediction and word cueing, and SR. The research base and implementation guidance are provided for each category below.

Technologies to Support Transcription—Word Processing

Word processors include two compensatory tools for transcription: (a) keyboarding, which changes the task from forming letters by hand to finding and selecting the keys (Berninger & Amtmann, 2003), and (b) spell checkers, which help writers detect spelling errors and repair them by selecting the correctly spelled word. It has also been suggested that the editing (e.g., delete, move, cut, paste) and screen display components of word processors may enhance drafting by making letters, words, and sentences legible to the student and the teacher and may enhance revising because of the ease of modifying text and facilitating peer collaboration and teacher interaction. The desktop publishing features make possible attractive and neat final papers (Isaacson & Gleason, 1997; MacArthur, Ferretti, Okolo, & Cavalier, 2001). Editing and revising will be more closely examined in the next section.

Studies with typically developing students suggest the following:

- The impact of word processing as a transcription tool depends on a context of writing instruction; that is, improvement in text production may be necessary but not sufficient for improvement in writing (Bangert-Drowns, 1993).
- Computer literacy skills, especially keyboarding, have a direct impact on the potential of the word processor as a transcription tool for students (Wolfe, Bolton, Feltovich, & Bangert, 1996; Wolfe, Bolton, Feltovich, & Niday, 1996). Just as students are not be expected to use paper and pencil to write without instruction and practice in handwriting, word processors should not be expected to have an immediate, "no practice" effect.

The available evidence also indicates that the effect of word processing on transcription can be evaluated on several characteristics:

- Compositional length (number of words)
- Fluency (sentence length)
- Mechanical and spelling accuracy
- Appearance (legibility and neatness)
- Compositional quality (content elements, holistic quality)

Certain characteristics, such as appearance or accuracy, may be more directly related to the actual act of text production, whereas others, such as compositional length or quality, may interact with other components of writing competence to produce effects such as improved editing or revision skills.

Research on the effects of word processor use as a compensatory transcription tool on writing quality is confounded by methodological concerns, the small number of studies, and the lack of recent studies using newer technology. In light of this, however, several trends are evident.

- Computer literacy skills differentially affect the impact of word processing on writing (Wolfe, Bolton, Feltovich, & Bangert, 1996; Wolfe, Bolton, Feltovich, & Niday, 1996). In fact, there are indications that a lack of keyboarding instruction has a negative impact on elementary-age students (Langone, Levine, Clees, Malone, & Koorland, 1996; MacArthur, Graham, & Schwartz, 1993; MacArthur, Graham, Schwartz, & Schafer, 1995; Vacc, 1987).
- Transcription speeds can be obtained that render word processing functional when compared with handwriting speeds (Lewis, Graves, Ashton, & Kieley, 1998), especially when systematic keyboarding instruction is provided (Lewis et al., 1998; MacArthur & Graham, 1987; Vacc, 1987).
- Improvements in transcription accuracy when a word processor is used instead of handwriting (MacArthur, 1999a; MacArthur et al., 2001) may be related to the initial error rates of students. Students with high baseline error rates (MacArthur & Graham, 1987), especially in spelling, appear to improve more than those with few baseline errors (Outhred, 1989). Improvements in legibility were also supported by one single-subject design study (Hetzroni & Shrieber, 2004).
- When students have adequate prior computer literacy or have received word processing or keyboarding instruction, compositional length is greater when they use a word processor than when they handwrite (Neuman & Cobb-Morroco, 1987/1988; Neuman & Morocco, 1987).
- This positive impact on composition length may be related to initial handwriting transcription skills. Elementary-age students with LD who received writing and word processor instruction and who had low initial composition length when handwriting (<50 words) wrote longer compositions when using the word processor; those with higher initial length when handwriting (>60 words) wrote longer compositions when using handwriting even after instruction (Outhred, 1989).

Thus, when studies of word processor use by students with LD and academic disabilities are interpreted, care must be taken to examine issues of computer literacy and the selection of writing outcomes, such as transcription rate or accuracy or composition length.

What to Do—Word Processing

- Use word processors to improve transcription accuracy (legibility) and length, especially with students with high initial error rates.
- Provide keyboarding training to produce functional levels of keyboarding speed and accuracy.

Technologies to Support Transcription—Word Prediction and Word Cueing

Word prediction benefits students with poor spelling abilities (MacArthur, 1999a, 2000; Newell, Arnott, Booth, Beattie et al., 1992). It does so by using the first one to three letters typed to predict the target word and then providing a list of choices, similar to what a spell-check application does. Typically using only the mouse, the writer simply selects the word from the list. Word prediction programs reduce the number of keystrokes necessary to transcribe a word (Koester & Levine, 1996b; Newell et al., 1992) by dynamically changing the word list offered as more letters are typed. Several variations of word prediction are available, including those that present word choices by

- frequency, which offer the most frequently occurring words in the English language drawn from a published dictionary or word bank;
- recency, which offer words from among those most recently used by the writer and gradually eliminate from the list previously frequent words (e.g., the person named in a report) as they are used less often;

- grammatically based prediction, which offer words on the basis of syntactic rules (e.g., a verb follows a noun and matches number and tense; after "Yesterday, the boys," the program offers "were"); and
- association, which offer words on the basis of words commonly used together in sentences (e.g., "good" produces "morning" and "night"; (Hunt-Berg & Rankin, 1994).

Word prediction programs may also offer automatic spacing (one following an inserted word) and automatic capitalization (of the first word after terminal punctuation).

Word prediction requires users to scan the list of words offered and make a selection. Research with children with physical impairments and those with normal development demonstrates that this selection requirement adds to the cognitive load on users by adding both search time and decision-making (Koester & Levine, 1996a), a potential disadvantage. The scan-and-select requirement actually decreases text generation (transcription) speed when compared with typing speed (Koester & Levine, 1996b) but may increase transcription accuracy by producing more correctly spelled words (Newell et al., 1992). Two factors affect transcription speed: practice and list presentation. Practice with the word prediction program, both short term (Koester & Levine, 1996a) and long term (Newell et al., 1992), improves the transcription rate. Also, the closer the target word is to the beginning of the first list, the faster the selection can be made, thus increasing the transcription rate (Newell et al., 1992).

Word prediction is a more sophisticated form of a technique called word cueing (Hunt-Berg & Rankin, 1994). Word cueing programs offer a list of words or phrases beginning with the first letters typed (e.g., all the words beginning with "m" or "in," depending on the number of letters typed). The word lists are generated from word dictionaries provided by the specific program. Word dictionaries vary in nature and size, ranging from single, small word lists to multiple dictionaries that can be selected by writers or teachers (Hunt-Berg & Rankin, 1994). In some applications, word lists can be modified or customized by students or teachers to add topic-specific lists or to include "trouble" words (Hunt-Berg & Rankin, 1994). Voice output, or synthesized text-to-speech pronunciation of the offered words, can be added to word prediction or word cueing to further assist students with reading and spelling deficits (e.g., (MacArthur, 1998, 1999b; Zhang, 2000; Zhang, Brooks, Fields, & Redelfs, 1995).

Although the research is limited, a few trends have emerged.

- In studies ranging from 2 weeks to 1 year (MacArthur, 1998, 1999b; Zhang, 2000; Zhang et al., 1995), increased operational competence increased the successful use of word prediction.
- Transcription speed does not increase when word prediction is used (MacArthur, 1998, 1999b); rates attained with word prediction used in conjunction with word processors may be only 30%–45% of the handwriting rate of students with LD (Lewis et al., 1998; MacArthur, 1999b). There is an indication that students with a low rate of transcription might attain functional rates relative to their own initial handwriting rate.
- Transcription accuracy, as measured by both spelling accuracy and word legibility, increases as a result of voice-output word prediction when used in conjunction with word processing in comparison to handwriting and word processing alone (Zhang et al., 1995).
- Task demand may influence students' use of the word prediction feature when keyboard text entry is also available; students with the most severe spelling problems may not benefit from the use of word prediction (MacArthur, 1999b).
- A study with the largest number of students and the widest grade range suggests that the number of genre-specific text elements is significantly higher in samples produced using word prediction than with word processor use alone (Lewis et al., 1998).

What to Do—Word Prediction

- Consider using word prediction with text-to-speech output for students with persistent spelling difficulties.
- Provide instruction in using word prediction, and expect students' success to improve with continued use.
- Expect transcription accuracy and composition length but not necessarily transcription speed to be better when word prediction is used in conjunction with word processors.

Technologies to Support Transcription—Speech Recognition

SR, or voice recognition, technology involves a speech-to-text system that interprets spoken language, directly produces transcribed text, and permits users to edit transcribed text and control operating system functions (e.g., opening or saving files by speech input). SR systems typically require users to train the software by speaking predetermined words or text passages, which are then analyzed by the program to compare voice patterns with the known words and word sequences. Because of the initial complexity associated with training the system, learning to dictate written compositions instead of talking to the computer (Honeycutt, 2003), learning correction procedures, and proofreading output, it has been suggested that users should be highly motivated, perhaps because of poor typing or spelling skills (Hartley, Sotto, & Pennebaker, 2003). For example, Sanderson (1999) reported that university students with LD (dyslexia) who were motivated to use technology to write had difficulty and frustration with training on and using continuous SR (SR-C) systems, which led to technology abandonment. Not surprisingly, even experienced users of SR systems differ in their attitudes toward return on time invested (Honeycutt, 2003). Despite these issues, SR technology continues to be of interest as an alternative means of transcription that addresses both handwriting and spelling deficits for writers with the most difficulties in these areas (Quinlan, 2004).

Given that SR technology is constantly evolving, research evidence for the effectiveness and availability of updated technologies has lagged (Berninger & Amtmann, 2003; MacArthur, 1999a, 2000). For example, research has reported limitations in the accuracy of word recognition even after training, but newer versions of the same software report higher accuracy levels (MacArthur, 1999a). Finally, basic differences in the underlying SR algorithms also contribute to the difficulty of interpreting the evidence base on effectiveness. Older systems used discrete SR, whereby each individual word was dictated with a slight pause between words; newer systems employ SR-C, permitting a more natural flow of dictation (MacArthur, 1999a; 2000). These differences in SR algorithms have associated differences in the user interface (A. Sanderson, 1999). However, both systems require the user to articulate clearly, attend to phrasing to increase context cues, dictate punctuation and formatting, and learn specific commands to edit without using the keyboard (Honeycutt, 2003; MacArthur, 2000). These issues suggest that careful attention must be paid to computer literacy skills and to the identification of the SR system (and version) when reviewing and interpreting the research evidence.

Despite the relatively small numbers of studies that have been conducted with school-age students and the changes in the technology over time, with respect to students attaining competence, trends are emerging on using SR for instruction:

- Struggling writers across grade levels can train the SR systems to an acceptable level of transcription accuracy when given instruction adapted to their age and reading abilities (Faris-Cole & Lewis, 2001; Higgins & Raskind, 1995; Litten, 1999; Quinlan, 2004; Roberts & Stodden, 2005; Wetzel, 1996).
- Some speech characteristics of students, such as extraneous vocal sounds, may need to be minimized through training to improve recognition accuracy; others, such as voice pitch and clarity, especially with younger students, or pronunciation or dialect differences may not be

amenable to change and may prevent students from successfully using SR (Faris-Cole & Lewis, 2001; Higgins & Raskind, 1995; Roberts & Stodden, 2005; Sanderson, 1999; Wetzel, 1996).

- Text-to-speech output of both text passages used in training and the transcribed phrases and sentences increases training success by students with reading impairments (Litten, 1999).
- Standard SR training procedures provided by the manufacturer will need to be modified, as will expected training times. Even systems promising “out of the box” capability may require a period of use beyond initial training for students to achieve functional levels of transcription accuracy. What constitutes a functional, or acceptable, level of transcription accuracy may depend on students’ preferences but is more likely related to the severity of students’ spelling inaccuracy (Litten, 1999; Roberts & Stodden, 2005).
- Struggling writers across grade levels can attain competence in using SR editing and correction procedures as well as speech commands to control the computer. However, additional instructional strategies, such as a gradual introduction of commands, modeling and guided practice (Quinlan, 2004), and the use of cue cards (Litten, 1999) may be needed.

Transcription accuracy in writing samples, which is analogous to spelling accuracy for writers composing on a keyboard (De La Paz, 1999) depends on SR system accuracy instead of on students’ proficiency in correcting recognition errors. Correcting such errors is an editing function, whether done while dictating or as a proofreading step. With respect to transcription accuracy, the following trends emerged:

- Based on limited data, discrete (word by word) SR systems may produce higher initial levels of transcription accuracy among school-age students with LD than SR-C, but these differences are minimized with continued use, even as little as 3 hours (Faris-Cole & Lewis, 2001; Wetzel, 1996).
- Transcription accuracy of 80% may be obtained after continued use by intermediate elementary students with LD (Faris-Cole & Lewis, 2001).
- Writing samples of struggling writers show significantly fewer mechanical errors (including spelling errors) when SR-C is used instead of handwriting (Faris-Cole & Lewis, 2001).

With respect to transcription speed, the following trends emerged:

- The speed of transcription, like transcription accuracy, appears to increase after continued SR use by students with LD (Wetzel, 1996).
- Comparatively, students using SR systems produce slower transcription speeds (3.5–5.5 words per minute (wpm)) than when handwriting (5–6 wpm) but equivalent to word processing (4.7–6 wpm) (Faris-Cole & Lewis, 2001). However, SR transcription speed analysis includes student self-editing of SR recognition errors. Self-editing is equivalent to self-correction of typing errors, both of which take time; self-correction during handwriting is typically not done during writing samples. Thus, comparing SR with word processing is a more appropriate comparison.
- In two studies, transcription speed was reported together with transcription accuracy, suggesting that speed and accuracy should be examined together when determining the effectiveness of transcription mode; slower speeds that produce fewer errors might be more effective than faster speeds accompanied by more errors (Faris-Cole & Lewis, 2001).

With respect to composition length and quality, the following trends emerged:

- For students with significant writing difficulties, using SR produces significantly longer compositions than does handwriting, both with and without advance planning of the composition (Quinlan, 2004).
- Composition quality was measured differently across studies and included holistic quality (Quinlan, 2004), readability expressed as grade-level equivalent (Faris-Cole & Lewis, 2001), word and sentence fluency (Roberts & Stodden, 2005), and sentence complexity (Higgins & Raskind, 1995). Even given these differences, writing quality using SR is better than with handwriting or keyboarding. This improvement may relate to improved word fluency (more mature, longer words) and sentence complexity (more main verbs) in compositions completed by students with LD using SR systems.
- Postsecondary students report that with SR, they can use longer words that they know but cannot spell than they can use with the other transcription methods (Higgins & Raskind, 1995). This effect is also evident in the compositions from a small sample of intermediate elementary students with LD (Faris-Cole & Lewis, 2001).

Given the unique demands of SR as a transcription tool, the available limited research suggests that technology abandonment might be a risk. However, this same evidence suggests that abandonment may not be due solely to the SR technology. The evidence indicates that variables such as competence in the use of text-to-speech technology, students' spelling accuracy, students' experience with technology, instructional method, and length of SR use (Roberts & Stodden, 2005) may have an impact on successful SR use and need further systematic research.

What to Do—Speech Recognition

- Consider using SR with students with the most severe spelling deficits.
- Use text-to-speech output with students having persistent reading deficits.
- Provide sufficient systematic instruction, using strategies adapted to the learner.
- Expect transcription accuracy to improve quickly, but not transcription speed, which will lag.
- Expect composition length and quality to improve with continued use.

TECHNOLOGIES TO SUPPORT EDITING AND REVISING

The final major phase of the writing process occurs when writers rework the initial transcribed draft into a final product. This process of reworking may be called *editing* or *revising* a composition. However, these terms may not be interchangeable. Writers may have two different purposes for rewriting a composition. One purpose involves detecting and correcting errors of spelling, punctuation, capitalization, and grammar to improve the written accuracy. This is commonly called "proofreading" but will be referred to here as *editing*. A second outcome of rewriting is improving the organization of ideas, the clarity of the composition, the supporting details, and do on. This process will be referred to as *revising*.

Students who struggle to write most often focus on the mechanics of the process, including transcription and spelling. This focus is made necessary by the extent of the problem; spelling accounts for 41% of the variability in the writing products of elementary grade students, and handwriting fluency accounts for 66% (Graham, Berninger, Abbott, Abbott, & Whittaker, 1997). Fifth- and sixth-grade students with LD misspell about 12% of their words and lack initial capitalization or final punctuation in about 33% of their sentences (MacArthur & Graham, 1987). Across grades 4 to 12, spelling errors are nearly 17% (17 per 100 words), with the total spelling, punctuation, capitalization, and grammar errors accounting for about 40% of words written (Lewis et al., 1998). The effort to overcome such problems is focused on making word substitutions (a thesaurus approach), correcting mechanical errors, and producing a neater product, with more than 70% of the changes being attempts to correct (edit) mechanical errors (Graham & Harris, 2003). Fewer than 20% of the revisions appreciably change (revise) what students write (MacArthur & Graham, 1987; MacArthur, Graham, & Schwartz, 1991).

Given the demands on working memory generated by transcription problems (MacArthur, 1999a), it is not suspiring that students with LD have difficulty managing the processes involved in revising (Graham & Harris, 2003). Revising brings attention to the substance of the composition, including organization, clarity, and detail; however, students with LD lack skill both in making meaningful evaluations of their writing and in executing the intended change (Graham & Harris 2003). Another important element of revising is concern for the reader, something often lacking in the revising efforts of students with LD (Graham & Harris, 2003). Such students consider the reaction of an audience to their text in only 6% of their revision decisions; of these, only 25% of the revisions actually improve the text (Graham, 1997).

Two categories of technologies that address the challenges presented by the editing and revising process are presented here: spell checkers with speech output and word processors with speech output. The research base and implementation guidance are provided for each below.

Technologies to Support Editing—Spell Checkers

To detect errors, spell checkers compare any given word that is typed with all words in the spell-check dictionary (Garfinkel, Fernandez, & Gopal, 2003; Ndiaye & Faltin, 2003). This is why spell checkers do not detect homophone errors, which are correctly spelled words with different meanings that sound the same, and contextual errors, such as “then” for “than” (Montgomery, Karlan, & Coutinho, 2001). The misspellings of students with LD in grades 5 through 8 contain 26% of such nondetectable errors (MacArthur, Graham, Haynes, & DeLaPaz, 1996). Having detected an error, most spell checkers then offer a list of *possible* replacements. The indicators of a good spell checker include whether the correct word appears in the offered list, whether it appears in the top five words offered, and whether it is the first choice in the offered list (Garfinkel et al., 2003). Ten spell checkers, including one handheld device developed prior to 1993, were able to detect and offer correct spellings for 53% of 555 words misspelled by students with LD in grades 5 through 8; 26% of errors were not detected (MacArthur et al., 1996). Nine spell checkers developed prior to 2000 were able to detect the errors in a pool of 1,008 words misspelled by students with LD in grades 3 through 8 (Montgomery et al., 2001). However, for only 53% of misspellings was the target word offered, and it was the first word for only 22% and in the first three choices for an additional 13% of misspelled words (Montgomery et al., 2001).

Learners who are not necessarily proficient in spelling but who have basic correspondences between graphemes and phonemes, such as students with LD, may write phonetically. Such phonetic, or “flexible,” spelling uses plausible but incorrect grapheme-to-phoneme correspondence, (e.g., “sed” for “said”), which requires *phonemic re-interpretation* (Ndiaye & Faltin, 2003), a process that attempts to discover the pronunciation of the erroneous word and find correctly spelled phonological matches. Correct suggestions by 10 spell check programs developed before 1992 increased from 53% overall to 76% for less severe spelling errors but decreased to 23% for more severe, less phonological errors (MacArthur et al., 1996). The ability of spell checkers developed before 2000 to offer choices in higher positions (i.e., first offered, top three, first screen) increased as the phonetic error level increased from preliterate spellers to transitional spellers, with significant differences across nine spell check programs (Montgomery et al., 2001). A final problem is presented by an unrecognizable word; that is, the string of letters bounded by a space on each end cannot be reasonably recognized as representing a real word. Unrecognizable, non-word errors are nearly 13% of the 17% error rate in the writing of students with LD in grades 4 through 12 (Lewis et al., 1998). Clearly, the capability of spell checkers to detect and offer corrections for the spelling errors generated by students with LD will be a major factor in establishing the effectiveness of their use as tools to support editing.

Conclusions about the effectiveness of spell-check technology are limited by the small number of studies that have directly examined the effects of spell-check technology and the changes that have occurred in technology in the last 10 years, including the emergence of homonym identification tools in word processing programs developed for struggling writers (e.g., SOLO™ writing suite by Don Johnston, Inc. and Read & Write Gold™ by Text Help Systems). Thus, despite the ubiquitous nature of spell-check programs, the research base supports their use as a promising practice pending further research, with certain trends being evident.

- Students with LD from grade school through college age are no better, and in some cases worse, at detecting their own spelling errors than are spell-check programs (Dalton, Winbury, & Cobb-Morroco, 1990; Gerlach, Johnson, & Ouyang, 1991; McNaughton, Hughes, & Clark, 1997) and may actually flag words as incorrectly spelled that are correctly spelled (Gerlach et al., 1991). Without technology, postsecondary students with LD are somewhat more capable of correcting spelling errors detected (51%) (McNaughton et al., 1997) than are school-age students with LD (9%–25%) (Dalton et al., 1990; MacArthur et al., 1996).
- Students with LD correct 80%–95% of spelling when the intended word is suggested by the spell checker (Dalton et al., 1990; Lewis, Ashton, Haapa, Kieley, & Fielden, 1999; MacArthur et al., 1996; McNaughton et al., 1997), but only 0%–27% when the intended word is not suggested (Dalton et al., 1990; Lewis et al., 1999; MacArthur et al., 1996).
- The addition of text-to-speech output in the spell-check program, used in conjunction with a spell-check strategy, increases to 53% the correction of errors by students with LD even when the intended word is not suggested (Lewis, et al, 1999). This increase is due to students using the speech output to try alternative words.
- In addition, teaching students with LD to use a strategy for proofreading in conjunction with the spell checker increases spelling corrections when compared with the spell-check program alone (McNaughton et al., 1997).

What to Do—Spell Checkers

- Teach students to strategically use a spell checker and understand possible errors suggested by the spell checker.
- Use a spell checker with text-to-speech output to improve spelling accuracy in the composition after editing.
- Select spell checkers that have "flexible spelling" or phonemic spell check to improve word-list offerings such that the correct word appears in at least the top five choices and especially in the first choice in the offered list.
- Use spell checkers in conjunction with instruction in a proofreading strategy.

Technologies to Support Editing and Revising—Word Processors and Speech Output

It has been suggested that word processors facilitate editing and revising by offering legible text, which may facilitate the detection of errors and the ability to easily modify text, both of which may encourage more revising (Hunt-Berg & Rankin, 1994; MacArthur, 1999a, 2000; MacArthur et al., 2001). Such facilitation and encouragement are needed, considering that students with LD focus most of their revising efforts on word substitutions, the correction of mechanical errors, and the neatness of the product, with fewer than 20% of revisions substantively changing the content to improve meaning, organization, or clarity (Graham & Harris, 2003). These students may not even understand the purpose of the revising process as it relates to the needs of their audience (Graham & Harris, 2003). Editing is made more difficult for these students when they use handwriting, because they may introduce new errors when recopying handwritten compositions to produce subsequent drafts (MacArthur, Graham et al., 1991).

As with the other tools reported thus far, limitations in the number of studies examining technology effectiveness indicate trends that require further confirmatory research.

- Although word processors have the potential to encourage and facilitate revision, their use alone by students with LD does not change the type or amount of revisions (MacArthur & Graham, 1987).
- The addition of text-to-speech output permits students who struggle with writing to listen and use their general language competence to monitor and correct errors or to revise what they have written (MacArthur, 1999a, 2000).
- Postsecondary students with LD detect more spelling, capitalization, punctuation, grammar, and content or organization errors when using text-to-speech review than when using either word-processed text alone or having their composition read to them by an adult (Raskind & Higgins, 1995).
- Procedural facilitators (Gersten & Baker, 2001) in the form of self-generated prompts for the process of revising have improved revision skills among students with LD.
- The use of a word processor combined with procedural facilitation for revising overall content increases the number of revisions, the number of substantive revisions, and the quality of the written compositions (Graham & MacArthur, 1988) as does combining word processing with peer-revision strategies (MacArthur, Schwartz, & Graham, 1991; Stoddard & MacArthur, 1993).

What to Do—Word Processors and Speech Output

- Use a word processor with text-to-speech output in conjunction with instruction in revising.
- Use electronic revision guides that provide procedural facilitation.
- Expect improvements in mechanical accuracy and composition quality.

INFORMED PRACTICE AND FUTURE NEEDS

The research base identified and summarized here suggests one inescapable conclusion: more research is needed to prove the effectiveness of many of the technological tools available to support students who struggle to write. Although studies with sufficient numbers of students have used research designs that permit valid conclusions, more research is needed to establish a complete evidence base for many of the more promising tools. The evidence available most strongly supports the following practices:

- Use planning and organization technologies, including outlining tools and draft templates, especially those that are genre specific and also have embedded content prompts and procedural facilitation cues.
- Use transcription technologies, including both word processing (keyboarding) and word prediction.
- Use spell checkers, especially with text-to-speech output, as an editing technology.

With any of these tools, text-to-speech output increases the effectiveness of the tool for the struggling writer who also struggles with reading.

The evidence also reveals promising technologies that need further systematic research but that can be recommended for use with care, using student data to monitor effectiveness.

- Use SR for transcription with students who have the most severe spelling difficulties, and give students sufficient time to develop competence in its use.
- Use text-to-speech output for editing and revising.
- Use tools containing revision guides based on procedural facilitation.

It is also the case that most of the studies used now-outdated versions of technologies or did not include more recently developed technologies. Direct and systematic evaluation of newer writing-support technologies is strongly recommended. Research is especially needed with students with LD and academic disabilities across grade levels, but particularly at the late elementary and middle school levels where mastering multiple genres and writing to learn are clear achievement goals.

Finally, not all studies used the same measure of writing outcomes. It has been argued that writing quality is the overriding outcome of interest (Graham & Perin, 2007), but writing quality may be more appropriately viewed as the priority *summative outcome*. To develop quality in writing, students who struggle to write need to learn discrete planning, transcription, and editing and revising strategies and skills. Teachers, in turn, need to monitor student progress in the amount, speed, accuracy, fluency, complexity, and organization of writing as separate *formative outcomes* in relation to the specific tools being used to effectively use technology to support writing.

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