2008

A review of assistive technology and writing skills for students with physical and educational disabilities

Howard P. Parette
Illinois State University

Jack J. Hourcade
Boise State University

George R. Peterson-Karlan
Illinois State University

A REVIEW OF ASSISTIVE TECHNOLOGY AND WRITING SKILLS FOR STUDENTS WITH PHYSICAL AND EDUCATIONAL DISABILITIES

GEORGE PETERSON-KARLAN
Illinois State University

JACK J. HOURCADE
Boise State University

PHIL PARETTE
Illinois State University

ABSTRACT

In recent years effective instruction in reading for learners with physical and educational disabilities has received great attention in the schools. However, instruction in the corollary skill of writing has received considerably less emphasis. This review paper notes that through the use of assistive technology, students with a variety of physical and educational disabilities can learn to effectively (a) plan and organize their writing, (b) draft and transcribe their work, and (c) edit and revise their narrative and expository writing.

With teachers increasingly being held accountable for the development of literacy skills in all students, including those students with physical and educational disabilities, schools are paying substantial and growing attention to reading. The expressive side of the literacy coin, writing skills, is arguably equally significant and worthy of instructional emphasis. However, there are growing indicators that writing has not received enough attention in the national educational reform debate (National Commission on Writing, 2003, 2006; National Writing Project & Nagin, 2006).

Along with reading comprehension, writing skill is a powerful predictor of academic success (Graham & Perin, 2007), and is an effective means of developing higher-order thinking skills (National Writing Project & Nagin, 2006). Writing helps learners make sense of the world (e.g., "Letters from Ground Zero," cited in National Commission on Writing, 2006). Yet to date the teaching of writing skills to students with disabilities, including physical disabilities, has not received the level of curricular emphasis that teaching reading skills has (Graham & Perin, 2007).

For students with physical and educational disabilities, stronger writing skills offer a variety of benefits. These include (a) more successful academic inclusion outcomes, (b) transfer of improved literacy skills to reading, and (c) greater pass rates on high stakes academic testing. As more and more careers require greater levels of literacy skills, students with disabilities who are unable to write effectively may find themselves increasingly minimized in these adult roles. Writing is considered to be an essential "threshold skill" for hiring and promotion (National Commission on Writing, 2003), and is a basic requirement for participation in civic life and the global economy (Graham & Perin, 2007; National Commission on Writing, 2003). This paper reviews the use of a variety of assistive technologies in enhancing writing skills in students with physical and educational disabilities.

INSTRUCTION IN WRITING

The lack of emphasis on teaching writing skills cannot be attributed to lack of information on effective instruction, as models and methods for teaching good writing are well-known (National Commission on Writing, 2006; National Writing Project & Nagin, 2006). Prior to the 1970's, most approaches to writing were product-centered and print-based, focusing upon a sequence of "essential skills." This included forming letters, building vocabulary, identifying parts of speech, diagramming sentences, mastering grammar and punctuation, and following prescriptive conventions for writing paragraphs and genres of writing (National Writing Project & Nagin, 2006). This approach targeted correctness, memorization and skill drills.

But by 1985 research was increasingly concluding that such an approach produced negligible improvement in quality of student writing (National Institute of Education, 1985, cited in National Writing Project & Nagin, 2006). Based on the work of Emig and Graves, a new approach to writing emerged in the 1970's: the *process writing approach* (National Writing Project & Nagin, 2006).

The process writing approach incorporates several separate and specific phases in writing, including planning, drafting, revising and editing. Each of these has been identified as critical to the process of writing (National Writing Project & Nagin, 2006). Competent writers cycle and recycle through three main subprocesses: planning (generating ideas, setting goals, and organizing), translating (turning plans into written language), and reviewing (evaluating and revising) (National Writing Project & Nagin, 2006). These processes may be represented as *writing strategies* (See Table 1).

TABLE 1.
Writing Process Strategies

STRATEGY	Explanation
Prewriting	Any planning activity that helps to create content and generate ideas to be developed into a composition, including brainstorming, free writing, discussion, drawing, etc. Planning also includes organizational activities such as grouping ideas or information into a web or clusters or generating an outline. Prewriting does not focus on correctness or mechanics.
Drafting	Development of content through sustained production of connected prose which may proceed from a "discovery draft" in rough form to a more focused form in which the material is transformed, organized and structured into a final form for an authentic audience. The number of drafts may vary in type, length and complexity depending on the writing task.
Revision	Activities involved in making structural changes to a text (macro-editing) to refine content and create structure by organizing ideas and themes into sequenced, coherent paragraphs. May involve identifying and deleting extraneous material and determining what needs to be elaborated and what needs to be cut.
Editing	Activities involved in making sure that what the writer meant to say is said exactly in the most appropriate language. While editing may be taken to be synonymous with revising, it is micro-editing at the sentence level, and includes proofreading sentences, phrases and words and focuses on mechanics, spelling, punctuation and other conventions.

Adapted from National Writing Project & Nagin, 2006

Students learning to write require models, direct instruction, and *scaffolding* (an explicit framework or sequence of steps). This provides students with an organizational scheme and guidelines for using strategies (e.g., imagining a situation from a perspective different than one's own, comparing and contrasting cases, explaining how evidence supports a claim, etc.) (National Writing Project & Nagin, 2006).

TECHNOLOGY & WRITING

Technology has significant potential to support both student writing and the teaching of writing (National Commission on Writing, 2003; National Writing Project & Nagin, 2006). While technology can be used to support all phases of the writing process, the specific processes of (a) drafting (including transcription) and (b) editing and revising may especially benefit (National Commission on Writing & Nagin, 2006).

In addition, technology enables writing in new ways. It can provide new sources of and means for obtaining information (e.g., the Internet and search engines). It enables sharing, editing, and commenting on writing. It can facilitate the development of new teacher-writer and peer-writer relationships, permit students to work with peers at remote locations, and allow them to gauge the quality of their writing and level of skill against peers elsewhere (National Commission on Writing, 2003, 2006; National Writing Project & Nagin, 2006). Finally, technology can dramatically transform the fundamental nature of writing by introducing new electronic genre and new multimedia forms in which composing involves a combination of media, including print, still images, video and sound (National Council of Teachers of English, 2004).

There has been a sustained interest in a variety of technologies to support writers with physical and educational disabilities. These include word processing, spell checkers, word prediction, speech recognition, and text-to-speech screen review (Berninger & Amtmann, 2003; MacArthur, 1996, 1999a, 2000). These technologies are not meant to replace good writing-as-process instruction, but are best used to support students who struggle to write (i.e., those who perform below the basic level of proficiency) and to provide "scaffolding" for basic writing skills (National Writing Project & Nagin, 2006). Technological scaffolding provides a compensatory function in that it permits them to perform at higher levels of proficiency than would otherwise be possible (Peterson-Karlan & Parette, in press) Technology providing such compensatory function is referred to as *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 skills required by the student due to the nature of the disability (Edyburn, 2002).

The purpose of this review paper is to provide an overview of technologies that can be used to support the development of writing by students with physical and educational disabilities, emphasizing those technologies which are evidence-based. (For additional information on this evidence base, see *Technology-Based Tools to Support Writing by Learners with Academic & Learning Disabilities* available at www.nationaltechcenter.org in the "Writing Tools Matrix.")

PREWRITING (EMERGENT WRITING SKILLS)

Language Development

The sequential emergence of writing skills is fundamentally intertwined with the child's overall development of language and the incorporation of world experiences. As a young child experiences the world, internal thought processes become increasingly symbolically-based, using as a foundation the child's rapidly developing receptive and expressive language skills. Children first begin to establish one-to-one correspondences between real and concrete objects/events, and their symbolic representations. Later on the child develops symbolic representations for more abstract concepts.

Text Generation

As the size of the child's symbolic receptive and expressive vocabularies expand, the next significant literacy milestone is the expressive combination of these symbols into multi-word sequences. A child's initial two (and more) word expressive utterances represent mastery not only of the individual symbols of language, but also of linguistic syntax, the way in which individual linguistic elements (words) are put together to form meaningful and more complex expressions than can be achieved by single words alone.

Typically this initially happens for most children through verbal utterances, and subsequently through visual expressive representations of symbols (usually through writing). The emergence of writing begins when the student begins to transform thought into a connected series of words and these words into a sequence of visual text. There are two interrelated processes that are developed here: *text generation and text transcription* (Berninger, 1999). Text generation refers to the relatively high level cognitive processes involved in

transforming one's basic thoughts into the symbols and structures appropriate to written communication. Text transcription refers to the relatively lower level cognitive skills associated with spelling and handwriting or keyboarding.

Students with physical disabilities often experience significant challenges with text transcription through both handwriting and keyboarding, as they may have limited strength and endurance for such tasks (Mezei & Heller, 2005). In addition, such physical disabilities as cerebral palsy and spina bifida are often accompanied by disorders in gross and fine motor movements, negatively impacting typing fluency (Lewis, Graves, Ashton, & Kiely, 1998). For students with physical or other disabilities that interfere with traditional written representations of multi-symbol communications, assistive technology offers several powerful alternatives.

For example, Boardmaker™ is a computer-based program that allows students to create printed symbol-based communications using either Picture Communication Symbols or other pictures and graphics. Featuring over 4,500 PCS symbols, the power Boardmaker to facilitate emergent writing can be further enhanced by integrating it with Speaking Dynamically Pro™, which gives voice output capability to these expressive communications.

Similarly, Clicker 5™ is a computer based writing support and multimedia tool for children of all abilities. At the top of the screen is a word processor called "Clicker Writer." At the bottom of the screen is the "Clicker Grid." The Clicker Grid has a number of individual cells containing letters, words or phrases that the user can click on. This can be accomplished with an adapted mouse (e.g., trackball or optical mouse) or via single-switch scanning. These selected words or phrases are then automatically sent into Clicker Writer, allowing users to write sentences without actually writing or using individual keyboard strokes.

These and related assistive technologies facilitate the generation of visual symbols to represent multi-element communications. In short, this sort of assistive technology makes it possible for students of widely diverse physical and academic ability levels to develop multi-element visual language representations; that is, to functionally write.

Text Transcription

In writing, many students struggle with the actual motoric skills required in handwriting, including grasping the writing utensil (e.g., a pencil) and creating the correct formations of and spacing for letters and words. This is especially challenging for many students with physical disabilities, who often have difficulty writing efficiently and accurately due to involuntary motor

patterns affecting both fine and gross motor movements (Mezei & Heller, 2005).

In addition, many students with physical disabilities may generate inadvertent spelling errors due to poor motor control of the pen or pencil leading to issues of legibility. Similarly, such students may experience spelling errors when keyboarding due to motor problems, with the accuracy of keyboard entries negatively impacted due to involuntary movement patterns (Heller, 2005).

In traditional handwritten drafts, students may become overly conscious in their attempts to produce legible handwriting and mistake-free spelling. This effort comes at a significant cost, as they then may lose track of their basic ideas, supporting details, and logical sequences to be conveyed in their writing. The result is poor quality writing.

However, analyses of these students' dictated stories or explanations often reveal that these writers can generate appropriate ideas, details, and logical sequences. Their poor skills in transcription simultaneously (a) decreases the readability and perceptions of the quality of their writing while (b) increasing the amount of time in takes these students to complete these writing tasks.

To facilitate student progress in text transcription, any assistive technology that is used should support a variety of related functions, including:

- Readability or legibility of print production
- Speed of the transcription
- Accuracy of the transcription
- Length of the composition
- Quality of the composition, including:
    - Increased variety of words
    - Increased length (complexity of sentences)
    - Improved number or quality of ideas, details, text elements

To the degree that assistive technology (AT) supports students in these relatively mechanical tasks, these young writers are then cognitively freed to concentrate on the clarity and complexity of their written work.

Assistive technology here can include such low tech systems as pencil grips or adapted writing devices combined with raised line paper and slant boards, all of which support legibility of the transcribed product. Of course, writing through keyboarding instead of handwriting eliminates the legibility of handwriting as an issue for students with physical and other disabilities. In addition, writing on the computer opens the door for a variety assistive technologies that may also address the more academic and cognitive demands of text transcription.

Most word processing programs include two compensatory tools that further facilitate transcription: (a) keyboarding, which changes the task from forming letters by hand to finding and selecting the correct keys (Berninger & Amtmann, 2003); and (b) spellcheckers, which assist writers in detecting and correcting spelling errors. Word processors may be further adapted through the use of separate adapted keyboards (e.g., Intellikeys™) or on-screen keyboards operated via scanning or optical mouse.

Spelling is the accurate production of letter sequences, a task that remains a substantial challenge for many writers, especially those with disabilities. Spelling accounts for 41% of the variability in the writing products of elementary grade students, while handwriting fluency accounts for 66% (Graham, Berninger, Abbott, Abbott, & Whittaker, 1997). Fifth and sixth grade students with learning disabilities misspell about 12% of their words and lack initial capitalization or final punctuation in about 33% of their sentences (MacArthur & Graham, 1987). Spelling, punctuation, capitalization and grammar errors are found in approximately 40% of all words written (Lewis, Graves, Ashton, & Kieley, 1998).

Accurate spelling can be supported through the built-in spell checker functions contained in most word processing programs. However, spell checkers with certain advanced functions, including (a) speech output, (b) the ability to interpret phonetically-based spellings, and (c) homonym identification tools, can provide further supports for accurate transcription among students with more severe spelling inaccuracies (e.g., *SOLO*™ writing suite by Don Johnston, Inc.; *Read & Write Gold*™ by Text Help Systems).

Two especially powerful assistive technologies to support text transcription are (a) *word prediction* and (b) *speech recognition* capabilities. Word prediction programs (e.g., Co:Writer 4000™ or WordQ™) reduce the number of keystrokes necessary to transcribe a word (Koester & Levine, 1996; Newell, Arnott, Booth, Beattie, & et al., 1992) by using the first one to three letters that are typed to predict the target word. Based on what letters of the word have been typed, these programs first provide a list of choices or guesses as to the ultimate word. The proposed word list offered is then dynamically changed as more letters are typed, thus increasing the accuracy of the predictions. Word prediction programs may also offer automatic spacing (e.g., one space following an inserted word, two spaces following terminal punctuation), and automatic capitalization (e.g., of the first word following terminal punctuation). Word prediction offers substantial potential benefits to students with poor spelling abilities or with physical disabilities that may impair their ability to quickly and accurately enter keystrokes (MacArthur, 1999a, 2000; Newell et al., 1992).

Typically using only the mouse, the writer scans the list of words offered and selects the word from the list. However, research with both children with and without physical impairments has concluded that this selection requirement adds to the cognitive load on the user by adding both search time and decision-making, a potential disadvantage (Koester & Levine, 1996). The scan-and-select requirement may actually decrease text generation (transcription) speed as compared to typing (Koester & Levine, 1996), but increase transcription accuracy by producing more correctly spelled words (Newell et al., 1992). It does have the benefit of requiring fewer keystrokes for students with physical disabilities (Koester & Levine, 1996).

It may be that word prediction technologies offer the greatest potential for enhancing typing speed in students with the most severe levels of physical disability and the slowest typing speeds (Tumlin & Heller, 2004). Practice with these word prediction technologies, both short-term (Koester & Levine, 1996) and long-term (Newell et al., 1992), improves transcription rate. Voice output (i.e., synthesized text-to-speech pronunciation of the offered words) can be added to word prediction or word cueing to offer further support (e.g., (MacArthur, 1998, 1999b; Zhang, 2000; Zhang, Brooks, Fields, & Redelfs, 1995).

Speech recognition technology uses a microphone and computer program to input spoken language of the "writer," and then directly generate transcribed text. (Sample programs of this type include *Dragon Dictate Naturally Speaking*™ and *SpeakQ*™). Speech recognition systems typically require the user to "train" the software by speaking pre-determined words or text passages. This input is then analyzed by the program to compare voice patterns with the known words and word sequences, with the user fine-tuning the speech recognition accuracy as necessary. Newer versions of these programs boast reduced training time and more immediate functionality.

The rapid and ongoing evolution and refinement of speech recognition technology has made it difficult to assess its effectiveness for students with disabilities (Berninger & Amtmann, 2003; MacArthur, 1999a, 2000). Older systems utilized discrete speech recognition whereby each individual word was dictated with a slight pause between words. Newer systems employ continuous speech recognition, permitting a more natural flow of dictation (MacArthur, 1999a; 2000). However, both systems require the user to articulate carefully, to attend to phrasing to increase context cues, to dictate punctuation and formatting, and to learn specific commands in order to perform editing without use of the keyboard (Honeycutt, 2003; MacArthur, 2000). These issues suggest that careful attention must be paid to both (a) operational competence and (b) the ability of students to articulate accu-

rately enough for the speech recognition program to respond effectively. Such programs may be less than optimal for students with physical disabilities that impact speech intelligibility (e.g., cerebral palsy).

Assistive technology software possibilities to support text transcription include the following programs:

- AppleWorks
- Co:Writer 4000
- Dana
- Dragon Naturally Speaking Essentials
- Dragon Naturally Speaking Preferred
- Kurzweil 3000
- Microsoft Word 2003
- Neo
- Read and Write—Gold 8.1
- SOLO
- Word Q
- Word Q + Speak Q
- Word Bar
- Write Brain
- Write:Outloud v3.0
- Writer's Companion
- WYNN
- Writer II
- Zoho Writer

WRITING THROUGH THE GRADES

There is a typical sequence in the development of writing skills. Writing at the first grade level tends to be centered on *expository writing,* where students write brief descriptions of real objects, people, places, and/or events. In the third through the fifth grades, many language arts curricula further develop expository writing, seeing it as the foundation for the subsequent academic report writing that typifies much writing at the secondary and post-secondary levels. Expository writing is designed to convey academic or research information, to explain ideas or concepts.

More specifically, in expository writing the writer seeks to:

- Identify and stay on topic.
- Develop the topic with simple facts, details, examples, and explanations.
- Exclude extraneous, inappropriate, and unnecessary information.

- Use such structures as cause and effect relationships, chronologies, and similarities and differences.
- Use a variety of credible sources of information.
- Provide a concluding summation section.

At the second grade many teachers begin to also instruct students in *narrative writing*. In narrative writing, students write brief stories that move through a logical sequence of events, describing settings, characters, objects and events in some detail. The development of narrative writing typically continues through the secondary level.

The following represent typical school assignments and requirements at the secondary and post-secondary levels for (a) expository writing/research reports, and (b) narrative writing.

RESEARCH REPORT APPLICATION

Write a research paper that separates information on a specific topic into major components based on a set of criteria, examines critical relationships between and among elements of a research topic; addresses different perspectives on a topic, achieves balance between research information and original ideas, integrates a variety of information into a whole, draws conclusions, uses a variety of resource materials to gather information, and uses appropriate methods to cite and document reference sources.

NARRATIVE WRITING APPLICATION

Write a narrative account, such as a short story, that establishes a context that enables the reader to imagine the event or experience; develops characters, settings, plot and point of view; reveals a theme; creates an organizing structure; sequences events; uses concrete sensory details; uses a range of strategies and literary devices such as dialogue, tension, suspense, figurative language; uses narrative action such as movement gestures, and expressions; and uses an identifiable voice.

Such writing assignments mean that students with writing difficulties likely will need writing support tools that go beyond mere support for transcription. These complex and higher level writing tasks require that students engage in systematic planning, organization, editing and revising of written works. Assistive technologies are available to support these more advanced components of the writing process.

Planning and Organization

The first stage in the writing process is the planning and organization of what is to be written. Prior to any words being recorded, the effective writer considers and plans what is to be said, and the best way(s) to say it. Students with disabilities frequently struggle with this task. Particular issues include (a) lack of understanding of the purpose of the composition (i.e., the specific writing task, such as free writing, narrative, and expository writing), (b) lack of time spent in planning, (c) lack of strategies or procedures for generating and organizing ideas, (d) lack of knowledge of "text structures" (i.e., compare-and-contrast, persuasive argument, opinion essay, etc), and (e) over-reliance on narrative or descriptive text structures (Englert & Raphael, 1989; Newcomer & Barenbaum, 1991; Raphael & Englert, 1990). Writing outcomes of an unplanned approach are brief, disorganized, and lack a logical sequence and systematic development of ideas. Compositions tend to be simple strings of thoughts, with one idea apparently randomly generating the next.

In effective writing, the writer begins a cognitive planning process in which the following questions must be considered:

- What is the *purpose* for this writing (the writing task)?
- What is the basic *topic* of the writing?
- Who is the intended *audience* for this writing?
- What *ideas and points* should be included or covered in the writing?
- How can the basic ideas and points best be *organized?*

The writer's responses to these questions serve to guide subsequent work.

For example, if the purpose is to generate a narrative story, the writing should seek to incorporate such elements as main and supporting characters, one or more settings, one or more conflicts to be resolved, etc. Conversely, if the purpose is to develop an opinion essay, critical elements might include a statement of the issue, the writer's position on the issue, and a list of reasons why that position was taken.

Procedural facilitation, or instructional scaffolding, involves the provision of cognitive supports regardless of the specific content or substance of the writer's composition. It is a remedial approach that allows students to "emulate the performance of mature writers, in spite of their less advanced devel-

opmental levels" (Englert, Raphael, Anderson, Anthony, & Stevens, 1991), p. 340). In writing, scaffolds may be a series of graduated questions that are provided during planning by teachers to cue strategy use, or such tools as cueing cards (Graves, Montague, & Wong, 1990) or "think sheets" (Englert & Raphael, 1989; Raphael & Englert, 1990). This support contains information about text structures and strategies for developing and organizing information prior to beginning writing (Englert et al., 1991; Graham & Harris, 2003). Such cognitive scaffolding tools in the form of paper or electronic guides to planning have served effectively as the basis for the improvement of prewriting planning (Bahr, Nelson, & Van Meter, 1996).

A variety of assistive technologies incorporate supports for planning and organization, including procedural facilitators that provide reminders of what information or elements should be present in the written product; and how to generate, select and/or organize the information. For example, with the software Kidspiration™, students build graphic organizers by combining pictures, text and spoken words to represent their thoughts and information. Using the program's Picture View, they create graphic organizers to brainstorm and organize ideas.

Other assistive technology software possibilities to support planning and organization include:

- AppleWorks
- Inspiration
- Kidspiration
- Microsoft Word 2003
- Read and Write—Gold 8.1
- Draft:Builder
- SOLO
- Write Brain
- Writer's Companion
- Zoho Writer
- Writer II

Drafting, Editing, and Revising

In preparing a first draft, the student must plan how best to say what was initially conceived; select specific words, sentences, and text structures; produce the text; and monitor the writing in order to revise "on the fly." Students must understand that, perhaps unlike other kinds of academic work, what is initially committed to paper is likely to be substantially different than the final submitted product. This process of *drafting,* wherein a initial written product is produced with the foreknowledge that it will then be revised and

further polished, is not instinctive for many writers, especially students with physical and educational disabilities. Students must learn that it is acceptable, even desirable, to first get something down on paper that will then be further refined at a later stage.

Many students with physical and educational disabilities may not intuitively produce first drafts with the foreknowledge that that work will then be further refined. Although students may resist revision, it is critical in completing acceptable writing. In the *editing* and *revising* phases, students learn to review and reflect upon the initial version of their written work, determining how well it conveys the ideas the writer had intended. Editing and revising are two distinct (though complementary) processes.

In *editing* the writer seeks to identify and correct so-called mechanical errors in the conventions of writing, a process often referred to as *proofreading*. Typical errors include mistakes in spelling, capitalization, punctuation, and grammar. *Revising* (literally meaning "to see again") refers to the higher level cognitive task of clarifying the intended purpose and meaning of the written product through better word and syntax structural choices. The goal is to make the writing more understandable to the reader, to enhance reader accessibility to the writing.

In revision the writer seeks to clarify, expand, and/or rearrange ideas, or to provide greater detail. Given the demands on working memory generated by transcription problems (MacArthur, 1999a), it is not surprising that students with physical and educational disabilities have difficulty managing the revision processes (Graham & Harris, 2003). Revising brings attention to the substance of the composition, including organization, clarity, and detail. Too often students with physical and educational disabilities lack skill in both (a) making meaningful evaluations of their writing and (b) executing the appropriate change(s) (Graham & Harris 2003). Another important element of revising is concern for the reader, something often lacking in the revising efforts of students with physical and educational disabilities (Graham & Harris, 2003). These students have been found to consider the reaction of an audience to their text in only 6% of their revision decisions. Of these, only 25% of the revisions actually improved the text (Graham, 1997).

Assistive technology can aid writers with physical and educational disabilities in both editing and revising their compositions. Most contemporary word processing programs can automatically detect mechanical errors in spelling, punctuation, and grammar, signaling these to the reader visually, audibly, or both. In addition, the programs typically offer several suggested alternatives for improvement. In combination with these detection tools, the student might then use tools such as the spell checker or homonym identi-

fiers (as discussed earlier) to assist in repairing errors. The editing and screen display component of word processors (e.g., delete, move, cut, paste) may enhance drafting effectiveness by making letters, words and sentences visible to the student and legible to the teacher, and may enhance revision through ease of modifying text and facilitation of peer collaboration and teacher interaction (Isaacson & Gleason, 1997; MacArthur, Ferretti, Okolo, & Cavalier, 2001).

Assistance in the higher level task of revision is a more challenging task. Although it has the potential to encourage and facilitate revision, word processor use alone by students with physical and educational disabilities does not change either the type or amount of revisions (MacArthur & Graham, 1987). However, the inclusion of procedural facilitators (Gersten & Baker, 2001) in the form of self-generated revision prompts have been found to improve revision skills among students with physical and educational disabilities. Two types of procedural facilitation strategies have been developed: (a) sentence-by-sentence analysis and revision; and (b) a two-pass strategy that first analyzes and revises overall organization and meaning, and then analyzes and revises each sentence (Graham & Harris, 2003). The use of a word processor combined with procedural facilitation for revising overall content does increase (a) the overall number of revisions, (b) the number of substantive revisions, and (c) the quality of the written compositions generated by students with physical and educational disabilities (Graham & MacArthur, 1988). Word processors combined with text-to-speech output using speech synthesis have demonstrated potential as an effective support for the editing and revising processes (Raskind & Higgins, 1995).

The writing software SOLO (Don Johnston) provides a number of tools to support students as they revise and edit written work. SOLO has a simple one-click toolbar that provides a variety of easy-to-use editing tools. Electronic revising guides are available. In addition, SOLO features a natural sounding text-to-speech feedback function. As students listen to their written product this way, they are able to better evaluate their writing, literally hearing how it sounds to a reader. They are then able to make editing choices to make their writing "sound" even better.

Other assistive technologies that can support the process of editing and revising include the following:

- AppleWorks
- Dana
- Dragon Naturally Speaking Essentials
- Dragon Naturally Speaking Preferred
- Kurzweil 3000

- Microsoft Word 2003
- Neo
- Read and Write—Gold 8.1
- Write Brain
- Write:Outloud v3.0
- Writer's Companion
- WYNN
- Writer II
- Zoho Writer

CONCLUSIONS

The Individuals with Disabilities Education Act (IDEA) required school professionals who work with students who have physical and educational disabilities to consider the potential educational contributions of assistive technology when developing individual education programs (IEPs). Unfortunately, many current educators lack sufficient knowledge, skills, and competencies in assistive technology to functionally integrate this resource into educational programs for their students with physical and educational disabilities.

The importance of assistive technology becomes even more compelling in light of the academic achievement emphasis of the No Child Left Behind (NCLB) Act of 1991 (P. L. 107–110), as well as the increasing emphasis of the recent reauthorization of IDEA on access to the general education curriculum (National Center for Learning Disabilities, 1999–2004). The reauthorizations of IDEA and NCLB have resulted in a dramatic increase in the numbers of students with physical and educational disabilities being educated in inclusive general education settings. This has been accompanied by substantial demands for accountability concerning student academic achievement, including the significant subgroup of students with physical and educational disabilities.

Given these legislative developments, reading and writing skills are critical to the success of inclusive educational programs for these students. While reading skills typically are emphasized in educational programs, writing skills may not receive equivalent instructional attention. A variety of assistive technology applications can facilitate the development of writing skills in each of the three phases of writing for students with physical and educational disabilities: (a) planning and organization, (b) transcription (drafting), and (c) editing and revising. By incorporating these readily available technologies into writing instruction for students with physical and educational

disabilities, educators can enhance the success of their students with physical and educational disabilities. Readers wishing to view more detailed information concerning the specific features of writing support offered by the various technologies cited here are referred to www.nationaltechcenter.org to examine the writing tool matrices available there.

REFERENCES

Bahr, C. M., Nelson, N. W., & Van Meter, A. (1996). The effects of text-based and graphics-based software tools on planning and organizing stories. *Journal of Learning Disabilities, 29,* 355–370.

Berninger, V. W. (1999). Coordinating transcription and text generation in working memory during composing: Automatic and constructive processes. *Learning Disability Quarterly, 22*(2), 99–112.

Berninger, V. W., & Amtmann, D. (2003). Preventing written expression disabilities through early and continuing assessment and intervention for handwriting and/or spelling problems: Research into practice. In H. L. Swanson, K. R. Harris, & S. Graham (Eds.), *Handbook of learning disabilities* (pp. 345–363). New York: Guilford Press.

Edyburn, D. L. (2002). 2001 in review: A synthesis of the special education technology literature. *Journal of Special Education Technology,* 17(2), 5–24.

Englert, C. S., & Raphael, T. E. (1989). Developing successful writers through cognitive strategy instruction. In J. E. Brophy (Ed.), *Advances in research in teaching: A research annual* (Vol. 1, pp. 105–151). Greenwich, CT: JAI Press.

Englert, C. S., Raphael, T. E., Anderson, L. M., Anthony, H. M., & Stevens, D. D. (1991). Making strategies and self-talk visible: Writing instruction in regular and special education classrooms. *American Educational Research Journal, 28*(2), 337–372.

Gersten, R., & Baker, S. (2001). Teaching expressive writing to students with learning disabilities: A meta-analysis. *The Elementary School Journal, 101,* 251–272.

Graham, S. (1997). Executive control in the revising of students with learning and writing difficulties. *Journal of Educational Psychology,* 89(2), 223–234.

Graham, S., Berninger, V. W., Abbott, R. D., Abbott, S. P., & Whittaker, D. (1997). Role of mechanics in composing of elementary school students: A new methodological approach. *Journal of Educational Psychology,* 89(1), 170–182.

Graham, S., & Harris, K. R. (2003). Students with learning disabilities and the process of writing: A meta-analysis of SRSD studies. In H. L. Swanson, K. R. Harris, & S. Graham (Eds.), *Handbook of learning disabilities* (pp. 323–344). New York: Guilford Press.

Graham, S., & MacArthur, C. A. (1988). Improving learning disabled students' skills at revising essays produced on a word processor: Self-instructional strategy training. *Journal of Special Education, 22*(2), 133–152.

Graham, S., & Perin, D. (2007). *Writing next: Effective strategies to improve writing of adolescents in middle and high schools*. Retrieved 10/31/2006, from http://www.all4ed.org/publications/WritingNext/index.html.

Graves, A., Montague, M., & Wong, Y.-L. (1990). The effects of procedural facilitation on the story composition of learning disabled students. *Learning Disabilities Research, 5*(2), 88–93.

Heller, K. W. (2005). Adaptations and instruction in writing. In S. J. Best, K. W. Heller, & J. L. Bigge (Eds.), *Teaching individuals with physical or multiple disabilities* (5th ed.). Upper Saddle River, NJ: Pearson.

Honeycutt, L. (2003). Researching the use of voice recognition writing software. *Computers and Composition, 20*(1), 77–95.

Isaacson, S., & Gleason, M. M. (1997). Mechanical obstacles to writing: What can teachers do to help students with learning problems? *Learning Disabilities Research and Practice, 12*(3), 188–194.

Koester, H. H., & Levine, S. P. (1996). Effect of a word prediction feature on user performance. *Augmentative and Alternative Communication, 12*(3), 155–168.

Lewis, R. B., Graves, A. W., Ashton, T. M., & Kieley, C. L. (1998). Word processing tools for students with learning disabilities: A comparison of strategies to increase text entry speed. *Learning Disabilities Research and Practice, 13*(2), 95–108.

MacArthur, C. A. (1996). Using technology to enhance the writing processes of students with learning disabilities. *Journal of Learning Disabilities, 29*(4), 344–354.

MacArthur, C. A. (1998). Word processing with speech synthesis and word prediction: Effects on the dialogue journal writing of students with learning disabilities. *Learning Disability Quarterly, 21*(2), 151–166.

MacArthur, C. A. (1999a). Overcoming barriers to writing: Computer support for basic writing skills. *Reading and Writing Quarterly, 15*(2), 169–192.

MacArthur, C. A. (1999b). Word prediction for students with severe spelling problems. *Learning Disability Quarterly, 22*(3), 158–172.

MacArthur, C. A. (2000). New tools for writing: Assistive technology for students with writing difficulties. *Topics in Language Disorders, 20*(4), 85–100.

MacArthur, C. A., Ferretti, R., Okolo, C., & Cavalier, A. (2001). Technology applications for students with literacy problems: A critical review. *Elementary School Journal, 101,* 273–301.

MacArthur, C. A., & Graham, S. (1987). Learning disabled students' composing under three methods of text production: Handwriting, word processing, and dictation. *The Journal of Special Education, 21*(3), 22–42.

Mezei, P., & Heller, K. W. (2005). Evaluating word prediction software for students with physical disabilities. *Physical Disabilities: Education and Related Services, 23,* 93–113.

National Commission on Writing. (2003). The neglected R: The need for a writing revolution [Electronic Version]. Retrieved 6/29/2007 from http://www.writingcommission.org/.

National Commission on Writing. (2006). Writing and school reform [Electronic Version]. Retrieved 6/29/2007 from http://www.writingcommission.org/.

National Council of Teachers of English. (2004). NCTE beliefs about the teaching of writing. Retrieved 7/2/2007, from http://www.ncte.org/prog/writing/research/118876htm

National Writing Project, & Nagin, C. (2006). *Because writing matters: Improving student writing in our schools.* San Francisco: Josey-Bass.

Newcomer, P. L., & Barenbaum, E. M. (1991). The written composing ability of children with learning disabilities: A review of the literature from 1980 to 1990. *Journal of Learning Disabilities, 24*(10), 578–593.

Newell, A. F., Arnott, J. L., Booth, L., Beattie, W., & et al. (1992). Effect of the "PAL" word prediction system on the quality and quantity of text generation. *Augmentative and Alternative Communication, 8*(4), 304–311.

Peterson-Karlan, G. R., & Parette, H. P. (in press). Integration of technology into the curriculum. In H. P. Parette & G. R. Peterson-Karlan (Eds.), *Research-based and emerging best practices in developmental disabilities.* Austin: TX: Pro-Ed.

Raphael, T. E., & Englert, C. S. (1990). Reading and writing: Partners in constructing meaning. *The Reading Teacher, 43,* 388–400.

Raskind, M. H., & Higgins, E. L. (1995). Effects of speech synthesis on the proofreading efficiency of postsecondary students with learning disabilities. *Learning Disability Quarterly, 18*(2), 141–158.

Tumlin, J., & Heller, K. W. (2004). The use of word prediction software to increase typing fluency and reduce spelling errors of students with physical disabilities. *Journal of Special Education Technology, 19*(3), 5–14.

Zhang, Y. (2000). Technology and the writing skills of students with learning disabilities. *Journal of Research on Computing in Education, 32*(4), 467–478.

Zhang, Y., Brooks, D. W., Fields, T., & Redelfs, M. (1995). Quality of writing by elementary students with learning disabilities. *Journal of Research on Computing in Education, 27*(4), 483–499.

Address all correspondence to: Dr. Jack J. Hourcade, Department of Special Education, MS 1719, Boise State University, Boise, ID 83725 jhourca@boisestate.edu