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Text Transformations

Curriculum Enhancement

This report was written with support from the National Center on Accessing the General Curriculum (NCAC), a cooperative agreement between CAST and the U.S. Department of Education, Office of Special Education Programs (OSEP), Cooperative Agreement No. H324H990004. The opinions expressed herein do not necessarily reflect the policy or position of the U.S. Department of Education, Office of Special Education Programs, and no official endorsement by the Department should be inferred.

The implications for UDL content and lesson plan information in this report was developed by CAST through a Subcontract Agreement with the Access Center: Improving Outcomes for All Student K–8 at the American Institutes for Research. This work was funded by the U.S. Department of Education, Office of Special Education Programs (Cooperative Agreement #H326K02003).

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INTRODUCTION

Curriculum enhancements are add-ons directed at helping students to overcome curriculum barriers that impede access to, participation, and progress within the general curriculum. For many students, a primary barrier is printed text—a staple of classroom instruction. To give a few examples, students without a well-developed ability to see, decode, attend to, or comprehend printed text cannot learn from it and are severely disadvantaged throughout their education. Students' difficulties with printed text range from subtle to profound but every student can benefit from a curriculum enhanced with alternative media and text supports. The discussion below introduces a set of curriculum enhancements, which we call text transformations, that represent such alternatives.

DEFINITION AND TYPES OF TEXT TRANSFORMATIONS

We use the term text transformations as a broad classification inclusive of *text modifications* and innovative *technology tools* that alter or add to the features of printed text. To facilitate intelligent and productive discussion, within these two categories we have developed subcategories that group together similar enhancements. Although many enhancements rightly belong to multiple categories, to avoid redundancy, we have placed them in what appears to be the best fit.

Modified Text

Modified text is any text that has been changed from its original print format. The category encompasses texts with altered content or physical characteristics and printed texts presented in a different modality. Traditionally, teachers have carried out text modifications by hand—enlarging text on a photocopier, rewriting text with simplified language, or underlining main ideas in a textbook. This approach places an unnecessary burden on teachers, for whom it becomes very cumbersome—even infeasible—to accomplish on a class-wide scale. Technology can make this job easier to achieve with many more students. Because we feel that technology is essential to making modified texts a realistic kind of enhancement, we will discuss only technology-based modified texts.

Most text modifications begin with conversion to electronic text, because this conversion releases teachers and students from the rigidity of the print format. Once converted to an electronic form, text can, for example, be easily converted to modified text in the form of *text-to-speech.* It can also be converted to *hypertext,* which incorporates hyperlinks to existing or supplemental content. These hyperlinks may help explain difficult vocabulary or concepts, provide background information, or prompt self-reflection or the use of comprehension strategies. These same kinds of supports can be built-in through hyperlinks to images, sound, animation, and video—resulting in a *hypermedia* text.

Multimedia, video, and videodiscs are additional examples of modified texts. They represent a change of modality, and in some cases a change of content. These types of modified texts use images, moving images, and sound to provide information redundant with or supplementary to the text.

Technology Tools

We define a technology tool as any technological device or program that affects the use of text or content that would otherwise be presented with text. Examples include *spell checkers, word processors, word prediction software, speech recognition software, and computer/software programs.* Word processors provide a means to generate text, edit its content, and alter its physical characteristics. Spell checkers, speech recognition software, and word prediction software also scaffold the writing process. Computer and software programs can offer multiple technological tools in one package, providing a non-print environment for teaching, studying, and practicing skills.

APPLICATION ACROSS CURRICULUM AREAS

Text transformations have potential applications across a range of curriculum areas. Although reading and writing are by far the best studied applications, a wide range of subject areas is represented in the research base: reading (N=61), writing (N=25), spelling (N=7), English (N=2), language arts (N=1), mathematics (N=14), social studies (N=4), science (N=10), health (N=2), social problem solving (N=2), reasoning (N=1), and telling time (N=2). Research investigations of text transformations have not been evenly distributed across these different curriculum areas. Word processing and word prediction, for example, have mostly been evaluated as enhancements to the writing curriculum, text-to-speech as an enhancement to reading instruction, and video and videodiscs as enhancements to math and science curricula. To an extent, this inequality reflects the compatibility of different text transformations with different curriculum areas. However, it is useful to keep in mind when reading this review that the operations and skills supported by a text transformation in one curriculum area are likely to be beneficial to other curriculum areas as well.

EVIDENCE FOR EFFECTIVENESS

The research literature is a valuable resource for evaluating the usefulness of enhancements and the ideal conditions for their classroom use. In the following sections, we digest the research findings for 10 enhancements, characterizing the extent to which each one is research validated and identifying the factors that influence its effectiveness. The discussion incorporates findings from an expansive survey of the peer-reviewed literature between 1980 and 2002. This survey included research studies conducted in K–12 education settings.

Modified Text

Modified Text Defined

Modified text represents a change of modality that alters or adds to features of printed text. It is any text that has been changed from its original print format. This may include altered content or physical characteristics and printed texts presented in a different modality. The types of modified text reviewed for this report include: electronic, text-to-speech, video and videodiscs and finally hypertext and hypermedia. Each represents a change of modality, and in some cases a change in content.

Electronic Text

Our discussion of electronic text is restricted to studies implementing it in its purest form, that is, absent other media such as sound and images. Studies of media-supplemented texts are discussed in the sections on hypermedia and multimedia. Their exclusion leaves relatively few studies, but the four studies discussed below contribute fundamental insights into the use of computers in the classroom.

In its simplest form, electronic text consists of an online display of print material. Studies of simple electronic text enable researchers to address the basic question of whether there is some advantage to digital display alone. Casteel (1988-89) for example, compared reading comprehension of text passages under three conditions: when the text was chunked and displayed on the printed page, when the text was chunked on a computer screen, and when the text was unchunked on a computer screen. Although chunked passages were associated with significantly greater reading comprehension than were the unchunked passages, student performance was statistically equivalent in the online and offline conditions (Casteel, 1988–89). Consistent with these findings, both Reinking & Schreiner (1985) and Swanson & Trahan (1992) showed that the text medium (print or electronic) does not affect reading comprehension or reading rate (Reinking, 1985; Swanson & Trahan, 1992). In contrast, Swanson & Trahan (1992) provide evidence that electronic text better supports vocabulary learning. It is not clear, however, that Swanson & Trahan performed the necessary statistical controls when making the relevant comparisons. Moreover, the study design did not offer any control for the potential novelty effect of reading on the computer.

It is not surprising that merely displaying material on a computer screen does not bring about superior reading skill. Exact reproduction of print material on a computer screen fails to take full advantage of the electronic medium's flexibility, which allows for reformatting and enhancement of the text with, for example, supports for reading comprehension (Leong, 1995; Reinking, 1985) and vocabulary (Feldmann & Fish, 1991; Leong, 1995). Reinking & Schreiner (1985) designed a computerized version of expository text passages that included four supports for reading comprehension: definitions for difficult words, main ideas for each paragraph, background information, and simplified versions of the passages. Students that read these supported electronic texts significantly outperformed those who read a basic electronic or print version. These findings suggest that electronic text can be a highly beneficial learning tool when the flexibility of the medium is put to use. In contrast, Leong (1995) found no differential benefit of regular text passages, simplified text passages, regular text passages with explanations of difficult words, or regular text passages with explanations and prereading questions—all read on the computer with text-to-speech (Leong, 1995). However, the sample size in this study was rather small to effectively detect differences, and treatment effects might have been obscured by pre-test differences.

Factors Influencing Effectiveness

This body of literature is too small to draw many supported conclusions about the factors influencing the effectiveness of electronic texts in the classroom. However, the limited research does caution that some characteristics can undermine electronic text's effectiveness. Reinking & Schreiner (1985) found that poorer readers in their sample performed better offline than they did when reading online with optional viewing of reading comprehension supports. This finding suggests that students, or at least poorer readers, may need advisement on when and how to use online supports effectively. Although the ability to add various supports is a clear benefit to this medium, electronic texts must be designed carefully and accompanied with sufficient guidance that different types of learners can navigate the text efficiently and put to their advantage its innovative features.

Text-to-Speech

Thirteen studies were identified relating to the effectiveness of text-to-speech or recorded speech as a learning tool in the classroom. The literature indicates that text-to-speech can be a valuable tool, but its effectiveness is contingent on numerous factors. These are discussed in the following sections.

Factors Influencing Effectiveness

Type of text-to-speech. Synthetic text-to-speech is more widely available and easier to generate than digitized text-to-speech, and this is reflected in the literature, where studies of synthetic speech predominate. Eight of the studies in this review used synthetic speech (Borgh & Dickson, 1992; Elbro, Rasmussen, & Spelling, 1996; Elkind, Cohen, & Murray, 1993; Farmer, Klein, & Bryson, 1992; Leong, 1992; Lundberg & Olofsson, 1993; Olson & Wise, 1992; Wise, 1992), four digitized speech (Davidson, Coles, Noyes, & Terrell, 1991; Dawson, Venn, & Gunter, 2000; van Daal & van der Leij, 1992), and one both (Hebert & Murdock, 1994). Four studies used recorded human speech (Abelson & Petersen, 1983; Davidson, Elcock, & Noyes, 1996; Montali & Lewandowski, 1996; Shany & Biemiller, 1995).

Six of the 8 studies evaluating synthetic speech reported some positive effect. Olson and Wise (1992) found that reading online with synthetic speech feedback led to significantly greater improvement on word and nonword recognition scores than did spending time out on a computer. Given the control group wasn't engaged in reading practice for the same amount of time, this is not surprising. Wise (1992) demonstrated an improvement in word recognition following time spent reading with text-to-speech. However, this study had no control group. Borgh & Dickson (1992) reported that writing on the computer with sentence level speech feedback led to significantly more sentence-level editing than did writing on the computer without the feedback. In a study by Elbro, Rasmussen, Spelling (1996) word recognition, comprehension, and fluency were all more positively affected by the use of synthetic, syllable- or letter name-level synthetic speech than by ordinary remedial training. Improvements in oral reading fluency were equivalent to the traditional instruction group, however. Additional positive effects have been reported for certain subpopulations within student samples. Both Leong (1992) and Lundberg and Oloffson (1992) reported a grade level-dependent advantage of reading with text-to-speech on reading comprehension.

Several of these authors evaluated other learning outcomes, with negative results. Elbro et al. (1996) could not establish any advantage of text-to-speech instruction over regular instruction for phonics and phonemic awareness—neither the computer instruction nor traditional instruction stimulated improvements in these skills. Lundberg & Oloffson (1993) found that word decoding scores were roughly the same whether students read online with speech feedback for targeted words or without it. Borgh and Dickson (1992) report no significant differences in the length, quality, or audience awareness of student compositions when they wrote with or without text-to-speech. Farmer et al. and Elkind et al. reported wholly negative findings, reporting no significant differences in vocabulary (Elkind et al.), word recognition (Farmer et al. 1992), reading comprehension (Elkind et al.; Farmer et al., or total normal curve equivalent (Elkind et al.) between students who worked with and without text-to-speech.

There is little corroboration within the synthetic text-to-speech literature, which makes it difficult to draw conclusions. However, there is tentative evidence to suggest a beneficial impact of this text transformation tool on nonword recognition and sentence level editing. Evidence regarding its impact on word recognition and reading comprehension is contradictory and needs to be resolved.

Research investigations of digitized text-to-speech and recorded speech are few but generally favorable. There is some converging evidence to suggest that reading text with recorded or digitized text-to-speech effectively improves vocabulary (Davidson et al.; Davidson et al.; Hebert & Murdock, 1994). There is also some evidence to suggest that reading with the support of digitized text-to-speech favors the development of better word reading accuracy and fluency (Davidson et al. 1991; Dawson et al. 2000; Shany & Biemiller, 1995; van Daal & van der Leij, 1992). Although Montali & Landowski (1996) found that students made equivalent gains in word recognition scores when just listening to prerecorded text, reading the text on the computer, and reading a text-to-speech version of the text, the intervention lasted only 3 sessions. Thus, there is evidence, although somewhat limited, that digitized text-to-speech or recorded speech can promote several reading skills.

Another, perhaps more important, question that needs to be resolved is how the advantages of reading with text-to-speech compare to those of reading with a human model. Shany & Biemiller (1995) found that students who took part in regular reading sessions where they listened to and followed along with a book on tape showed improvements in reading, speed and verbal efficiency (speed and accuracy of reading aloud) equivalent to those made by students who engaged in teacher-assisted reading sessions. Neither form of practice improved letter or word naming speed. Although Dawson & Venn (2000) found that word reading is more accurate with a teacher than a digitized text-to-speech model, they sampled a very small number of students and present data that is very inconsistent. Abelson & Petersen (1983) found that listening to a book on tape during silent reading supports story recall, as well as listening to a reading by the teacher. Finally, Montali & Landwoski (1996) found that students reading with recorded speech scored significantly higher on a later test of reading comprehension than those in text- or audio-only conditions. Thus, there is literature support equivalent and in some cases greater effectiveness of recorded and digitized text-to-speech relative to live human speech. However, more research is needed to clearly identify which reading skills are best promoted by these technologies.

Another practically relevant question is whether one form of text-to-speech is more effective than the other. There are no direct statistical comparisons of digitized and synthetic text-to-speech. However, Hebert and Murdock (1994) conducted a quantitative experimental study comparing the two types. Three students with learning disabilities and speech impairments alternated between reading vocabulary words with definitions and sentences online using digitized speech, synthetic speech, or no speech. All 3 students scored highest on vocabulary tests during one of the text-to-speech treatments—but which type of text-to-speech was most advantageous was not consistent: in 1 case, synthetic text-to-speech brought the best results, and in 2 cases, digitized text-to-speech.

At this point, it is not clear whether one form of text-to-speech has an advantage over the other. Given the arduousness of developing digitized speech representations of classroom materials, the research does not yet justify prioritizing it over synthetic speech. However, the picture could very well change, when more studies of digitized text-to-speech are published.

Level of speech feedback. Text-to-speech can be used to provide different levels of speech feedback, including passage (Davidson et al.; Davidson et al.; Dawson et al.; Leong, 1992; Montali & Lewandowski, 1996), sentence (Borgh & Dickson, 1992; Elkind et al.; Hebert & Murdock, 1994), word (Davidson et al.; Davidson et al. 1996; Elbro et al.; Elkind et al.; Farmer et al.; Hebert & Murdock, 1994; Lundberg & Olofsson, 1993; Olson & Wise, 1992; Wise, 1992), onset rime (Olson & Wise, 1992), syllable (Olson & Wise, 1992), and subsyllable (Elbro et al.; Elkind et al.; Wise, 1992). Looking at the research base, there appears to be a clustering of positive findings around studies using word- or sentence-level feedback. However, this is not a fair way of interpreting the data because word- and sentence-level feedback have been investigated in far more studies than have other types of feedback. A better approach is to look at direct comparisons. Wise (1992), for example, compared four types of feedback: whole word, syllable, subsyllable, and single-grapheme-phoneme and found single-grapheme-phoneme feedback to be the most effective for improving word recognition (Wise, 1992). Olson & Wise (1992) reported that reading on the computer with onset rime, syllable, or whole word synthesized speech feedback all promoted significantly better word recognition than equivalent time out on the computer (Olson & Wise, 1992). However, for nonword recognition, only whole word and syllable feedback produced significantly better results than time out on the computer. Similarly, Elbro et al. (1996) found that whole word- and letter name-level synthetic speech feedback both offered benefits greater than traditional instruction. Both significantly improved word recognition, comprehension, and fluency. They differed only for syllable segmentation and nonword reading, for which syllable-level feedback was more effective. The apparent bottom line is that many types of speech feedback can be effective enhancements of reading instruction. Some types of text-to-speech may, however, have an advantage when it comes to elevating certain reading skills.

Grade level. Grade level is one of the most highly variable factors in this literature. Because the various studies targeted different grade-level mixtures of students, it is impossible to speak assuredly to the issue of whether and how age or grade-level influences the effectiveness of text-to-speech as a learning tool. However, certain worthwhile observations can be made.

Positive effects of one form or another have been demonstrated for students in grades 2 through 9. Abelson & Petersen (1983) did not find any statistically significant effect of age in their analysis. Leong (1992) reported an interaction between grade level and the effect of text-to-speech on text comprehension, but its meaning is unclear because the statistical tests necessary for interpretation were not performed. Lundberg & Oloffson (1993) are the only authors who clearly demonstrate grade level-dependent effects, showing that text-to-speech feedback improved reading comprehension for readers (students in grades 4, 6, and 7) but not beginning readers (students in grades 2 and 3). Word decoding improved for both groups.

Interestingly, Farmer et al. (1992), one of two groups to report entirely negative findings, were also the only group to include high school students in their sample. It is possible, although unverifiable without more research, that the contradictions in the literature regarding text-to-speech's effects on reading comprehension and word recognition reflect poor effectiveness of text-to-speech with older readers. As more studies begin to explore grade level as a factor, firmer statements can be made about the types of students for which text-to-speech is most beneficial as a curriculum enhancement.

Educational group. Nearly every study in this text-to-speech survey focused on students outside the average-performing population. Samples included below grade level students, below average students, a mixture of below and above average students, students with reading disabilities, students with learning disabilities or speech impairments, students with dyslexia or from special education classes, and regular education students. There is not enough overlap in the various study samples to justify conjecture about the impact of educational group status on the effectiveness of text-to-speech.

Video and Videodisc

Video and videodiscs offer a new way to deliver content and instruction to students, either as an alternative or supplement to traditional methods. Ten studies in this survey investigated the impact of video- (Bain, 1992) or videodisc-based (Bottge, 1999; Bottge & Hasselbring, 1993; Friedman, 1984; Hasselbring et al.; Kelly, 1986; Sherwood, Kinzer, Bransford, & Franks, 1987; Thorkildsen & Reid, 1989; Xin, Glaser, & Rieth, 1996; Xin & Rieth, 2001) instruction on student learning. In six of seven cases, video or videodisc-based instruction was demonstrated to have a positive impact on learning, superior to that of alternative forms of instruction. The remaining three studies (Friedman & Hofmeister, 1984; Thorkildsen & Rieth, 1989; Xin et al. 1996) were unable to establish superiority to more traditional approaches, because they did not include a non-videodisc control group.

Mathematics is a popular curriculum application for video and videodiscs. Hasselbring et al. and Kelly et al. evaluated a videodisc-based curriculum for fractions computation, called Mastering Fractions (MF). The MF videodisc offers lessons, exercises, guided and independent practice, quizzes, reviews, and feedback and correction relating to fractions concepts. Students interact with the program by responding orally to prompts. Kelly et al. compared the impact of 9 lessons with the Mastering Fractions (MF) videodisc-based curriculum to 9 lessons of a basal curriculum. Students in the MF group significantly outperformed students in the basal curriculum group on a criterion-referenced post-test and maintenance test. Unfortunately, these findings are weakened somewhat by the fact that instruction was delivered by experimenters and not by the teacher. Moreover, interpretation of the findings is problematic because both the medium and content of the two curricula were different, leaving unclear which of these factors contributed to the videodisc intervention's advantage.

A later study by Hasselbring et al. addressed these lingering questions by controlling for both medium and curriculum content. Students received 35 lessons with the videodisc-based MF program, a teacher-based replication (with transparencies in place of video), or the regular curriculum (a spiraling fractions curriculum). Mastering Fractions instruction, with or without videodisc, yielded significantly higher scores on a fractions post-test compared to the regular curriculum group. These findings suggest that the content of the MF program—not the videodisc medium it uses – gives it an advantage over traditional curricula.

Other studies, however, support the idea that the video/videodisc medium can itself offer a unique advantage. Bottge & Hasselbring (1993) and Bottge (1999) investigated an approach that uses a videodisc to situate mathematical problem-solving instruction within a meaningful, real-world, context, providing contextualized problem solving instruction. The approach uses videodisc-based math problems that unlike conventional word problems are not explicitly stated and therefore require the student to extract relevant information that is embedded within the video scenes. Bottge and Hasselbring (1993) found that students given 5 days of contextualized problem solving instruction (using the MF videodisc program and videodisc-based contextualized math problems) scored significantly higher on a test of contextualized problem solving than did those receiving conventional word problem instruction. These findings are weakened somewhat by the failure to perform a necessary statistical control and the extreme variability in post-test scores for the MF group. However, using the same basic paradigm, with the addition of cognitive strategy instruction in both conditions, Bottge (1999) obtained very similar findings. Students that received 10 days of videodisc-based contextualized problem solving instruction significantly outperformed students in the conventional instruction group on a contextualized problem solving post-test and transfer test. Collectively, these two studies argue that the videodisc medium may be able to support mathematics learning by contextualizing instruction in a way that traditional media presently do not.

Context is also important when reading. Sherwood et al. examined the use of videodisc to contextualize expository text. Before reading a science passage, half of the students in the study watched a videodisc that provided a “macro-context” for the text (for example, before reading a passage about tarantulas, students watched a segment of the movie Raiders of the Lost Ark that involved tarantulas). Students were later quizzed on science concepts. Students in the videodisc group scored significantly higher on the quiz than did students who read the passage without watching the videodisc. The lingering question in this one-day study is whether this is a lasting effect and not a consequence simply of students’ excitement at watching video in class. Findings by Xin & Rieth (2001) suggest caution, demonstrating that traditional methods can be used to nearly equivalent success to anchor instruction. Students taught vocabulary through a traditional anchored instruction approach (using printed materials and the teacher) demonstrated improvements in cloze sentence completion equivalent to those taught with a videodisc-based anchored instruction approach. However, the videodisc group did make significantly greater performance gains on a word definition test. Thus, it cannot be assumed that the addition of a technology will drastically improve upon the effectiveness of a traditional approach. The choice should take into account other factors, such as the level of resources needed for each approach and the ease of integration of technology into the curriculum.

Factors Influencing Effectiveness

Subject area. The research literature has focused almost entirely on the potential of video and videodiscs for mathematics instruction, and even more exactly, for word problem solving and fractions computation. Exceptions are Sherwood et al., Blain et al., Thorkildsen & Reid (1989), Xin et al., and Xin and Rieth (2001).

Sherwood et al., in a study detailed above, found that contextualizing expository science passages through the use of videodisc significantly improved student understanding of the science concepts presented in the text. Xin et al. and Xin and Rieth (2001) provide evidence for the effectiveness of videodisc-based anchored instruction for teaching vocabulary. And a videodisc time telling program was an effective instructional tool in Thorkildsen and Reid’s study (1989). Blain et al. provide evidence to support the use of a video-based approach to social problem solving instruction. Thus, there is a strong indication that video and videodiscs may be beneficial in a broad range of curriculum areas. This evidence must, however, be corroborated and expanded upon to even out knowledge across the curriculum.

Novelty. A factor not generally addressed in the literature, but of certain relevance to the use of video and videodiscs, is novelty. Any novel approach to instruction—but certainly one involving a medium as appealing as video – would be expected to engage and motivate students to a great degree. Only Blain et al. included a control for the novelty of the medium. It could be argued, based on their finding that the group with the highest performance scores also had the highest scores on attention, that the reported success of video- and videodisc-based approaches is tied to their novelty. To sort out this possibility, future studies should make a priority of incorporating the necessary control groups and conducting maintenance tests.

Grade level. Reflecting in part the research focus on algebra instruction, experimental studies of video and videodiscs have primarily sampled students in upper elementary and high school grades (grades 7-12). There is fairly strong evidence to support the use of video and videodiscs within this cross section of students. Applications in lower grades have received less attention, but there are promising findings regarding the use of videodisc approaches for teaching vocabulary in grades 4–6.

There is no indication in the existing research for an age-related difference in the effectiveness of video- and videodisc-based instruction. Sherwood et al. (1987) did not observe any differences in the effectiveness of their videodisc science intervention with 7th and 8th graders. However, no other study has incorporated grade-level as a factor in its analysis.

Educational group. A range of educational groups is represented in this body of research. The ten studies surveyed sampled students from general education classes (Bain, 1992), students from remedial math classes (Bottge & Hasselbring, 1993; Kelly, 1986), a mixture of students from general math and remedial math classes (Bottge, 1999), students with learning disabilities or mental retardation (Friedman, 1984; Xin et al.; Xin & Rieth, 2001), a mixture of students from regular and special education classes (Thorkildsen & Reid, 1989), students with above or below average math ability (Sherwood et al.), and students with average to high math ability (Hasselbring et al.). This diverse sample lends good support to the contention that video and videodiscs can be beneficial enhancements for students across a range of math abilities and educational groups.

Multimedia

Digital media offer a range of new options for teaching and learning. One of their advantages is that they allow for multiple representations of the same information—for example, as text, images, and speech. These representations can be redundant, presenting the same information in multiple media, or supplementary, providing background information or alternative perspectives. Simple devices like CD-ROMs make the presentation of multiple media simple and practical. Twelve studies in this survey relate to the use of multimedia in the classroom. Overall, the results of these studies are mixed, necessitating thoughtful interpretation.

One of the strongest arguments for multimedia enhancements is an investigation of picture-word processing by Chang & Osguthorpe (1990). These researchers investigated the impact on kindergartners of a tutoring program involving the use of picture-word processing to learn words and write simple sentences. The picture-word processing program allows students to write messages on a computer by selecting pictures on an electronic tablet. Kindergartners who underwent tutoring in place of their regular instruction over the course of 6 weeks made significantly greater reading gains (word identification and passage comprehension) and demonstrated a significantly greater enjoyment of reading than their peers (Chang & Osguthorpe, 1990). These findings suggest that a picture-word processing tutoring program is an effective way to improve early reading and writing instruction.

A more common and more widely investigated multimedia form is the CD-ROM storybook, which offers digital text together with features such as animations, sound, speech, and illustrations (Lewin, 1997, 2000; Matthew, 1997; Miller, 1994; Talley, Lancy, & Lee, 1997). Talley et al. findings suggest that exposure to CD-ROM storybooks is valuable for even the youngest students, helping pre-readers to develop an understanding of story structure and sequence.

Evidence regarding the impact of CD-ROM storybooks on elementary school readers is more plentiful but generally less persuasive. Lewin (1997) reported an association between increased vocabulary knowledge and reading with talking books. Nine poor readers who spent one month reading online using multimedia talking book software made daily gains averaging 5.7 words on the Common Words Knowledge test. Although promising, the case study methodology and lack of control group limits the meaningfulness of these findings. The findings are substantiated somewhat by Miller et al. who document vocabulary improvements following repeated readings with a CD-ROM storybook. In this case, CD-ROM reading was favorably compared to repeated reading of a traditional print storybook. However, the small sample size (N=4) again prevented statistical comparisons.

A methodologically stronger study by Matthew (1997) raises question as to whether CD-ROM storybooks are necessarily better than traditional print storybooks. Matthew (1997) engaged third grade students in an extended reading activity where they read, discussed, and wrote a retelling of a traditional print or CD-ROM storybook, the latter offering animation, online definitions, and sound effects. Subsequent comprehension scores were statistically equivalent between the two groups. Although students who read the CD-ROM storybooks scored significantly higher on retellings, when members of the control group were switched over to the experimental intervention, results favored the traditional print storybook. These findings may perhaps be reconciled by some kind of practice effect in the control group. Nevertheless, they create a level of uncertainty.

Indeed, findings by Large, Beheshti, Breuleux, and Renaud (1994) further question the ability of multimedia materials to support comprehension and recall better than printed materials do. Sixth graders in this study scored equivalently on tests of free recall and comprehension whether reading from a multimedia encyclopedia (with text, animation, video, and sound), text-only digital encyclopedia, or print encyclopedia (with text and pictures). However, the circumstances of the study may not have been maximally favorable to the use of multimedia. Namely, the students in the study were novices to the technology and the intervention lasted only 2 short sessions. Thus, it is possible that students simply need more training to reap the benefits of multimedia materials for comprehension and recall.

The issue of needing to equip students to take full advantage of multimedia supports surfaced in another study by Lewin (2000) comparing the effectiveness of 2 different versions of talking book software with 5- and 6-year old low ability readers. The basic version offered onset-rime- and passage-level text-to-speech with highlighting, whereas the enhanced version offered, in addition, pronunciation hints (which could be made optional or mandatory) and 5 reinforcement activities to improve the use of reading cues and develop sight recognition of key vocabulary. Lewin (2000) found no significant difference in the two versions' impact on Commons Words Knowledge test scores. An important observation made by a teacher taking part in the study was that most students failed to access the pronunciation hints for their intended purpose, as a device for considering alternative word identification strategies. It is not clear that the students were given the instruction necessary to recognize this purpose and apply such strategies. Providing struggling readers, particularly early struggling readers, with such knowledge and guidance may be essential for them to take full advantage of more sophisticated vocabulary supports.

With sufficient training, students can learn to produce their own multimedia texts, offering an alternative to the traditional essay. Daiute & Morse (1994) trained students on multimedia software (scanning and digitizing, image editing, writing on computer) and over a series of 5-8 sessions had them create books on the topic of young people's interests in their city. The study produced some qualitative evidence to suggest that this multimedia composition approach was more engaging for students, but without a control group it is unclear whether the added engagement derived from the multimedia tools or simply the writing topic. Beichner (1994) also reported strong student engagement during the production of multimedia materials as part of a science curriculum. However, this study, as well, failed to provide quantitative data or incorporate a control group.

Glaser et al. and Bonk et al. investigated more elaborate forms of multimedia instruction. Glaser et al. investigated a multimedia anchored instruction unit where 8^{th} grade students researched and reported on a topic using multimedia tools (Glaser, Rieth, Kinzer, Colburn, & Peter, 2000). Unfortunately, the only data collected were student-teacher interactions. Results suggest a reduction in teacher directives but do not speak to the question of changes in student performance. Bonk et al. did address learning outcomes in their study, which followed a large group of fifth and sixth grade students as they completed a multimedia weather unit involving email with other students, use of online weather databases, multimedia composition software such as Hyperstudio, and video (Bonk, Hay, & Fischler, 1996). The authors note improvement in several cognitive measures, including conceptual understanding, metacognitive task performance, and the ability to generate concept maps. Again, however, there was no control group to which to make comparisons.

A unique approach to multimedia enhancement of the curriculum was taken by Hay (1997). Hay developed narrated, captioned versions of instructional video that were tailored to students' developmental reading level. Students were assigned to one of three scripts differing in their vocabulary and narration rate. A large group of 4^{th} graders worked with the videos over the course of 24 weeks. Unfortunately, Hay did not present the results of the comprehension and vocabulary assessments administered to the students, instead only commenting on student and teacher reactions to the technology, which were overall favorable (Hay, 1997).

Overall, the research base within the area of multimedia enhancements is weak. Many of the studies rely on qualitative observations, seek to generalize from small samples, and lack necessary control groups. There is some evidence to support the usefulness of multimedia enhancements in elevating engagement, vocabulary knowledge, and certain cognitive measures. However, in most cases the evidence presented does not support their advantage over the more traditional. The existing research is too flawed and the evidence too incomplete, however, to build an argument for or against multimedia enhancements.

Factors Influencing Effectiveness

Grade level. Most of the research base involving multimedia instruction targets students in grades three to six. Exceptions are the studies by Glaser et al. and Beichner (1994), which sampled students in grade eight and Lewin (2000), who sampled 5-6 year old students. Clearly, it will be important that future studies investigate other grade levels.

Educational group. Research investigations into multimedia enhancements have focused nearly exclusively on students' in the general education classroom lacking special needs. There are some exceptions. Lewin (1997) sampled only poor readers, and Glaser et al., Beichner (1994), and Lewin (2000) used mixed samples. Half of the students in Glaser et al. sample were students with learning disabilities or mild mental retardation. Roughly 10% of Beichner's (1994) sample had some kind of disability. Lewin (2000) sampled low and high ability readers. None of these three, however, sought to differentiate the effects of the intervention on students from different educational groups. Thus, at this point, little can be said about the promise of multimedia for students with special needs.

Curriculum application. It's generally understood that different types of media are best suited to communicating different types of information (Rose & Meyer, 2002), but what should be used and when? There has been little research to address this question, but Large, Beheshti, Breuleux & Renaud (1995) made an effort by comparing different combinations of media for their effectiveness in communicating procedural content to sixth grade students (Large, Beheshti, Breuleux, & Renaud, 1995). Students were presented with procedural content in the form of digital text; digital text and animations; digital text, animations, and captions; or animations and captions. Although student recall was statistically equivalent across the 4 conditions, student enactment of the procedures was significantly more accurate when content was presented with a combination of text and animations or text, animations, and captions. Interestingly, the combination of animation and captions had no such benefit, suggesting that engagement alone was not responsible for the advantage of the other treatments. The authors suggest that combinations of text and animations or text, animations, and captions may be particularly well suited to instilling comprehension of procedural information. However, because of the brevity of the intervention (one session only), these findings require elaboration. Additional research of this kind, evaluating the ideal applications for various forms of multimedia, would be greatly beneficial.

Hypertext

Hypertext documents offer links within the text-to-text-only resources. Three studies in our survey conducted investigations relating to this type of enhancement.

Anderson-Inman and colleagues (Anderson-Inman, Chen, & Lewin, 1994; Horney & Anderson-Inman, 1994) have made extensive and insightful observations of eighth grade students working with hypertext. Importantly, they have shown that readers of this age, whether poor, average, or above average, are able to learn to use hypertext. They have also noted important differences in readers' interactions with hypertext, distinguishing several reader profiles and noting that not everyone uses text and resources in depth, integrating reading with accessing of hyperlinked supports. This work suggests that instruction on how to access hyperlinked resources purposefully is important to the successful integration of hypertext into classroom instruction.

Based on their student observations, Anderson-Inman et al. identified 5 major elements to hypertext literacy: traditional reading skills, facility with hardware, knowledge of a document's structure and navigation, ability to engage the text and enhancements with purpose, and ability to reevaluate the reading purpose. They point out that a student's skill in these areas, as well as his or her motivation and perception of the task, the design of the hypertext document, the instructional context, and teacher expectations can all influence the effectiveness of a hypertext environment for a particular student.

Horton et al. (1990) directly investigated the impact of hypertext on learning outcomes, testing the effects of a hypertext study guide on the social studies learning of four high school students classified as remedial or learning disabled (Horton, Boone, & Lovitt, 1990). The study guide presented passages from a History text together with study questions and leveled instructional cues based on students' responses to the questions. After working with the study guide, students answered the study guide questions significantly more accurately. However, students showed no improvement when quizzed on related questions absent from the study guide. These results suggest that a hypertext study guide with leveled supports can facilitate recall of study guide questions, but not perhaps generalized comprehension of the text. Because of the low sample size, however, none of these findings should be weighted too heavily.

Hypertext, although omnipresent in online learning environments, has received little attention by K–12 education researchers. The three studies presented here are suggestive of a beneficial impact on learning. However, much additional work is necessary to better evaluate this potential.

Hypermedia

One quite active area of research is the investigation of hypermedia for use in the classroom. Liao (1998) identified 35 studies published between 1986 and 1997 that compared hypermedia to traditional instruction (Liao, 1998). However, much of this research was conducted in college or university settings or published outside the peer-reviewed literature and is therefore outside the scope of this review. Our survey identified 9 peer-reviewed studies (one a metaanalysis) involving hypermedia-based enhancements in the K–12 classroom. The hypermedia enhancements under investigation include hypermedia design software, hypermedia lessons, and hypermedia texts such as study guides.

A hypermedia study guide (Higgins & Boone, 1990; Higgins, Boone, & Lovitt, 1996; MacArthur, 1995) is an educational text presented in an electronic format, with embedded hyperlinks to multimedia supports such as explanatory notes, animated graphics, text-to-speech, definitions, and rereading prompts. Higgins and Boone (1990) and Higgins et al. investigated the effectiveness of a hypermedia study guide consisting of chapters from a social studies textbook supplemented by explanatory Notes, text Replacements (clarifying versions of the text or related graphics), and an Inquiry function that directed student movement through a series of study questions. Although both authors draw positive conclusions regarding the effectiveness of their study guide compared to traditional methods, the data do not support their claims. Higgins & Boone reported no significant differences between the impact of study guide, study guide plus lecture, and a combination of lecture, text, and worksheets save for on day 1 of the 10-day intervention, when students in the study guide group outperformed those in the study guide/lecture group, who outperformed those in the lecture only group. Likewise, Higgins et al. could not statistically differentiate study guide, study guide plus lecture, and lecture only based on daily quiz scores; which were statistically equivalent. Although the authors claim a statistical difference between retention scores, they report a p-value that is outside the conventional cut-off. These studies should not however be interpreted as evidence against the effectiveness of hypermedia because they probably lack the statistical power to detect any effect of hypermedia.

Higgins and Boone (1991) and Boone & Higgins (1993) investigated the benefits of hypermedia texts intended not as study guides but as lessons supplemental to the basal reading series. The texts differed across the three years of the study:

- Year 1 hypermedia texts incorporated vocabulary and decoding support in the form of synthetic and digitized speech, structural analysis of words, animated graphics, computerized pictures, definitions, and synonyms.

- Year 2 hypermedia texts incorporated the Year 1 supports as well as syntactic and semantic support in the form of graphical demonstration of pronoun/referent relationships.

- Year 3 hypermedia texts incorporated the Year 1 and 2 supports as well as comprehension strategies.

Student participants worked with the hypermedia texts or spent an equivalent amount of time on non-computer reading-related activities. Progress was evaluated by comparing MacMillan Standardized Reading Test scores from the beginning and end of each year. Results for year 1 generally favored the hypermedia condition. Average total test scores for hypermedia readers in kindergarten, second, and third grade significantly exceeded those of the non-computer group (Boone & Higgins, 1993; Higgins, 1991). There were no significant differences in total test scores for first graders. Individual subtest scores were also compared, revealing more complex effects, favoring in some cases the hypermedia group and other cases the non-computer group. In contrast, in Years 2 and 3 the only significant differences in overall test scores favored the non-computer group. For Year 2, as for Year 1, comparisons of individual subtest scores indicated some differences favoring the hypermedia group. For Year 3, however, only grade 3 vocabulary subtest scores favored the noncomputer group.

The results of this 3-year study are difficult to summate due to the tremendous number of statistical comparisons and experimental variables. However, as a whole they provide little support for hypermedia supplementation of basal reading series. Of the three sets of hypermedia materials, only those from year 1 appeared to somewhat consistently raise reading test scores above normal. In fact, the most supported hypermedia materials (from Year 3) produced inferior results.

In contrast, MacArthur & Haynes (1995) found that an enhanced hypermedia study guide was more effective at developing student comprehension than a basic version containing fewer supports. Both study guides were developed from a science text. The basic version presented a text passage together with a chapter outline, a graphics window showing associated pictures or graphs, and a notebook window for entering and editing text (MacArthur, 1995). The enhanced version incorporated six additional aids:

- glossary
- speech synthesis
- ability to copy text into the notebook
- display of the textbook questions within a separate window
- teacher explanations (brief summaries of important ideas or simplified statements of the main ideas)
- optional text reformatting by the teacher

MacArthur and Haynes' (1995) findings argue that the integration of multimedia text supports can strengthen the effectiveness of a hypermedia study guide. However, their study does not allow conclusions to be made regarding the effectiveness of different hypermedia study guides relative to more traditional methods.

Moore-Hart (1995) evaluated a hypermedia program designed to supplement an offline Multicultural Literacy Program "that integrates multicultural literature and literature-based activities with the reading/writing curriculum." The hypermedia program, Multicultural Links, combines a word processor with interactive hypermedia such as maps, annotations of multicultural books, minibiographies, and a multicultural calendar. Student participants in the study used Multicultural Links with the Multicultural Literacy Program, the Multicultural Literacy Program only, or the traditional basal reader program. Reading comprehension and vocabulary normal curve equivalent scores spoke in favor of the hypermedia condition. However, the presence of what appear to be significant pre-test differences on these measures raises questions about these findings. Pre-test reading comprehension and vocabulary scores were considerably lower in the hypermedia group, raising the possibility of a ceiling effect that would limit vocabulary and comprehension gains in the nonhypermedia groups (Moore-Hart, 1995).

The focus of the Moore-Hart study as with most others is on the reading of hypermedia texts. An exception is a study by Tierney et al. evaluating a project where students create hypermedia documents. The 10 ninth grade participants, all with hearing impairments, wrote both conventional compositions and HyperCard texts over a series of 3, three to five-hour sessions. Data, which are restricted to qualitative information from interviews and observations, indicate that students appreciated the multimedia composition options available with HyperCard and regarded the hypermedia-based projects more favorably (Tierney et al.).

Overall, with little solid evidence to show that hypermedia enhancements can improve upon the outcomes achieved with traditional K–12 instruction, it is difficult to build an argument in their favor. However, this may be a consequence of the poor quality of research in this area, making it important to conduct additional research.

Factors Influencing Effectiveness

Prior knowledge. A potentially important factor influencing a student's ability to efficiently interact with and learn from hypermedia materials is the subject matter knowledge that he or she brings to the text. Shin, Schallert & Savenye (1994) investigated the impact of prior knowledge on students' learning in a hypermedia environment by dividing student participants into low and high prior knowledge groups, based on the results of a subject area pre-test (Shin, Schallert, & Savenye, 1994). Students spent one session working with a hypermedia lesson on food groups and were then tested a second time. Students with high prior knowledge scored significantly higher overall. These findings lead to the unsurprising conclusion that students who can bring prior knowledge to a hypermedia lesson, as with any lesson, will have an advantage.

A more interesting aspect of the Shin et al. findings was the presence of an interaction between students' prior knowledge and the complexity of the hypermedia environment. When working with a hierarchically structured lesson (topics were linked one to the next in a hierarchical format) students with low prior knowledge performed significantly better than when they worked with the lesson in an open format (any topic could be accessed at any time, from any location in the lesson). However, the degree of openness in the environment did not significantly affect the scores of students with high prior knowledge. These findings suggest that the structure of the hypermedia environment can strongly affect the impact of prior knowledge. Simplifying the hypermedia environment may help to scaffold students that are unfamiliar with the subject area.

Learner control. Navigating a hypermedia environment can be intimidating and confusing for students because of the unfamiliar format and the unusual number of resources and possible paths (Horney & Anderson-Inman, 1994). One approach to making hypermedia texts less overwhelming is to reduce the number of potential paths through the text, giving students fewer options. Another approach is to coach students on the best navigation route through a particular hypermedia text. Shin et al. evaluated the impact of both types of scaffolds on student learning by comparing performance when working with 4 versions of the same hypermedia text: 1) a version offering free access to the various subtopics—students could access them in whatever order they chose, 2) a version offering limited access—subtopics were linked one to the next in a hierarchical format, 3) a version offering free access together with advisement on the best sequence to follow, 4) a version offering limited access with advisement. Students in the limited access conditions performed significantly better on the immediate post-test, but not on the delayed post-test, suggesting that limiting the openness of the hypermedia environment can facilitate student learning in the short term. Advisement did not significantly affect student performance, but this may be an artifact of the way the data was analyzed. Advisement would likely have had little impact on student performance in the limited access condition, where there is only one path to take. To overcome the weak or absent effect in the limited access groups, the effect of advisement in the free access groups would have to have been extremely powerful.

Shin et al. findings may account in part for the data reported by Higgins and Boone (1991) and Boone & Higgins (1993) showing the greatest success with the simplest hypermedia text, containing the fewest supports. The more elaborate texts may have been too complex for the students to use effectively.

Grade level. Six of the eight studies discussed above included students from multiple grades (Boone & Higgins, 1993; Higgins, 1991; Higgins & Boone, 1990; Higgins et al.; MacArthur, Graham, Schwartz, & Schafer, 1995; Moore-Hart, 1995), but only two (Boone & Higgins, 1993; Higgins, 1991) incorporated grade level as a factor. Their results show quite clearly that the effectiveness of hypermedia materials across grades K–3 is variable. For example, results for kindergarten students in Year 1 overwhelmingly favor the hypermedia group, whereas the scores of first graders in the two groups weren't any different. It is difficult however to pick out any consistent patterns concerning differences in hypermedia effectiveness associated with grade level. These patterns will certainly vary depending on the characteristics of the intervention.

Educational group. Nearly every study surveyed here included students with learning disabilities or students classified as below average (Boone & Higgins, 1993; Higgins, 1991; Higgins & Boone, 1990; Higgins et al.; MacArthur, 1995; Moore-Hart, 1995; Tierney et al.). Four studies incorporated educational group as a factor in their data analysis (Boone & Higgins, 1993; Higgins, 1991; Higgins & Boone, 1990; Higgins et al.). Educational group (remedial, regular education, and learning disabled) did not interact in a significant way with the effectiveness of hypermedia study guides investigated by Higgins and Boone (1990) and Higgins et al. In contrast, Higgins & Boone (1991) and Boone & Higgins (1993) reported numerous educational group differences in their 3-year longitudinal study of hypermedia reading materials. The researchers argue a promising role for hypermedia as an instructional tool for students whom have been classified as poor readers, but their data provide no evidence of a consistent advantage of the hypermedia intervention for any educational group. Moreover, it is not evident that they performed the proper statistical controls when making their educational group comparisons. Thus, it appears that educational group may be relevant to the effectiveness of hypermedia enhancements, but precisely how, it is still unclear.

Technology Tools

Technology Tools Defined

Any technological device or program that affects the use of text—or content that would otherwise be presented with text summarizes the definition of Technology Tools for the purposes of this report. Examples include word processors, spell checkers, word prediction devices, speech recognition, and software/computer programs. Many of these tools provide scaffolds for users, many devices offer multiple technologies in one package.

Word Processing

The word processor is one of the most widely available technology tools today and, understandably, one that researchers are interested in evaluating as a learning tool. This discussion includes ten studies that evaluated the impact of word processor use on learning outcomes as well as two studies that evaluated students' ability to master the operation of a word processor.

Experimental studies have reported with good consistency a beneficial impact of writing or editing with a word processor on overall writing quality (Graham, 1988; MacArthur et al.; Rosenbluth & Reed, 1992; Williams & Williams, 2000) and fluency (positive impact reported by Crealock & Sitko, 1990; Graham, 1988; Kurth, 1987; MacArthur et al.; Outhred, 1987, 1989; Rosenbluth & Reed, 1992; Williams & Williams, 2000). There is also fairly clear evidence to counterindicate the use of word processing to reduce errors of capitalization and punctuation (Dalton & Hannafin, 1987; Graham, 1988; MacArthur et al.). With respect to some outcomes, namely style (Kerchner & Kistinger, 1984), thematic maturity (Kerchner & Kistinger, 1984), word usage (Kurth, 1987), vocabulary knowledge (Kerchner & Kistinger, 1984), number of revisions (Kurth, 1987), quality of revisions (Kurth, 1987), composition structure (Dalton & Hannafin, 1987), and composition organization (Dalton & Hannafin, 1987), the evidence is too sparse to draw any conclusions.

Spelling is an additional area of interest that has earned the attention of research investigators. The evidence here, however, is contradictory. Kerchner & Kistinger (1984) and Dalton & Hannafin (1987) reported no effect of word processing on spelling ability, whereas Outhred (1987, 1989) and Kurth (1987) both reported a positive effect. These seeming contradictions may be partially explained by the fact that the word processor in Kurth's (1987) study included a spell checker, which might have exaggerated the effects of the word processor itself on spelling. In addition, Outhred failed to provide statistical evidence for a spelling improvement. Thus, there isn't any strong evidence to recommend the use of a word processor without a spell checker strictly to improve spelling.

The research findings reported by Casteel (1988-89), discussed in the electronic text section, are worth emphasizing again here because they underline the important fact that simply displaying text within a word processor does not significantly advance student learning. All of the positive findings discussed above were from word processing interventions that involved more than simply moving the display of information from the printed page to the computer. The successful implementation of word processing enabled students to manipulate text in new ways, and this difference is likely to be responsible for the beneficial outcomes.

Another important question to ask when evaluating word processing as a classroom enhancement is how readily students can learn to master a word processor's use. This question has been largely overlooked in the research literature. Exceptions are Geoffrion (1982-83) and MacArthur & Shneiderman (1986) who evaluated how well students with special needs (specifically students with hearing impairments and learning disabilities, respectively) are able to use a word processor. Their qualitative research revealed a high frequency of errors in the use of editing operations, irrespective of the duration of training (from 1 to 6 sessions), suggesting that students with special needs may require direct instruction on points of difficulty (Geoffrion, 1982-83; MacArthur & Shneiderman, 1986). However, neither study addressed the quality of student revisions, leaving open the question of whether students need to fully master editing commands to make beneficial revisions.

Although the word processing literature is quite positive regarding the usefulness of this tool in the classroom, some degree of caution is warranted as only two of these studies (Crealock & Sitko, 1990; Kerchner & Kistinger, 1984) support their conclusions with quantitative data and statistics. Moreover, all these studies used technology that is by now rather antiquated. As the technology continues to evolve, these questions about word processing must be newly addressed.

Factors Influencing Effectiveness

Grade level. The word processing literature is rather evenly split across middle elementary and upper grades. Five of the studies discussed above sampled students from grades 4–6. The five remaining studies sampled junior high and high school students. Thus, there is little information regarding the use of word processing by students in lower grades.

Educational group. Ten of the twelve studies we have discussed sampled students with special needs, specifically students with learning disabilities (Crealock & Sitko, 1990; Kerchner & Kistinger, 1984; MacArthur et al.; MacArthur & Shneiderman, 1986; Outhred, 1989), remedial students (Dalton & Hannafin, 1987; Rosenbluth & Reed, 1992), special education students (Outhred, 1987), English language learners (Williams & Williams, 2000) and students with hearing impairments (Geoffrion, 1982-83). This work provides converging evidence that word processing can be an effective tool for students with special needs. However, little can be concluded regarding the benefits of word processors for average-performing students. Only one study sampled exclusively general education, average-performing students without disabilities (Kurth, 1987).

There is some evidence to suggest that the benefits of word processing are unevenly distributed across the spectrum of student ability levels. Qualitative work by Outhred (1987, 1989) suggests that students with different writing and spelling abilities may benefit differently from word processing. Outhred compared the effects of composing with a word processor and composing by hand on fluency and spelling in a group of elementary age readers with learning difficulties. For fluency, the editing medium made little difference for the highest reading age students, but students with the lowest reading age seemed to benefit from word processor use (Outhred, 1987). Interestingly, the students who wrote long stories by hand were less fluent when using a word processor, whereas those who wrote short stories by hand were more fluent when using a word processor. There was also some evidence, although less consistent, for differential spelling outcomes. The 1987 study found that all students' spelling improved when using the word processor, but in the 1989 study, only the worse spellers showed improvement.

Findings by Rosenbluth & Reed (1992) quantitatively compared outcomes between educational groups. Their findings indicate a differential impact on remedial and accelerated students, demonstrating significantly greater benefits of writing process-based instruction with the use of a computer for accelerated students. The question of differences in outcome for different educational groups is one that more studies should investigate.

Composition or strategy training. One way to potentially improve upon students' use of a word processor is to provide accompanying instruction in composition or editing strategy. Several studies have evaluated word processor use within the context of such instruction. Graham & MacArthur (1988) and MacArthur et al. investigated the effectiveness of interventions coupling composition strategy instruction to revision on the computer. Kerchner & Kistinger (1984) and Rosenbluth & Reed (1992) investigated word processor use embedded within a process approach to writing (where students learn spelling and other skills as the need arises). Crealock & Sitko (1990) evaluated composition training in combination with keyboard and word processor training. Although all of these studies report positive findings, none include the necessary comparison groups to draw conclusions regarding the usefulness of composition instruction beyond that of using word processing alone.

Spell Checker

Another widely available and popular curriculum enhancement is the spell checker. This survey identified 8 research studies investigating the merits of spell checkers as a writing and editing support. Two of these studies evaluated the ability of various spell checkers to identify and offer corrections for spelling errors (MacArthur, Graham, Haynes, & De la Paz, 1996; Montgomery, 2001). Six investigated the impact of spell checker use on learning outcomes, specifically proofreading and editing success (Dalton, Winbury, & Morocco, 1990; Gerlach, Johnson, & Ouyang, 1991; Jinkerson, 1993; MacArthur et al.; McNaughton, Hughes, & Ofiesh, 1997; Zordell, 1990).

Research studies have made it clear that spell checkers suffer a number of flaws, primarily with respect to identifying and correcting the spelling errors of students with learning disabilities. Montgomery et al. (2001) analyzed misspellings in 199 writing samples from students with learning disabilities and then ran them through spell checkers. Although the 9 spell checkers evaluated had high error identification rates, they failed to identify the target word for an average of 47.5% of all misspellings. Likewise, MacArthur et al. (1996) report that on average the 10 spell checkers they analyzed provided a mean 47% incorrect suggestions. Spell checker performance in these studies was especially poor when the misspellings were severe and/or had a low level of phonetic match to the target word, a frequent characteristic of misspellings by students with learning disabilities.

However, MacArthur et al. also report that when presented with purely incorrect alternatives, students selected one of those alternatives only 22% of the time. Thus, although spell checkers are deficient at offering correct alternatives for misspellings of middle/elementary students with learning disabilities, this may not be a major problem for students.

Studies investigating the effects of spell checker use on learning outcomes support the idea that, in spite of their flaws, spell checkers are beneficial tools for students, including those with disabilities. These studies demonstrate an increase in the number of identified misspellings and the number of corrected misspellings, and a reduction in spelling error rates, when using a spell checker versus proofreading or editing off the computer. Improvements were reported after as little as one day spent using a spell checker.

The overall evidence is, however, less overwhelmingly convincing than it may seem due to pervasive methodological weaknesses in this literature. For example, Gerlach et al. (1991) do not include a control group or condition with which to compare the results for students working with spell checkers. A more rampant problem in the literature is lack of statistical validation. Only Jinkerson & Baggett (1993) demonstrated statistical significance of their findings. Four of the remaining studies provided quantitative data without statistics (Gerlach et al.; MacArthur et al.; McNaughton et al.; Zordell, 1990), and the 6th study was exploratory and provided only qualitative evidence for two students (Dalton et al.). The studies by McNaughton et al. (1997) and Zordell (1990), although not described as exploratory, included only a small number of students: 3 and 4, respectively.

Factors Influencing Effectiveness

Grade level and educational group. Spell checkers appear to be beneficial tools for students across a range of age and educational groups. Positive results were reported for students in Grades 3-9, 10, and 12 (our survey did not locate peer-reviewed work addressing other elementary and high school grades); including students of average ability (Gerlach et al.; Jinkerson, 1993) and students with learning disabilities (Dalton et al.; MacArthur et al.; McNaughton et al.). MacArthur et al. directly refuted the possibility that struggling spellers cannot use a spell checker as effectively as other students. They found no relationship between spelling ability and the number of errors corrected using a spell checker. Interestingly they did find a correspondence between spelling ability and number of misspelled words found: low spelling ability was correlated with a higher percentage of misspelled words found. Thus, low spelling ability does not appear to undermine successful use of a spell checker.

Method of evaluation. The literature establishes that using a spell checker can improve the identification and correction of misspellings while students proofread and edit on a computer. Does spell checker use lead to generalized spelling improvement? In Jinkerson & Baggett's (1993) study, students who had edited with a spell checker and students who had edited by hand did not score differently from one another on an oral spelling test administered after the treatment period. However, these scores are representative of only the students' performance at the conclusion of their intervention – not their improvement over its course. Thus, the possibility cannot be ruled out that the spell checker group made generalized spelling gains. Also, extending the duration of the intervention (which was only 1 session) would be expected to facilitate a more profound impact.

A related point, also involving generalizability, is raised by the findings of McNaughton et al. When students were tested with generic proofreading materials, spell checker use was found to have a positive impact. However, this improvement did not fully generalize to the students' own writing materials. More carefully delineating the contexts in which spell checkers are beneficial would be a useful step forward.

Strategy training. Embedding spell checker use within a training program is one potential way to improve upon its effectiveness as a learning tool. McNaughton et al. directly investigated this possibility by evaluating the embedding of spell checker use within 5-step proofreading strategy training. Although the combination proved effective, McNaughton et al. did not include a spell checker only control group. Therefore, it is impossible to draw conclusions about any added benefit that the training had.

Word Prediction

Word prediction software is another tool that when combined with a word processor can support student writing. Our survey identified only 3 peer-reviewed studies evaluating word prediction software. These studies provide some intriguing—although preliminary—findings.

Zordell (1990) reported a variety of improvements in 4 special education students' writing following a 2-month period spent composing with a word processor with spell checker and word prediction software. The improvements included a drop in misspellings, an increase in word variety and correct use of word endings, and an improvement in attitude towards writing. Without a control group, however, it is unclear whether these improvements were due to the intervention or simply normal progress anticipated to occur over the course of a semester.

MacArthur (1998) compared the impact of word processing to word processing with speech synthesis and word prediction in a group of five, 9^{th} and 10^{th} grade students with learning disabilities (MacArthur, 1998). Students spent 4–9 sessions with each set of writing tools. Students' writing during the word prediction/speech synthesis segment contained an increased proportion of legible and correctly spelled words. The number of legible word sequences and the total number of words did not differ, and differences in composing rate and word recognition were inconsistent. Unfortunately, without a control group, it cannot be determined whether these improvements are a result of the speech synthesis or the word prediction.

Von Tetzchner, Rogne & Lilleeng (1997) report a case-study of a deaf student who was functionally illiterate on entering the 5^{th} grade. A six-year intervention that combined a process approach to language, Norwegian sign language, and word processing with word prediction software led to dramatic improvements in the student's reading and writing skills (von Tetzchner, Rogne, & Lilleeng, 1997). The authors suggest that word prediction may have played an important role in this progress by ensuring appropriate levels of challenge and assisting the development of orthographic strategies.

These three sets of findings provide some promising evidence to support particular benefits of word prediction software for students with special needs. Strong conclusions cannot be made from such limited samples of students and without additional control groups, but this area deserves further study.

Speech Recognition

Speech recognition enables students to use their voice to write on the computer, of potentially instrumental use to a variety of students, including those who have learning disabilities or physical disabilities making it difficult to type. In the limited research literature, there is some support for the idea that speech recognition can improve student outcomes in reading and writing.

A qualitative study by Wetzel (2000) examined one 6th grade student's writing after 12 sessions composing with the use of speech recognition software (Wetzel, 1996). Wetzel's observations suggest improvement of the student's writing, but Wetzel declines to draw conclusions about its quality, and by extension, the impact of speech recognition on writing performance. Clearly, this study requires repetition with a larger sample and quantitative methodology before such conclusions can be made. Stronger support for a beneficial impact of speech recognition on student learning comes from Raskind and Higgins (1999). This pair compared students' word recognition, spelling, reading comprehension, and phonological deletion after they spent 16 sessions performing writing exercises with speech recognition software or an equivalent amount of time taking a keyboarding class. All 4 measures exhibited significant differences favoring the speech recognition condition (Raskind, 1999). These findings raise the intriguing possibility that speech recognition can have beneficial effects on reading as well as writing. However, Raskind and Higgins' failure to rule out the possibility of preexisting group differences on the experimental measures is a significant methodological flaw that casts some uncertainty on their findings.

Clearly, research support for the hypothesis that speech recognition can support improved student outcomes in the areas of reading and writing is very limited at this time. Additional research is needed to uphold what are promising findings.

Factors Influencing Effectiveness

Educational group/grade level. The three studies identified in this survey sampled students with learning disabilities, age 11–14 years. The paucity of research in this area makes it impossible to draw conclusions about the potential impact of educational group or grade level on speech recognition's effectiveness.

Type of speech recognition. Today there are two major types of speech recognition systems available. Discrete speech recognition systems, the first to have been developed, require students to pause between words in order for their speech to be recognized. Later developed were continuous speech recognition systems, where speakers do not have to rest between word pronunciations. Naturally, researchers are interested in possible differences in the effectiveness of these two types of systems.

Higgins and Raskind (2000) compared the impact of reading with discrete speech recognition, continuous speech recognition, and an equivalent amount of time (16, 50-minute sessions) spent in a keyboarding class on the writing of 14-year-old students (Higgins & Raskind, 2000). Consistent with Raskind and Higgins (1999), the students composing with discrete speech recognition made significantly greater gains than the control group on word recognition, spelling, reading comprehension, and phonological processing. Students who worked with the assistance of continuous speech recognition also made significant gains relative to the control group, however these gains were confined to word recognition and reading comprehension.

The results of this one study suggest that discrete and continuous speech recognition are both beneficial enhancements for developing reading skills. Although it also suggests that the two types may differ in their effectiveness, this needs to be corroborated by additional research.

Software and Computer Programs

The most actively researched technology tool is clearly the software/computer program. This survey identified 37 studies evaluating software and computer programs. Two primary curriculum areas have been investigated: reading and mathematics, with a handful of additional studies investigating applications in other subject areas. To simplify the discussion, we will address the research in each of these curriculum areas separately.

Mathematics

Our survey identified 9 studies evaluating mathematics software and computer programs. All 9 of these studies sampled populations composed partially or entirely of students with learning disabilities, handicaps, or below grade level mathematics performance. The research is not only sizeable but also quite solid. As a whole, it suggests that computer-assisted mathematics instruction can be as effective as traditional methods of instruction.

A 3-day drill and practice software intervention and a 7-day tutorial-based software intervention had little impact on one high school student with a learning disability (Howell, 1987). Of course, the single-subject design and the brevity of the intervention could all have undercut more positive results. A controlled experimental study with 50 subjects conducted by Bahr & Rieth (1989) found that neither a drill and practice nor instructional game component of the commercially available Math Blaster software program significantly improved student performance on a timed written test of decimal multiplication. However, the intervention in this case, as well, was quite short—9 sessions (Bahr & Rieth, 1989).

Two studies with longer interventions report more positive findings. Nine students who for 18 days were instructed on multiplication and division story problems by a computer program delivering direct explicit strategy instruction (Gleason, Carnine, & Boriero, 1990) showed mathematics gains equivalent to those of ten peers receiving otherwise identical teacher-delivered instruction. In addition, twenty-seven students whose conventional remedial math instruction was replaced for 9 months by two computer programs, improved standardized arithmetic scores to the same degree as their peers (McDermott & Watkins, 1983). These two studies provide convincing evidence that mathematics software and computer programs can be as effective as traditional mathematics instruction.

A few studies suggest that computer and software programs can even improve upon the outcomes of traditional instruction. Trifiletti et al. report that students who spent 12 months receiving math instruction with SPARK-80 software instead of regular resource room math instruction, learned significantly more math skills and made significantly greater gains on the Key Math Diagnostic Arithmetic Test. SPARK-80 software teaches each of 112 basic mathematics skills using a combination of tutorial instruction, drill instruction, skill game, assessment, and word problems (Trifiletti, Frith, & Armstrong, 1984). Further support comes from Chiang (1986) who demonstrated improved multiplication scores following a 7- to 12-day intervention involving drill and practice and conceptual software programs teaching multiplication facts (Chiang, 1986). Chiang's evidence is weaker, however, due to the 6-student sample, the absence of statistical validation, and the lack of a control group to show greater effectiveness than a more traditional approach. Podell et al. present positive evidence as well, showing an advantage over traditional instruction of a drill and practice program for developing subtraction speed and for some students (see Educational Group section below) addition speed. At the same time, addition and subtraction accuracy were unaffected by the intervention (Podell, Tournaki-Rein, & Lin, 1992).

The research literature suggests that mathematical computer and software programs are generally beneficial. At the same time, there is an indication that these instructional tools vary in their effectiveness or at least their effective conditions. Identifying features and conditions that are most favorable is a useful direction for research.

Reading

The overwhelming majority of the research into computer programs and software focuses on reading instruction as the curriculum application. The research is plentiful, numbering 26 studies, and as a whole speaks greatly in favor of using software and computer programs as part of reading instruction. Twenty-one studies demonstrated a positive impact of software and computer programs on reading skills. Of these 17, nine established greater effectiveness than control interventions involving the use of the computer (Barker & Torgesen, 1995; Das-Smaal, Klapwijk, & van der Leij, 1996; Hurford & Sanders, 1990; Jones, Torgensen, & Sexton, 1987; Mitchell & Fox, 2001; Torgesen, Waters, Cohen, & Torgesen, 1988; van den Bosch, van Bon, & Schreuder, 1995; Wise & Olson, 1995; Wise, Ring, & Olson, 2000), three established effectiveness equal to traditional methods (Mitchell & Fox, 2001; Nicolson, Fawcett, & Nicolson, 2000; Reitsma & Wesseling, 1998), and 7 demonstrated effectiveness superior to that of traditional approaches (Boone, Higgins, Notari, & Stump, 1996; Erdner, Guy, & Bush, 1998; Foster, Erickson, Foster, Brinkman, & Torgesen, 1994; Lin, Podell, & Rein, 1991; Olson, Wise, Ring, & Johnson, 1997; Reitsma & Wesseling, 1998; Wise, Ring, & Olson, 1999). Nine others demonstrated significant improvements over baseline performance or a no-intervention control group (Frederiksen, 1985; Heimann, Nelson, Tjus, & Gillberg, 1995; Holt-Ochsner, 1992; Hurford, 1990; Lynch, Fawcett, & Nicolson, 2000; Malouf, 1987-88; Marston, Deno, Kim, Diment, & Rogers, 1995; van den Bosch et al.; Wentink, van Bon, & Schreuder, 1997), and one equivalent improvement to a no-intervention control group (Wentink et al.). In fact, in only three studies did use of a computer or software program fail to improve certain targeted reading skills (Lynch et al.; van den Bosch et al.; Wentink et al.), and in only one did this use produce an outcome inferior to that of traditional methods (Lin et al.—vocabulary).

Favorable outcomes have been reported for many facets of reading instruction, including the five highlighted by the National Reading Panel: phonemic awareness (Barker & Torgesen, 1995; Foster et al.; Heimann et al.; Hurford, 1990; Hurford & Sanders, 1990; Mitchell & Fox, 2001; Olson et al.; Reitsma & Wesseling, 1998; Wise & Olson, 1995; Wise et al.), phonics/word recognition (Barker & Torgesen, 1995; Das-Smaal et al.; Erdner et al.; Holt-Ochsner, 1992; Jones et al.; Lynch et al.; Marston et al.; Olson et al.; Wentink et al.; Wise & Olson, 1995; Wise et al.), fluency (Frederiksen, 1985; Holt-Ochsner, 1992; Jones et al.; Torgesen et al.; van den Bosch et al.; Wentink et al.), vocabulary (Erdner et al.; Lin et al.), and comprehension (Erdner et al.; Holt-Ochsner, 1992; Lynch et al.; Wise & Olson, 1995; Wise et al.). There is however, strongest evidence to support applications for phonemic awareness, phonics/word recognition, and fluency instruction, at least in part because fewer research studies have been conducted in other areas.

For the most part, the evidence presented in these studies is quite strong. There are technical weaknesses that appear here and there, such as failing to randomize subject assignment (Erdner et al.; Nicolson et al.; Wentink et al.). However, in one respect nearly all of the research is lacking—establishment of the duration of the effects. Given the very brief interventions that were used in many of these studies, the question of whether they have more than a short-term impact is a very appropriate question to ask. Another weakness within this body of research relates to the selection of control groups. To establish that computer instruction is as or more effective than traditional methods and that the effect isn't merely due to the fleeting novelty of the medium, it is necessary to include at least two control groups: one taught by traditional methods and one given some time and/or instruction on the computer (but for purposes outside the targeted area of reading instruction). Very few studies (Mitchell & Fox, 2001; Nicolson et al.; Wise & Olson, 1995) satisfy these criteria.

Other: Spelling, Writing, and Geography

Spelling and writing have received much less attention than reading and math when it comes to investigating applications of computer and software programs. Chambless & Chambless (1994) conducted a very large 3-year study evaluating the impact of supplementing reading and writing instruction with computer reading and writing programs (Chambless & Chambless, 1994). Results suggest this kind of supplementation can significantly improve reading and writing achievement. MacArthur et al. (1990) provided evidence to support the use of a computer program to practice spelling. Students practicing spelling on the computer rather than off the computer spent significantly more time engaged and scored significantly higher on spelling tests (MacArthur, Haynes, Malouf, Harris, & Owings, 1990). Nicolson et al. (2000) reported that students working with a computer-based, multimedia literacy support computer program made gains in spelling performance equivalent to those working with a similar literacy program off the computer. Although Lynch et al. (2000) failed to demonstrate spelling improvement following use of a computerized IEP implementation program, they propose that this may be because of an ill-effective, spelling initiative that co-occurred with the intervention. Thus, studies suggest it may be worthwhile to further investigate the use of computer programs and software for writing and spelling.

Horton, Lovitt & Slocum (1988) investigated the effectiveness of a tutorial computer program that teaches geography. Students working with the program made significantly greater gains in geography knowledge compared to peers who did offline work using an atlas (Horton, Lovitt, & Slocum, 1988). However, the study was very brief and did not address the possibility of novelty effects or the question of maintenance of learning effects.

Although a few studies within this research base suffer significant design flaws, there is strong evidence to support the effectiveness of computer and software programs as learning tools, particularly for mathematics, fluency, phonemic awareness, and phonics/word recognition. In the following sections, we discuss potential factors influencing this effectiveness.

Factors Influencing Effectiveness

Duration of intervention. It is possible to argue based on the literature that brief interventions, approximately 3–9 days (Bahr & Rieth, 1989; Howell, 1987) are less effective than longer ones. However, lengthy interventions are not always successful (Nicolson et al.), and significantly improved outcomes have also been reported after interventions lasting as few as 2 sessions (Chiang, 1986; Torgesen et al.) and even 5–8 hours (Foster et al.). Clearly, although intervention duration is important, it is not the sole determinant of outcome.

Drill and practice versus tutorial. Software and computer programs vary in terms of the relative quantities of instruction and practice that they provide. Our sample includes research studies of so-called "drill and practice" programs (Frederiksen, 1985; Howell, 1987; Jones et al.; Torgesen et al.), purely instructional programs (Collins, Carnine, & Gersten, 1987; Foster et al.; Howell, 1987), and programs that share both features (Chiang, 1986; Trifiletti et al.). There is research support for all three types of programs, but they have been directly compared in only one study. Bahr & Rieth (1989) found no difference between the effectiveness of drill and practice and instructional game components of a commercial mathematics software program. However, because neither component improved performance, there was a problematic floor effect. Thus, additional research is needed to address the effectiveness of instructional versus drill and practice programs.

Specific program features. As technology and our adeptness with it continue to evolve, computer and software programs become increasingly elaborate. Determining which of the many possible features are most effective at improving learning outcomes is an important task. A few groups have begun to pursue it. Axelrod, McGregor, & Sherman (1987), for example, have investigated the impact of different reinforcement schedules in the context of mathematics software. Their very small study, limited to 4 students, found no difference between outcomes when working with no reinforcement or scheduled reinforcement (Axelrod, McGregor, Sherman, & Hamlet, 1987).

Rieber (1990) focused on the types of illustrations and the forms of practice offered within computerized lessons. Results of their brief, 1-session study indicated that behavioral practice (multiple-choice questions after each lesson) and cognitive practice (a simulation activity) were equally effective for students (Rieber, 1990). However, students seemed to learn better when given animated as opposed to static graphics.

Feedback is a variable that has the potential to greatly influence student learning. Computer and software programs can extend the teacher's reach by enabling the provision of individualized feedback on a classwide basis. But what type of feedback is best? Collins et al. compared two different forms of feedback in the context of a reasoning skills computer program. Students trained on a program offering elaborative feedback performed better than those trained on a version offering only basic feedback (Collins et al.).

Also of interest is the value of introducing a game element to learning on the computer. Several researchers have investigated the impact of game elements within software and computer programs, and the results of their studies are somewhat complex. Christensen and Gerber's (1990) findings suggest that a game format may be distracting and counterproductive for students with learning disabilities (see Educational Group section below). Malouf (1987-88) also found some negative quality to a game format – students with learning disabilities working with a drill and practice vocabulary game performed less accurately on a word definition matching test than did students who practiced using a non-game format vocabulary program. However, the game version of the program appeared more effective at developing continuing motivation to learn these skills.

More of this kind of research is needed to squarely address the features that may impact the success of computer and software programs in elevating learning outcomes. Present findings suggest that different students may benefit from different features.

Educational group. Nearly all of the studies we identified, concentrated on students with special needs (students with disabilities or handicaps, remedial students, below average students, special education students, and students with autism). The studies by Trifiletti et al. and Jones et al. and the reading literature as a whole (see above) provide strong evidence that students with special needs can use software and computer programs effectively and to their benefit.

At the same time, Jones' et al. findings suggest that these enhancements may not succeed in normalizing student performance to that of average performing students. Moreover, performance comparisons of students from different educational groups suggest important differences in how they respond to software and computer programs. Christensen & Gerber (1990), for example, present evidence that students with disabilities may benefit to a lesser degree from a game format than do students without disabilities and may even find them distracting. Moreover, Podell et al. found that within a group of students trained via a drill and practice mathematics program, those with mild mental handicaps were slower to reach the speed criterion on addition problems. Boone et al. found that low-ability kindergartners responded to a computer intervention in the opposite manner to medium- and high-ability kindergartners, developing better letter identification when taught by traditional teacher lessons versus a multimedia computer version of those lessons.

Less information is available regarding the use of computer and software programs by students outside the special needs population. However, findings reported by Foster et al., Reitsma & Wesseling (1998), and Chambless & Chambless (1994) suggest that these enhancements can also be a powerful tool for such students.

Grade level. The studies included in this review span grade levels from kindergarten through high school and support positive outcomes with preschool children and students in grades 4 through 12. The reading research focuses more intently on the kindergarten and early elementary grades. Many studies sampled students from multiple grade levels. Although the possibility of grade level-dependent differences in the effectiveness of computer and software programs has not been directly addressed in the math literature, a few reading studies have addressed the question (Hurford, 1990; Mitchell & Fox, 2001; Nicolson et al.; Wise et al.). All but one of these studies (Mitchell & Fox, 2001- sampling K–1 students) found evidence for a difference in effectiveness across grade levels. Two studies (Hurford, 1990; Nicolson et al.) found a greater benefit of computer training for older students (3rd graders - versus 1st or 2nd graders), and one a greater benefit for younger students (Wise et al.). It is unclear what sort of pattern was found by Wise et al., who did not detail the nature of the grade level by treatment interaction. These data are difficult to interpret due to the differences between the studies' design, but they seem to recommend a closer look at the influence of grade level.

Presence or absence of teacher-based instruction. Most of the studies discussed here investigated a stand-alone program of software-based instruction. Their findings are generally positive (an exception is McDermott & Watkins, 1983); a few studies even suggest a benefit beyond that of traditional instruction (McDermott & Watkins, 1983). Of interest, however, is how effective it is to supplement rather than replace a regular program with the use of software and computer programs. Studies by Erdner et al. and Howell et al. both suggest that a combinatorial approach that supplements the normal reading program with the use of software and computer programs delivers a much more substantial benefit than either component alone. Corroboration of these findings could be very consequential in determining how best to integrate the use of software and computer programs into regular classroom instruction.

ACKNOWLEDGEMENTS

This report is based in part on an earlier version conducted by Roxanne Ruzic and Kathy O'Connell, National Center on Accessing the General Curriculum. We would like to acknowledge the assistance of research assistant Melissa Mengel in collecting the research articles.

Ruzic, R. & O'Connell, K. (2001). *An overview: enhancements literature review.*

LINKS TO LEARN MORE ABOUT TEXT TRANSFORMATIONS

Modified Text

Text-to-Speech

www.research.att.com/projects/tts/

This is the web page of AT&T Labs that describes the research conducted on text-to-speech (TTS) technology. The Next-Generation TTS converts English text into audible speech. The Next-Generation TTS was introduced in 1998 and continues to improve dramatically in the quality and naturalness of the voices. The web site has interactive demonstrations in which users can enter text and select one of five voices. The TTS is only for demonstration purposes only.

www.naturalvoices.att.com/demos/

This web site has the AT&T TTS natural voices demonstrations similar to the previous listing. This version is updated to include three new voices. The languages that this engine supports include: U. S. English, German, Latin American Spanish, U.K. English, and Parisian French.

Hyper Text and Hypermedia

http://wwwis.win.tue.nl/ah/

This technical web site provides information on adaptive hypertext and hypermedia. It includes links to conferences, journals, projects, and people in the field of multimedia.

http://top.pefri.hr/mr/

This thesis paper deals with implementation of hypermedia systems in education, and particularly with the networked hypermedia systems, best represented by the World Wide Web. The third portion of the paper addresses the issue of hypermedia in education. It also includes links to a glossary of commonly used hypermedia and computer terms.

http://www.usask.ca/education/coursework/skaalid/site/hypertxt.htm

This homepage of a University of Saskatchewan instructor gives a multitude of guidelines on web design for instruction. It includes links to teacher resources, site and page design, and multimedia.

http://www.vanderbilt.edu/create/tech/index.html

This web site by Vanderbuilt University walks the viewer through an on-line web design tutorial. It also provides examples of hypertext and hypermedia, as well as giving tips for creating an effective web site.

http://www.mcli.dist.maricopa.edu/tut/

"Writing HTML" was created to help teachers create learning resources that access information on the Internet. On this site, the viewer will be writing a lesson called *Volcano Web*. The tutorial, however, may be used by anyone who wants to create web pages.

http://www.cogs.susx.ac.uk/users/theoa/simq/tutorial_issue2/node1.html

This web site provides an excellent tutorial on hypertext and hypermedia in the context of designing own web page. It is produced by the University of Sussex and includes information about structure and navigation in hypertext and web site structure.

Multimedia Supported Text

http://hotwired.lycos.com/webmonkey/multimedia/tutorials/tutorial3.html

This web site provides an eight-day multimedia tutorial by an Internet consultant that uses pop culture to make his learning interesting. The author briefly discusses the history of multimedia, and then focuses on RealAudio, RealVideo, and RealFlash technologies to add sound and animation to the web.

http://ncam.wgbh.org/richmedia/captioning.html

National Center for Accessible Media's web site on how to create captions for rich text-provides links out to different web sites as well. This page offers a development strategy split into two parts: Part 1: Creating Captions, for those starting from scratch, and Part 2: Adding Captions to Media, for those who already have a timed-text caption file.

Video and Videodisc Instruction

http://www.tools4teachers.com/t_dvdtech.html

A web site designed for teachers that includes an article about the implications of DVD technology on education. This site also provides helpful DVD titles in numerous subject areas such as science, social studies, art/humanities, language arts, and math.

http://seamonkey.ed.asu.edu/~mcisaac/disted/week1/5focuslj.html

This web site contains an article addressing video instruction as a constructivist tool. It specifically discusses *The Adventures of Jasper Woodbury*, a series of six videodiscs from the Optical Data Corporation. Each disc contains a story that includes embedded mathematical data and ends with a problem that students must use the data to solve. It includes a link to an example of the Jasper Series.

http://peabody.vanderbilt.edu/projects/funded/jasper/preview/AdvJW.html

This web site gives the viewer an opportunity to experience the Jasper Series, including story and solution summaries for four different topics.

http://www.tomsnyder.com/free_stuff/free_demos.asp?LinkSource=HomePage

A web site by Tom Snyder Production's that provides free demos and product overviews of numerous software packages for teachers in math, social studies, science and cross-curricular subjects.

http://www.studyworksonline.com

Study Works Online, is a free learning site delivering original approaches that help students develop an understanding of math and science concepts usually taught from grades 7 to 12.

StudyWorks Online gives students, parents, and teachers access to high-quality content, interactive activities, real-world examples, diagnostic testing, monitored learning forums, personalized guidance and software packages.

http://www.birchlane.davis.ca.us/webstuff/tup.htm

This web site lists the goals of integrating technology into all subjects of an elementary school classroom. The authors address how technology can be used to improve learning by listing the desirable software and on-line resources for each subject area.

http://www.videodiscovery.com/demovideos.asp

Free demo videos of science for middle and high school age students; videos are available for purchase.

http://www.dositey.com/teach/teachers.htm

Dositey.com offers a collection of interactive educational modules and printable worksheets for grades K–8. The lessons and games are predominately focused in the subjects of math and the language arts.

http://anatome.ncl.ac.uk/tutorials/index.html

This web site provides online tutorials on anatomy of the human body. It provides detailed medical information and gives the viewer a great overview of different parts of the body.

http://www.kn.pacbell.com/wired/donner/

"Donner Online" is a type of Web-based activity in which you learn about a topic by collecting information, images, and insights from the Internet, and then you "paste" them into a multimedia Scrapbook (a HyperStudio stack or a Web page) to share your learning with others. Includes a link to a Hypertext dictionary.

http://www.byteachers.org.uk/school.htm

This web site is produced by the Association of Teachers' Web sites and is intended for teachers. It allows the viewer access to a range of twelve virtual departments for a range of online lessons.

Text Transformations

Word Processing

www.quasar.ualberta.ca/edpy202/tutorial/wptut/wpweb.htm

This web site is managed by the University of Alberta. This web site provides a series of internet links to several online word processing web sites and tutorials. Tutorials are provided for the software programs Microsoft Word, Word Perfect and Apple/Claris Works. Some of these tutorials are Windows compatible, others are Mac compatible and some are compatible with both platforms.

www.baycongroup.com/wlesson0.htm

The Bay Con Group offers various free, online software tutorials. This page offers tips and tools for using Microsoft Word 97. The tutorial is comprehensive and provides users with basic step-by-step instructions for beginning Microsoft Word. The Bay Con Group has made this web site easily navigable for first time users.

Spell Checker

www.spellcheck.net/

Spellcheck.net is a site providing a free spell check program. Users can type, or paste in a word or multiple paragraphs (up to 5,000 characters) for the spell checker to process and correct. Each misspelled word is highlighted and alternative words are provided.

Word Prediction

www2.edc.org/NCIP/library/wp/toc.htm

This web site is for the National Center to Improve Practice in Special Education through Technology, Media and Materials (NCIP). The general features and applications of word prediction software are explained through the use of case stories. The profiles of each child varies in every case story, but the examples can help parents and teachers understand how to use word prediction to assist their children or students. Links to research articles that have found benefits to word prediction software are listed along with descriptions of various word prediction software programs that are currently available.

www.ldonline.org/ld_indepth/technology/word_prediction.html

This is a link to an article written by Charles A. MacArthur in Teaching Exceptional Children July/August 1998 about a third grade student with reading and writing learning disabilities. MacArthur presents a case story in which the student participated in a study of word prediction and speech synthesis. This computer program enabled the student to expand his writing and communication abilities while improving his spelling.

http://www.ataccess.org/

The Alliance for Technology Access is an organization that connects children and adults with disabilities to technology tools. This web site provides the reader with information about the Alliance, assistive technology and augmentative communication. Additionally, this ATA site provides links to a number of sources for word prediction including software programs such as Outloud, Intellitalk and Read and Write.

Speech Recognition

Scan soft company web site
http://www.scansoft.com/

This is the web site of a software company that has developed several products in the speech recognition software area.

The CTD Resource Network, Inc.
http://www.tifaq.com/speech.html

This web site is the CTD resource network frequently asked questions page regarding Speech recognition software and usage. The site provides information about tools and wares available with manufacture descriptions and user comments. There are multiple links to sites to obtain specific information about speech recognition software.

Mississippi State University Dept. of Electrical and Computer Engineering
http://www.isip.msstate.edu/projects/speech

This is a site housed on the Mississippi State University web site that provides information about an Internet-Accessible Speech Recognition Technology project. Their goal is to create a freely-available, modular, state-of-the-art speech recognition system that can be easily modified to suit research needs. This site also provides several links to resources and research about speech recognition.

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