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RESEARCH ON COMPUTER-MEDIATED INSTRUCTION FOR STUDENTS WITH HIGH INCIDENCE DISABILITIES

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ABSTRACT

In this literature review, the effects of computer-mediated instruction on the learning of students with mild and moderate disabilities are synthesized from 1996 onward that extends our previously published synthesis for the period 1987-1995. Empirically based findings are reviewed and discussed in the basic skills areas of reading, writing, and mathematics, as well as in the content areas of social studies and science. Results are interpreted and discussed regarding traditional teaching methodologies in special education as well as changes in the instructional ecology and expectations for students created by the inclusion movement and reforms in general education. Limitations found in the reviewed studies are described and future directions for research in special education technology for students with high incidence disabilities are identified.

During the last two decades, special educators have adapted and evaluated computer-mediated instruction (CMI) to assist students with disabilities. Early research efforts focused primarily on the benefits of computer software for the mildly handicapped and adaptive devices for those with physical and sensory

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disabilities. By the mid-1990s, syntheses of research findings supported the conclusion that students with disabilities learned as well or better through computer-assisted instruction (Fitzgerald & Koury, 1996; Roblyer, Castine, & King, 1988), but conceded that the advantage was due to effective instructional design of the software rather than the use of the computer per se (Hall, Hughes, & Filbert, 2000; Woodward, Gallagher, & Rieth, 2001). As the field advanced, researchers shifted from comparative studies on the effectiveness of computer-assisted instruction to questions about how to effectively integrate computers and technology into instruction with particular attention to maximizing learning and enabling students with high incidence disabilities to learn in general education environments in the content areas (Maccini, Gagnon, & Hughes, 2002; Woodward & Rieth, 1997).

Other variables in the instructional ecology were examined—roles of teachers, setting variables, and instructional methodologies—to determine how they might enhance the benefits of computer-mediated learning. CMI was no longer viewed as separate from its context of use. Questions were raised about CMI outcomes within instructional contexts, looking at how CMI could be used to help learners recall prior knowledge, how to scaffold new learning, procedures to maintain new skills, methods to teach learning strategies for independent use, and advantages of anchored instruction for contextualizing problem solving.

As the 20th century closed, it became apparent that the technological gap was growing between students with and without disabilities. The teaching and learning paradigms in general education were rapidly changing, requiring students to use learner-centered approaches, become self-directed learners, and demonstrate higher order thinking and problem-solving skills. CMI was also changing to emphasize information-age skills, such as finding and evaluating information through the Internet and using presentation tools to demonstrate learning (Means, Penuel, & Padilla, 2001). Classrooms saw a decline in the use of educational software for mastery learning on individual work stations and an increase in online, inquiry-oriented activities and general-purpose technology, oftentimes used for collaborative learning (Means, 2001). A report from the National Research Council (1999), describes technology, including CMI, as having the potential to support meaningful learning through technology-enhanced real-world learning contexts, electronic communication with outside experts, visualization and analysis tools, scaffolds for problem solving, and opportunities for feedback, reflection, and revision.

Facing these immense learning challenges are students with high incidence disorders in learning disabilities, emotional/behavioral disorders, and mental retardation, who have poor information-seeking and organization skills, reading and writing difficulties, and problems with cognitive focus. In the new reformed, standards-based general education curriculum that demands knowledge and analytical thinking skills, students with disabilities are at risk. They have difficulties learning standard curriculum because of inadequate prerequisite skills and poor group learning skills and from demands inherent in the structure and content of the curriculum itself (Pugach & Warger, 2001; Woodward & Montague, 2002). Concern is heightened that students with disabilities remain unprepared for technological survival due to problems of access, instruction in technology usage, and a poor ability to transition to technology use in postsecondary environments (Burgstahler, 2003; Fitzgerald & Koury, 1996; Woodward & Montague; 2002). The changes in curriculum and technology as well as the movement to educate students with mild disabilities in general education settings bring about immense new challenges for researchers to examine how CMI can be used to enhance learning in school and beyond (Pugach & Warger, 2001).

EMPIRICAL STUDIES 1996-2006

This literature synthesis analyzes research findings and trends for the use of CMI for students with mild and moderate disabilities from 1996 onward and updates our previous research synthesis (Fitzgerald & Koury, 1996). Together, these two publications provide a unique, in-depth summary of research in the effectiveness of educational technologies for students with high incidence disabilities within the standard curricular framework of K-12 schools.

The research studies in this review met the following criteria. First, only empirical studies utilizing appropriate quantitative, single subject, or qualitative (case study or field observation) methodologies were included. Descriptive articles that did not report methodological procedures with supporting data or position statements were not included. Second, articles were selected from peer-reviewed journals or proceedings. Third, participants needed to include students who were identified with the high incidence categories of learning disabilities (LD), emotional/behavioral disabilities (ED), mental retardation (MR), and other health impaired (OHI). These four categories comprise 72.9% of students with disabilities receiving special education services requiring curricular modifications (U.S. Department of Education, 2004). In some studies, participants included a mixture of students with disabilities as well as other low-achieving students. Studies that focused primarily on at-risk students were not included in this review. Fourth, instructional interventions had to include computer-mediated instruction in K-12 settings ranging from special classes to integrated, inclusive classrooms. Descriptive information published by the authors for each of the studies is provided in the tables below in each section.

Appropriate research articles were located by searching electronic databases (Educational Resources Information Center (ERIC) and PsychINFO), and conducting a physical search of key journals. In addition, reference lists included in other research syntheses published during this period were searched for appropriate citations (Edyburn, 2001, 2002, 2003, 2004; Edyburn, Higgins, & Boone, 2005), and Google searches were conducted for writers whose names emerged from these related publications.

These literature searches located 34 studies that met our criteria. These were grouped for analysis into the basic skills curricular areas of reading, writing, and mathematics and the content areas of science and social studies. Within each curricular area, findings are compared to results from previously published syntheses (Fitzgerald & Koury, 1996; Gersten, 1998; Hall et al., 2000; MacArthur, Ferretti, Okolo, & Cavalier, 2001; Woodward & Rieth, 1997). The state of the art for research in special education technology reveals a publications acceptance of studies that do not fully meet rigorous standards for empirical research as described in a special issue of *Exceptional Children* (Council for Exceptional Children, 2005) with criteria for quantitative and qualitative research. Throughout our review, limitations and recommendations to improve the research methodologies are described; such changes would move the field closer to meeting the recommended research standards. Following a review of all studies, future research directions are discussed.

LEARNING IN THE BASIC SKILLS AREAS

Traditional research studies in the basic skills areas compared student performance with or without some form of computer assistance. With the shift from educating students with high incidence disabilities in individualized programs in special classes to general education classrooms, the use of CMI has shifted to supporting learners in the general education curriculum and research strategies have moved beyond limited media comparisons (MacArthur et al., 2001). As stated by Pugach and Warger (2001), "The general education curriculum is the starting point for any individualization or accommodation that is required to foster their success in learning" (p. 227). The prominent uses of CMI in general education classrooms now require student engagement in learner-centered inquiry, knowledge construction, and higher-order thinking and problem solving (Means, 2001). Some of these themes were evident in research during this time period. The studies focused on computer delivery of instruction for skill acquisition, the use of computer tools to support literacy, and the use of computer-based learning environments to situate knowledge and problem solving.

Literacy

Literacy is viewed broadly based on the Lerner (2000) model that emphasizes its recursive nature and developmental sequence involving the processing of information by listening, speaking, reading, and writing. The literature published during this period primarily involved reading and writing. Nineteen literacy studies were found that focused on word recognition and reading comprehension with hypertext tools; software for improving decoding skills, sentence writing, and reading readiness skills; the use of spelling and grammar checkers; speech recognition; and composition tools for written expression and multimedia production.

Reading

Most reading studies focused on the use of CAI to improve word recognition skills or software that helped students with strategic reading to improve comprehension. Variables known to improve software design for teaching word recognition include controlling the size of the learning set, controlling response times to build fluency, immediacy of feedback, and practice to build and maintain performance at mastery level. Research in the mid-1990s provided initial support for changes in software that allowed more user control over the software, use of speech synthesis, and access to hypermedia supplements to enhance understanding (Fitzgerald & Koury, 1996). These research themes showed little change in the current review other than a reduced interest in the design of CAI and an increased emphasis on the computer as a personalized learning tool. Table 1 provides a summary of the reading studies included in this review.

Lee and Vail (2005) studied a computer-based sight word reading recognition program with four students with developmental disabilities, aged 6-8. The study incorporated a constant-time-delay procedure and involved sounds, video, text, and animations. Video segments included cartoons and movie segments 7-15 seconds long made as QuickTime movies. The computer program used a 5-second constant time delay procedure requesting the student to "click" on the correct word. After 5 seconds elapsed, students received a correct answer prompt and were given a second chance to answer correctly. A generalization procedure using storybooks followed. Results suggested that all students acquired their target words and generalized sight word recognition across modes and materials. The study verified previous findings about constant-time-delay for word recognition and added content generalization as a benefit.

Marston, Deno, Dongil, Diment, and Rogers (1995) compared the effects of computer-assisted reading (CAI) to other instructional methods, including peer tutoring, reciprocal teaching, effective teaching principles, and direct instruction models on the achievement of elementary students with mild disabilities. Results showed that achievement was significantly greater using CAI than peer tutoring and effective teaching principles. However, the observation data suggested that direct instruction was the most engaging method for students. The findings confirmed earlier studies reporting that computer-aided instruction in the reading skills of sight word recognition, decoding, and comprehension is highly effective when compared to other instructional methods.

In a comprehensive study on integrated language and literacy, Raskind and Higgins (1999) investigated the use of speech recognition software to improve reading and spelling of 39 students with LD, ages 9-18. The control group was used to reduce differences that were due to computer use rather than speech recognition itself. Both groups worked on computers to complete writing tasks for 50 minutes per week for 16 weeks. Results demonstrated that the speech

Table 1. Reviewed Studies on Computer-Mediated Instructional Interventions in Reading

Author (Year)	Subjects	Age/Grade	Disability	Design	Intervention	Dependent measures
Blankenship, Ayers, & Langone (2005)	3	9th grade	EBD	Single subject multiple probe across behaviors (chapters)	*Inspiration* concept mapping software	20 concept multiple choice/short answer chapter test
Higgins & Raskind (2005)	30	10-18 years	LD	Group comparison; random assignment	*Quicktionary Reading Pen II*	Formal Reading Inventory
Higgins, Boone, & Lovitt (1996)	25	14.6 mean age	13 LD 12 remedial	Group comparison	Three types of hypermedia supports	Daily comprehension quizzes and retention test
Howell et al. (2000)	32	1st grade	Mild/moderate and at-risk	Group comparison	*IntelliTools* (decoding, comprehension and writing software)	CBA decoding and word identification; total words written
Jerome & Barbetta (2005)	5	5th grade	LD	Single subject	Three different hypermedia conditions	Percentage correct social studies facts
Lee & Vail (2005)	4	6-8 years	DD	Single subject multiple probe across word sets	Sight word reading recognition program using constant time delay	Percentage of correct responses
Marston et al. (1995)	176	Elementary grades	Mild disabilities	Group comparison	CAI compared with reciprocal teaching, direct instruction, peer tutoring	CBM and observation coding
Raskind & Higgins (1999)	39	9-18 years	LD	Group comparison random assignment	Speech recognition software and word processing	Reading recognition and reading comprehension

recognition group had significantly higher improvement scores than the control group in spelling, reading recognition, and reading comprehension.

In a subsequent study, Higgins and Raskind (2005) tested Quicktionary Reading Pen II on reading comprehension of 30 students with LD, ages 10-18. The Quicktionary Reading Pen II does what desktop optical character recognition (OCR) with speech synthesis capability systems do but at a much-reduced cost with more portability. The user is able to scan single words to entire lines of text at a time, that will then appear on-screen and be read aloud within 1-3 seconds. Students received training and 2 weeks of practice using the system and then were tested twice on consecutive days using different forms of the Formal Reading Inventory (Wiederholt, 1986). Results indicated that regardless of order of use, the Reading Pen II system students' standard scores were significantly higher than when they did not use it. Results of both studies (Higgins & Raskind, 2005; Raskind & Higgins, 1999) verify the positive compensatory effects of the related technologies combining speech synthesis and optical character recognition with CMI. Speech recognition provides simultaneous, multi-sensory presentation of text and its auditory counterpart, requiring the student to monitor the match between the visual output and its phonological representation. It also provides practice in reading correctly-spelled text.

Howell, Erickson, Stanger, and Wheaton (2000) used IntelliTools in inclusive classrooms to study the effects of an early reading program for reading failure on 32 first grade students with or at risk for mild high incidence disabilities. IntelliTools is a software program that integrates the features of word recognition with a direct instruction phonics approach (IntelliTools, 2000). It provides the capability of reading and writing connected text for the purpose of providing basic phonics instruction in meaningful contexts. The components of the software are:

1. reading connected text for comprehension;
2. word study and reading of connected text for building word identification and decoding shills; and
3. structured writing activities.

The software contains anchor stories emphasizing predictable text with repeated lines and pictures relating directly to the text. It also includes a feature called "little books" that provides opportunities to build fluency with sight words and to apply decoding skills to new words. Practice activities are provided for word analysis and sentence composition. The goal of IntelliTools is to generalize these basic skills into tasks and texts found in the general education curriculum. It was found that all students gained pre to post in phonemic awareness, word reading, and word writing skills, and there were no significant differences between the groups. The authors recognized limitations in the study as the lack of a true control group, not including a reading comprehension test, and possible ceiling effects in the criterion group performance. It was encouraging, however, that students within the at-risk group made equivalent achievement gains without receiving intensive direct instruction that is typically considered essential for such gains.

Hypertext has been identified as an effective approach for enhancing comprehension of low achieving students, particularly when supplements are used over sufficient time (Fitzgerald & Koury, 1996). Continuing this line of inquiry, Higgins, Boone, and Lovitt (1996) studied three different forms of support provided by hypermedia with 13 secondary students with LD:

1. notes related to an underlined word or phrase;
2. replacements of a word or phrase bolded in text with a synonym or clarification; and
3. hyper-linked multiple-choice questions for understanding.

Research questions focused on how students used supported text, its impact on comprehension, and differences in retaining information from supported passages. On the retention test, factual questions were answered correctly at a significantly higher rate than inferential questions, but there was no difference between text-based factual questions and hypermedia-supported factual questions. Analyses of the daily quiz scores yielded only one significant result: hypermedia-supported factual test questions were answered correctly at a higher rate than text-based factual questions or inferential questions. It appeared that students sustained unprompted use of hypermedia supports and that information provided by teacher lectures and enhanced with hypermedia was retained. Use of non-linear, hypertext supports did not interrupt or compromise retention. However, the effectiveness of hypermedia enhancements over an extended period of time cannot be determined due to the short duration of this study.

Blankenship, Ayers, and Langone (2005) studied the effect of computer-based cognitive mapping on reading comprehension of three 9th graders with EBD. The students used the computer program Inspiration for creating cognitive maps of the material they read. The reading material was a world history text that they independently read and created cognitive semantic maps. There were three chapters covered during the study and students completed the dependent variable both pre- and post-intervention. They were quizzed (partial dependent variable) using all 20 concepts daily after reading was completed on material that they had read and created computer-based concept maps. All students showed rising trends in whole test occasions and mastery (80% or higher) on partial test quiz content. The authors suggested that Inspiration may be an effective tool for students with EBD to assimilate world history content reading textbooks independently. Finally, the authors reported a reduction in office referrals while students were working independently using Inspiration to read their content textbooks.

A recent study compared different hypermedia features in self-study materials (Jerome & Barbetta, 2005). Five students with LD in fifth grade learned social studies facts through three different hypermedia conditions in CAI; clicking on the correct answer, listening to an audio answer, and repeating out loud an audio answer. Students acquired the most comprehension facts in the repeat aloud condition, and these outcomes were maintained over 1- and 2-week mastery tests. Findings suggested that learning was enhanced by active responding with an oral component, thus supporting continued investigation of speech recognition approaches in CAI and hypermedia.

No lines of research provide a comprehensive study of the application of CMI to the distinct benchmarks of reading—word recognition, decoding, and comprehension of context. The new literature during this period shows some promise related to isolated approaches for improving distinct components of learning to read; however, findings fail to relate CMI to an overall improvement in reading. For the most part, there are methodological concerns and insufficient identification of treatment groups in the reviewed studies that limit a conclusion that CMI has a beneficial effect on the development of reading skills (MacArthur et al., 2001).

Writing

Research in writing includes spelling, written expression, and multimedia composition. Previously, researchers concluded that spelling checkers and collaborative writing process software are beneficial for special learners. Multimedia composing systems that were fairly new in the mid-1990s had shown promise to help students generate quality products and to motivate novice writers. One cutting-edge educational application—voice transcription—had not been empirically validated as useful for students with LD due to problems in the equipment and student dictation problems in oral fluency and thought processes (Fitzgerald & Koury, 1996). Research during this period continued to focus on word processing, desktop publishing tools, spell checkers, speech synthesizers, and multimedia composition. Table 2 provides a summary of the written expression studies included in this review.

Two new studies were published that offer some direction on the selection of writing program software. Both studies were completed in an after-school university research setting with 3rd–8th graders with LD. The studies compared written products using two different software tools and evaluated how students used the different features of each software program. Instruction followed the process writing approach of plan/organize, write, and revise/edit. Bahr, Nelson, and Van Meter (1996) compared two story-writing software programs with nine 3rd–8thgrade students with LD. One program offered story prompts to support story composition and the other program allowed students to create graphic scenes prior to writing. Results did not favor either software tool, nor were there any significant differences on seven of the eight linguistic measures. An interesting difference was that more incorrect complex sentences were produced using the graphics-based software program than with the text-based program.

Table 2. Reviewed Studies on Computer-Mediated Instructional Interventions in Written Expression

Author (Year)	Subjects	Age/Grade	Disability	Design	Intervention	Dependent measures
Bahr, Nelson, & Van Meter (1996)	9	3rd–8th grades 11.4 mean years of age	LD	Group comparison, counterbalanced	Two-story-writing software programs; one with story prompts and one with graphic scene creation	Scores on Boder Test of Reading Spelling Patterns, Writing Process Test (WPT), and Test of Written Language (TOWL-2)
Bahr, Nelson, Van Meter, & Yanna (1996)	8	3rd–8th grades	LD	Comparison of instructional conditions	Two desktop publishing programs	Daily logs, interviews
Englert, Manolo, & Zhao (2004)	18	Primary grades	In some stage of identification/ referral for SPED	Comparison of instructional conditions	TELE-Web—teacher prepared online scaffolds, small-group instruction, independent seatwork	Writing quality using rubrics across different writing tasks
Langone et al. (1996)	6	Middle grades	EBD	Single case alternating treatment	Computer written vs. pencil/paper products	Errors in capitalization, spelling, punctuation; holistic score paragraph construction

Lewis et al. (1999)	233	4th–8th grades	118 LD 115 gen ed	Group comparison matched groups	Technology-supported (spell- and grammar-checkers) process-writing instruction vs. no technology	Holistic scoring writing samples; observations, interviews
MacArthur et al. (1996)	55 study 1 27 study 2	5th–8th grades	LD	Comparison	Use of spellchecker vs. non-use	Percentage of errors self corrected
MacArthur (1998)	3	9-10 years	LD	Single case	Word processing, enhanced word processing	Number of correct and legibly spelled words
MacArthur (1999a)	3	9-10 years	LD	Single case, alternating treatment design	Writing by hand, word processing, enhanced word processing	Number of correct and legibly spelled words
MacArthur (1999b)	3	9-10 years	LD	Single case, alternating treatment design	Writing by hand, word processing, enhanced word processing with less demanding writing task	Number of correct and legibly spelled words
Montgomery, Karlan, & Coutinho (2001)	111	3rd–8th grades	LD	Comparison	Word processing spell check programs	Percentage of correctly identified words
Zhang (2000)	5	5th grade	LD	Case study	*ROBO-Writer* (Brooks & Zhang, 1992), process writing software	Holistic evaluation written products

In the second study, the effects of two desktop publishing programs were compared on written products and the composition process (Bahr, Nelson, Van Meter, & Yanna, 1996). In this study with eight 3rd–8th graders with LD, desktop publishing programs differed in two ways—the range of options to support the writing process and navigation in the software. Outcomes significantly favored one desktop publishing program over the other where there was more time spent in writing, more frequent use of the spell checker, less time navigating, longer stories, and superior narrative complexity. Interview data suggested that students preferred both programs for different reasons, and both programs were preferred over paper/pencil writing. Implications from these studies are that students will benefit from simpler, time efficient programs that provide more writing time and require less time on navigation and non-writing activities.

Two studies examined the impact of word processing and writing process software on the quality of written products. Using case methodology, Zhang (2000) documented improvement in writing. Five 5th grade students with LD received writing instruction three times a week for a year's duration with the writing tool ROBO-Writer (Brooks & Zhang, 1992). A sample of written products for each student underwent holistic evaluation throughout the course of the study and improvement was seen on the written products over time. Qualitative observations led to recommendations that teachers actively monitor progress, provide emotional and technical support to students, and encourage students to think like writers.

A second study (Langone, Levine, Clees, Malone, & Koorland, 1996) compared the effects of computer-written versus paper/pencil products on writing performance of six middle school students with EBD. Students produced five products (complete paragraphs) under each condition. In the computer condition, students used a typing tutor program to develop touch-typing and word processing skills. Instruction in the writing process was similar in both conditions and involved cue cards, story starters, and process writing supports. Performance was equivalent under both conditions, exceeding the 80% criterion. The analysis for capitalization favored the paper/pencil condition. On punctuation, no differences were found for five of six students. Products were also given a holistic score for paragraph construction. Four of the six students demonstrated equivalent performance under both conditions and the other two students had higher scores using the computer tools. Overall, the researchers did not find a clear advantage for either approach.

The effectiveness of spelling and grammar checkers as tools to improve written expression was the focus of three studies. In a year long study with 4th–12th grade students, 118 students with LD and 114 students without disabilities received writing instruction using a process approach (Lewis, Ashton, Haopa, Kieley, & Fielden, 1999). Three groups of students received CMI support varying the use of word processors, spelling checkers, grammar checkers, and speech synthesizers. A fourth group of students wrote by hand. Research questions focused on differences in writing quality between computer-assisted and paper/pencil conditions. Results indicated that writing accuracy improved for all students pre to post on writing mechanics, with higher levels of performance for general education students. Comparing the four groups of students with learning disabilities, the CMI groups improved more than the paper/pencil group. On writing quality, all students improved pre to post with general education students outperforming the students with learning disabilities. No differences could be attributed to CMI supports on the quality measures for students with LD. Attitudes toward writing decreased pre to post in all groups. Observations of the use of computer writing tools indicated that spell checkers were more accurate than grammar checkers and that speech synthesis was most successful in aiding spelling correction when the spell checker offered no options to the writer.

The problems with spell checkers were examined in two studies reported by MacArthur, Graham, Haynes, and DeLaPaz (1996). In their first study, typical spelling errors taken from the writing of 55 students with LD in grades five through eight were analyzed with 10 spell checkers. There were 555 unique misspellings of 373 different words. A number of faults were identified with the operation of the spell checking programs. Often, spell checkers did not discriminate between homonyms. Another problem occurred when text was covered up by the spelling checker dialogue box, thus negating the option of seeing the word in context on the screen. Some spell checkers were not integrated with word processors and did not suggest replacements. Difficult-to-use spell checkers disrupted the writing process. Results indicated that spell checkers were more useful to students who had less severe misspellings.

In their second study, MacArthur et al. (1996) examined the use and benefits of spell checkers with 27 students with LD in grades 5–8. Students attempted to self correct their spelling mistakes with and without a spell checker. Students were taught to use the spell checker for correcting misspellings, and then they created a first draft in writing class without using a spell checker. Next they corrected misspellings on a computer printout of their first drafts, and the following week corrected their drafts using the spell checker. Without the spell checker, students found 28% of their errors and corrected 9%; with the spell checker they found 63% of their errors and corrected 37%. When the spell checker gave suggestions, 81% were corrected; when no suggestions were given to students, only 25% were corrected; and when suggestions were made, students chose incorrectly 22% of the time. Recommendations were made that spell checkers should not be used exclusively but when students examine words with a spell checker in context, more corrections are made.

A series of studies was conducted that examined the combination of word processing with speech synthesis and word prediction in writing for three students with LD, ages 9-10. This research line examined whether the enhanced word processing programs improved accuracy and length of writing. In the first study by MacArthur (1998), the writing tasks included typing unknown words dictated by the research assistant and writing entries into journals to dialogue with the teacher. Students read aloud their journal entries with the aid of speech synthesis. Students participated in a series of baseline (word processing without the aid of speech synthesis and word prediction) and treatment (word processing enhanced by speech synthesis and word prediction). Speech synthesis and word prediction had strong, positive effects on spelling and the legibility of recognizing words even though they were misspelled in written artifacts for four of five students. There were no effects on the rate of composing or length of compositions. The students expressed a preference for the enhanced word processor and felt it helped them write better.

In two follow-up studies, MacArthur (1999) introduced a more sophisticated word prediction program with a larger dictionary with three students with LD, ages 9-10. Students' daily journal entries were compared across three conditions: writing by hand, plain word processing, and enhanced word processing. With this writing task, little impact was found on spelling, legibility for recognizing words even though misspelled, or on writing outcomes. Since these results conflicted with an earlier study, a second study was conducted using the same procedures but using a less demanding writing task. Writing was done from dictation at each student's level. Two of three students benefited from enhanced word processing with this writing task. The student that was unsuccessful seemed to have difficulty getting good predictions from the software because his initial letter was often incorrect, leading to a poor pool of possible word choices. Based on these three studies, the researcher suggested that word prediction software should be carefully matched to students and that students must be taught strategies to be successful with word prediction software.

Montgomery, Karlan, and Coutinho (2001) compared spell check features found in word processors with 111 3rd–8th grade students with LD. These students produced 199 writing samples that were spell checked to generate 1008 misspelled words. These writing samples came from a variety of sources including spelling dictation, written language compositions, book reports, letters, and content area reports and assignments. The research questions focused on the capability of the spell checker to produce the correct spelling in the first position of suggestions and how this differed across phonetic levels and correct letter sequences. Findings suggested that spell checkers failed to provide the replacements for misspellings almost half of the time on all words depending on the spell checker. The correct spelling for the word appeared first on the list of suggestions for only 21% of the words, and appeared on the first screen of suggestions for 46% of the words. The programs varied in their effectiveness for supplying the correct spelling under different phonetic levels and correct letter sequences. The findings suggested that students need to be taught strategies for evaluating spelling suggestions based upon their typical spelling errors, and the choice of spell checker should be matched to the patterns of student spelling errors.

An emerging research theme is the use of Web-based programs to scaffold the writing process. The rationale for this approach is to provide computer-based tools to support the mental work and processes involved in writing to enable students to perform at more advanced levels (Englert, Manalo, & Zhao, 2004). Using the customizable Web software Technology-Enhanced Learning Environments (TELE-Web), teachers delivered online scaffolds for the students to support their writing. These scaffolds included pop-up reminders, teacher-written directions, and teacher-prepared detailed cues and supports. Students also had access to spell checkers, text-to-speech read backs, collaborative sharing of work, and online submission of work and final drafts.

In this study, 118 primary grade students who had been referred for special education rotated through three instructional conditions: TELE-Web, teacher-led small group instruction, and independent seatwork. Three conditions for writing activities were examined: supported paragraph writing, unsupported paragraph writing, and paper and pencil writing. For all students, productivity was highest in the supported paragraphs condition; there was no significant use of writing conventions except for use of punctuation that favored the supported writing condition, and significant differences in genre-related features favored the supported writing condition in features such as topic introductions, text organization, and author's voice. Nearly two-thirds (62%) of the writing samples occurred in the supported writing condition. On a transfer task at the time of post-test, written compositions were significantly better than at pre-test in terms of text organization, introductions, topic sentences, inclusion of details but not different in terms of number of words and writing conventions. The areas of improvement were closely related to the use of embedded scaffolds during instruction in the supported paragraph condition. These findings clearly support the effectiveness of software with embedded scaffolds, whether delivered via the Web or within computer software programs. The authors concluded that more research is needed on the instructional conditions for utilizing scaffolding software and how to facilitate transfer and long-term impact. In spite of the demonstrated effectiveness of scaffolds, the authors concluded that its effectiveness was due to the overall instructional approach that combined teacher modeling and instruction with assisted performance.

The research in various areas of literacy appears to be fragmented and inconclusive. The new research on reading involved the use of speech recognition software and found gains equivalent to direct instruction. Research in hypermedia-supported reading continued to show improvement in understanding for all levels of learners. Much of the new research in writing during this time period focused on a very narrow use of CMI—spelling checkers—that are a very small component of editing and an even smaller part of the writing process. One useful result from the spelling checker research is that students cannot rely on this feature of word processing during independent writing activities since the commercial products do not perform very well. Writing software with scaffolding was implemented through a Web environment in combination with teacher-led instruction and had positive effects on writing quality for young children. The findings in literacy yield consistent recommendations: students must be taught strategies for using tools effectively; reading and writing cannot depend on CMI alone for creating success; and applications must be sustained over time for gains to be maintained.

Mathematics

Research in computer-mediated instruction in mathematics has been reported as sparse (Fitzgerald & Koury, 1996; Jitendra & Xin, 1997) and dwindled during this review time period. Only seven research studies were located where the computer was used to deliver instruction. Two studies dealt with acquisition of math facts, and the other five studies focused on strategies for improving math problem-solving skills. Table 3 provides a summary of the studies in mathematics included in this review.

Fact Fluency

Earlier studies established that computerized drill-and-practice could be effective when carefully designed to control the size of the instructional set, pace of responding based on mastery and keyboarding time, schedule for interspersing new and learned facts, and reducing extraneous stimuli. Although the belief that the computer is a motivating way to learn and may improve engagement and response rates, instructional effectiveness has been primarily related to features of software that optimize practice and retention (Fitzgerald & Koury, 1996).

The two acquisition studies published during this period do not support the conclusion that CAI is effective for building math fact fluency primarily because instructional design features were not controlled. In one study the number of multiplication facts mastered by four 3rd–4th grade students with LD was compared under two experimental conditions: computer-delivered practice using the software program Math Blaster versus teacher-delivered practice using flash cards (Wilson, Majsterek, & Simmons, 1996). Researchers found that differences emerged in favor of teacher-directed instruction after eight sessions (i.e., scores ranged from 4%-34% higher). However, inherent differences between the treatments suggested that students had greater response opportunities using the flashcards.

The second study also focused on multiplication fluency to evaluate the effects of learning math facts through a mnemonic keyword strategy (Irish, 2002). Six students with LD, ages 9-11, worked daily on the CAI program as well as classroom review with paper/pencil drill sheets recalling math facts. The CAI problems only required recognition of correct answers while the paper/pencil format required answer recall. Length of treatments varied across students from 3 to 10 weeks. Five of six students improved their accuracy on the electronic

Table 3. Reviewed Studies on Computer-Mediated Instructional Interventions in Mathematics

Author (Year)	Subjects	Age/Grade	Disability	Design	Intervention	Dependent measures
Math Computation Fluency						
Irish (2002)	6	9-11 years	LD	Single case multiple baseline	Computer drill program with mnemonic keyword strategy	Number correct math facts
Wilson, Majsterek, & Simmons (1996)	4	3rd–4th grades	LD	Single case alternating treatment design	Computer-delivered (*MathBlaster*) vs. teacher-delivered practice	Number correct multiplication facts
Math Problem-Solving						
Bottge, Heinrichs, Chan, Mehta, & Watson (2003)	11 low achieving; 26 average achieving	8th grade	5 with LD, EBD, other health impaired, or dual certification	Repeated measures with staggered baselines; qualitative	Video-based anchors for applied problem solving	Computation and word problems; talk-aloud
Bottge, Heinrichs, Chan, & Serlin (2001)	14 in remedial; 81 in comparison classes	8th grade	8 with LD in remedial class; 11 with LD in comparison classes	Pre/post group comparison	Video-based anchored instruction plus applied work vs. teacher demonstration plus applied work	Maintenance test scores on math computation and problem-solving
Calhoon, Fuchs, & Hamlett (2000)	81	Secondary grades	LD	Counterbalanced group comparison of four conditions	Standard written, teacher-read, computer-read administrations, vs. computer-read plus video vignettes	Rubric score on solving math story problems
Hasselbring & Moore (1996)	24	Primary grades	Mild disabilities	Group comparison	Video anchors and student-created multimedia presentations vs. direct instruction	Mathematical competency and problem-solving, self-esteem
Mastropieri, Scruggs, & Shiah (1997)	4	8-11 years	Mild MR	Case study post-test	Computerized tutorial and testing vs. paper/pencil	Number word problems solved correctly

quizzes, and all students demonstrated improvement in paper/pencil quizzes. However, speed of responding—a second component of fluency—was not addressed in this study. It is not clear whether the mnemonic strategy produced the effects since comparable achievement was not reported under both conditions. This study suggests that computerized drill may be an acceptable format to produce accurate responding for students, but no comparative conclusions can be drawn. Findings related to math fact acquisition are compromised by inadequate control of software design features and incomplete procedures to establish causal effects. Variables that were not adequately controlled included instructional set sizes, the mix of known and unknown facts, control of responding and keyboarding time, and unmatched treatment conditions.

Mathematical Problem Solving

Earlier research suggested that anchored instruction is effective for teaching problem solving because problems can be presented in a realistic context with embedded data and opportunities for exploration and multiple solutions (Fitzgerald & Koury, 1996). According to Gersten (1998), contemporary instructional approaches teach students strategies, teach how to use the strategies in meaningful contexts, and offer learning through experience. Gersten summarizes that "anchored instruction has the potential to enhance motivation and to increase generalization precisely because students learn how what they have absorbed applies to the real world" (p. 168).

A study by Mastropieri, Scruggs, and Shiah (1997) examined the ability of four 8- to 11-year old students with mild MR to learn word problem-solving strategies from a CAI tutorial program. Although the story problems were de-contextualized in the tutorial, computer animation was used to demonstrate the problems and reduce levels of reading. Students learned the problem-solving strategies through a computerized tutorial and solved word problems on the computer. Post testing was conducted in two formats: electronic and paper/pencil. Results indicated that students successfully learned the strategies using the computerized tutorial and showed significant improvement in applying problem-solving skills on the computer. However, students had difficulty recalling the problem-solving steps and transferring their skills when the format changed to paper/pencil tasks. This finding is typical for studies of transfer of training in strategy instruction when the strategies are not embedded in the teaching context itself (Hattie, Biggs, & Purdie, 1996; Ysseldyke, Algozzine, & Thurlow, 2000). The effectiveness of the computerized tutorial supported the use of the computer to make abstract information more concrete and meaningful for students (Mastropieri et al., 1997), but the study failed to support the effectiveness of anchored instruction for skill transfer.

Hasselbring and Moore (1996) described the use of anchored instruction to support mathematical problem solving with 24 primary-grade students with mild disabilities. Their results showed a significant impact on mathematical competency, self-esteem, and math problem solving. Researchers compared students' problem solving skills. The experimental group used and created a variety of video anchors to solve problems, and made multimedia presentations to demonstrate their solutions. Contrast students received traditional instruction in the state math curriculum using direct instruction methods. Students under both conditions made significant progress but the greatest gains were made in the experimental condition. Achievement gaps between the two groups were narrowed or eliminated. Although there were limitations in this study, findings were positive for the young students in the anchored instruction group in terms of improved achievement and more positive perceptions of their academic abilities.

Limited support for anchored instruction was provided in a study examining the problem solving ability of 81 secondary students with LD (Calhoon, Fuchs, & Hamlett, 2000). Video vignettes were used to provide information needed in the math story problems in a natural context. Students performed significantly better in all conditions that included accommodations, and performance levels were comparable across all conditions. No significant interactions occurred between conditions and reading levels. A moderate effect size was found for the video condition but the outcomes did not surpass those produced in the teacher-read condition. Although the authors suggested that these results support the effectiveness of video in anchoring information, no condition provided a video without computer reading; thus, the effects of video enhancement cannot be isolated.

Mixed results were reported from an extensive study that compared problem solving, computation, and maintenance for 8th grade students (Bottge, Heinrichs, Chan, & Serlin, 2001). Fourteen students in a remedial math class (eight had learning disabilities) received anchored instruction with a video anchor supplemented by applied work in a technology education class. Comparisons were made to 81 students in pre-algebra classes (11 had mild disabilities). Of these 81 students, 20 received the same technology education class instruction, and 41 received traditional instruction on word problems using teacher demonstrations and discussion along with applied work on a trip-planning project. The instruction covered 12 90-minute periods. Maintenance tests were created and given to all students 10 days following instruction. Results revealed no differences between groups on the post problem-solving test or the maintenance test in spite of existing differences on the pre problem-solving test. These results are encouraging and support the effectiveness of anchored instructional approaches to close the gap on problem solving when students understand the problems. However, scores on the computation test differed between students in the remedial and pre-algebra classes. Not only did students in the remedial class begin with lower scores on a computation test, their scores declined during the period they participated in the study. The researchers concluded that teachers need to "strike a balance between providing students opportunities for exploring abstract ideas and meaningful problems and the need for explicit instruction on procedural skills" (p. 312). Since the researchers did not analyze the findings of the students with disabilities separately, it cannot be determined whether this recommendation applies only to students with disabilities or for all students with low achievement.

Bottge, Heinrichs, Chan, Mehta, and Watson (2003) conducted a similar study comparing problem solving and procedural math skills of 19 students with LD, EBD, or OHI and 76 comparison students in 8th grade. The results were again mixed with some low achieving students demonstrating improved procedural math skills when engaged in video anchors and others unable to improve without more explicit instruction. Observational data and analysis of think-aloud descriptions revealed that students were more motivated and engaged when solving video-based problems, were able to solve problems in nontraditional ways, and benefited from collaborative discussions around solutions. Quantitative results showed that some students showed little or no growth in procedural skills, leading to the recommendation that effective instruction should continue to include direct instruction on procedural math skills within situated problem solving scenarios.

The latter four studies suggest that additional research is needed to determine the limits and potential of CMI anchored instruction in light of concerns for transfer and effect on skills requiring explicit instruction. As previously summarized (Fitzgerald & Koury, 1996), emerging work with the use of contextualized learning environments for students with disabilities has important implications for the design of materials and instructional offerings. Across all the CMI anchored instruction studies reviewed in this time period, teachers were enthusiastic and reported that students were motivated by anchored instruction approaches and demonstrated better understanding of relationships in problem solving in real environments. CMI anchored instruction appears to offer great potential for effective instruction for students with disabilities, blending applied curricular approaches with strategy support and instructional scaffolding in flexible, learner-controlled environments. The challenge is to intermix the prerequisite skills and explicit instruction needed for students with disabilities to be successful in solving complex problems (Woodward & Baxter, 1997).

LEARNING IN THE CURRICULUM CONTENT AREAS

In the mid-1990s, research on CMI in the content areas focused on ways to help students understand complex material and increase knowledge acquisition through video enhancements, simulations, and computerized study guides. CMI was embedded within instructional approaches based on direct instruction and mastery learning paradigms (Fitzgerald & Koury, 1996). This line of inquiry appeared in federally funded model demonstration programs designed to develop and investigate the effectiveness of computer-supported study strategies. Table 4 provides a summary of the studies in the content areas of science and social studies included in this review.

Table 4. Reviewed Studies on Computer-Mediated Instructional Interventions in Curriculum Content Areas

Author (Year)	Subjects	Age/Grade	Disability	Design	Intervention	Dependent measures
Anderson-Inman, Knox-Quinn, & Horney, 1996	30	Middle and high school	LD	Group comparison between three levels of users	Computer-based study strategies	Study skill test scores used as predictors of adoption
Ferretti, MacArthur, & Okolo (2001)	87 (28 mild disabilities)	5th grade inclusive classrooms	Mild disabilities	Group comparison	Project-based history unit with video anchor and technology supports	Knowledge and self-efficacy measures; attitude scale; student interviews
Glaser et al. (2000)	19 (9 LD or mild MR)	8th grade inclusive class	LD, MR, & general education	Ethnographic	Multimedia anchored instruction	Coding of classroom interactions, teacher and student interviews
Koury (1996)	123 (19 LD)	5th grade	LD	Group comparison	Video anchors and class discussion vs. class discussion	Scores on post science vocabulary test
Lancaster, Shumaker, & Deshler (2002)	22 (14 LD, 5 BD, and 3 OHI)	Secondary	Mild disabilities	Group comparison three conditions	Hypermedia-based self-advocacy instruction, teacher-delivered, and no instruction	Skill demonstration in practice situations and interviews
Okolo & Ferretti (1996a)	21	Upper elementary grades	Mild disabilities	Group comparison pre/post	Word processing vs. multimedia presentations	Teacher made test Attitude survey
Okolo & Ferretti (1996b)	21	4th grade	Mild disabilities	Group comparison pre/post	Multimedia presentations on different social studies topics	Observations and interviews
Solomonidou, Garouni-Areou, & Zafiropoulou (2004)	13	5th and 6th grades	9 with ADHD	Group comparison of students with and without ADHD	Individual and paired learning tasks using educational software	Videotaped observations, behavior ratings, performance assessment

Project Success is one example of these demonstration programs. Its purpose was to develop procedures for teaching students with learning disabilities how to use the computer as a tool for processing material in content areas (Anderson-Inman, Knox-Quinn, & Horney, 1996). In Project Success, the cognitive tasks of studying were identified as information processing; assessing, analyzing, and synthesizing; and active engagement. Procedural tasks of studying were considered to be self-management activities, such as underlining, outlining, and self-questioning. In this project, 30 middle school and high school students with LD were provided laptops and taught a variety of computer-based study strategies for real-time note taking, mapping, and outlining procedures for organizing and synthesizing information, and how to use electronic resources. In analyzing and interpreting the findings, the researchers grouped the students into three different level-of-adoption groups: power users, prompted users, and reluctant users. Power users were found to embrace the technology, applying electronic study strategies and demonstrating independent application of skills. Prompted users developed moderate to excellent skills in using computer-based study strategies, but needed prompting and assistance to move beyond the basics; they did not use the computer regularly for note-taking or outlining. Reluctant users developed limited knowledge of computer-based study strategies and rarely used the computer for assignments; some of these students disliked computers. Two characteristics found to predict level-of-adoption were the student's intelligence level and reading achievement. The line of work in Project Success contributed to the research by defining the complexities and multiple variables that must to be considered in implementing strategy-based supports for academic learning.

Researchers looked specifically at different software features that enabled students to learn from CMI in a variety of school subjects. Fifth and 6th grade students with and without ADHD used educational software of different types (drill-and-practice, multimedia, open-ended, Internet, etc.) for independent and paired learning activities (Solomonidou, Garagouni-Areou, & Zafiropoulou, 2004). Activities were provided in the subject areas of art, history, physics, geography, and mathematics. Students were videotaped as they worked on the computer activities; these tapes were analyzed for problematic behaviors and performance scores were given based on appropriate rubrics for each task. Significant differences were found between nine students with ADHD (OHI category) and four students without ADHD in grades 5-6 when comparing individual and paired learning tasks. Behaviorally, students with ADHD attended better when watching short videos or listening to short narration rather than longer selections; they resisted non-computer based activities they disliked such as writing, and showed poor cooperation on those tasks with partners. Students with ADHD were attentive and less kinetic only when they had control of the computer and were significantly more fidgety and inattentive when their partners controlled the computer. On task performance, students with ADHD answered fewer questions than students without ADHD and avoided tasks they clearly disliked. Comparing their performance between individual and paired learning tasks, they performed better on paired learning tasks in some of the subject areas. The findings suggest that students with ADHD can learn in the content areas from a variety of software types, both individually and as members of cooperative groups, but that attention must be paid to varying software features that help hold attention, require shorter periods of concentration, and constantly provide engagement and challenge.

During the later 1990s, the research focus broadened its scope to examining instructional practices that help students gain meaningful access to the core curriculum (Gersten, 1998). Consistent with the national movement to standards-based curriculum and assessment, special educators have re-focused on instructional interventions that help students engage in complex thinking, learning, and achievement, typically within integrated general education classroom environments. The new emphasis in schools on constructivist learning methodologies has also influenced research during this period. CMI in the reformed, general education curriculum requires the use of technology tools to support complex problem solving, facilitate deep understanding of information, and demonstrate and reflect on learning (Williams et al., 1998). As reported in a synthesis of technology research in special education, "while instructional adaptations are made for the special education learner, they may be a function more of a teacher's pedagogical techniques and materials than of the technology itself" (Woodward & Rieth, 1997, p. 524). Correspondingly, recent research has tended to nest the use of CMI and technology within larger questions of instructional approaches to facilitate active learning and gains in knowledge.

Research with non-disabled high school students supports that students can learn strategies from hypermedia computer programs, but knowledge of the strategies does not improve learning performance (Hartley, 2001). His conclusion, that the use of strategies ultimately depends on the decision to use a strategy, lends support to the computer-as-tool approach, making the learner responsible and in charge of his/her own learning and performance. Results of a study that utilized an interactive hypermedia program to teach self-advocacy skills to 22 secondary students with mild disabilities is consistent with this finding (Lancaster, Schumaker, & Deshler, 2002). The hypermedia program was delivered on CD-ROMs and compared students who learned the skills via CDs or via teacher instruction to students in a control group without instruction. The content of the instruction was comparable under both instructional conditions and included audio explanations and video clips of students describing and modeling the strategies. Results indicated that learning with the hypermedia program combined with a small amount of teacher interaction was as effective as learning the strategies in teacher-directed instruction. Also, learning under both conditions was superior to that of the control group with no instruction. Considerable teacher time was saved with the hypermedia instructional procedures. The researchers pointed out, however, that the hypermedia-based instruction did not eliminate the need for teacher instruction, as students still needed opportunities for role-playing use of the self-determination skills and this could not be done with state-of-the art technology. These results are consistent with previous findings that complex strategies can be learned through hypermedia instructional formats, but the use of these strategies depends on teacher interactions and students being committed to using the strategies.

Science

Koury (1996) studied the use of video anchors to support vocabulary development in science with 19 students with LD and 104 comparison students in 5th grade. In this intervention, video anchors were used to pre-teach concepts and abstract terminology to help understand material in science textbooks. The emphasis was on building word recognition and meaning. Three sessions were provided within 1 week to discuss terminology. A library/media specialist used the media and guided discussions in a whole class setting. A terminology test was given to all students following instruction. General education students outperformed students with LD in both comparison groups. Video anchors were not sufficient aids to facilitate equivalent levels of learning. Further, there was no clear advantage to using integrated media for the general education students; no differences were found in the achievement scores of students in the general education class.

This study raises concerns about effective uses of integrated media and suggests that simply using new technologies in traditional instructional formats (i.e., large group and teacher-directed methods) may not provide sufficient enhancement to improve learning for general or special education students. Although the findings are extremely limited by the study's short duration, these results support the current focus in research in the content areas on the instructional conditions and methodologies for implementing computer-mediated instruction.

Social Studies

In social studies, a series of studies were conducted on project-based learning in classrooms with upper elementary students with mild disabilities (Okolo & Ferretti, 1996a, 1996b). The general approach was to engage students in cooperative learning groups to investigate problems related to social studies curriculum, such as the Revolutionary War and industrialization, to construct knowledge, and to prepare group reports of their findings. In one study with 21 upper elementary grade students with mild disabilities attending a lab school, comparisons were made between groups that constructed reports with a word processor or constructed reports using a multimedia presentation program (Okolo & Ferretti, 1996a). Findings revealed that students acquired knowledge under both conditions; there was no difference in knowledge acquisition between the two conditions. No change in attitudes toward studying social studies was found.

In a related study, comparisons were made in pre-to-post knowledge gain and attitudes between two 4th grade groups totaling 21 students with mild disabilities (Okolo & Ferretti, 1996b). Both groups utilized a project-based instructional approach and produced their reports with multimedia presentation tools. Different topics were studied in each classroom group. Similar to the previous finding, significant improvement was found in knowledge acquisition for both treatment groups. Some differences emerged between topics studied, but not between students with and without disabilities. Students in both groups developed more positive attitudes toward cooperative learning and self-efficacy, although students without disabilities demonstrated a greater sense of self-efficacy than students with disabilities. Based on observational data, the researchers inferred that differences in general behavior between the two classes might have contributed to the differences in knowledge acquisition between social studies topics. Across both classrooms, students with disabilities tended to take more passive roles but the differences were small.

Based on their observations and post-interviews with the students in the two studies, the authors concluded that the change in declarative knowledge was due to student engagement in project-based learning activities and that the "technology *per se* did not directly affect learning outcomes." In their view, "particular pedagogical practices are most likely responsible for successful learning outcomes" (Okolo & Ferretti, 1996a, p. 100). The researchers felt computers played the role of a tool to facilitate complex learning in the content area. However, it should be noted that no control or contrast group was included in either study. Neither the use of project-based learning nor the role of technology could be isolated from the overall instructional methodology.

In the third study in the series, the research team further defined the instructional approach used to facilitate project-based learning (Ferretti, MacArthur, & Okolo, 2001). An instructional unit on westward expansion was designed to implement four principles of teaching for understanding:

1. authentic tasks that required understanding of concepts and historical analysis;
2. knowledge construction guided by questions for investigation;
3. use of cognitive strategies to help students retain information; and
4. use of cooperative groups to create a socially mediated learning process.

Twenty-eight students with mild disabilities and 59 comparison students in the 5th grade engaged in project-based learning and created artifacts to present their results. All students increased in demonstrated knowledge acquisition, understanding of historical content, understanding of historical inquiry, and self-efficacy. Students without disabilities scored significantly better on the knowledge test and had a higher level of self-efficacy.

The use of a cognitive strategy training procedure for analyzing historical information is noteworthy in this study. Group work was substantially structured by this procedure and prompt cards were used during group discussions. These procedures were described as taking "into account the types of difficulties students with disabilities were likely to experience in learning" (Ferretti et al., 2001, p. 63). The authors concluded that students with disabilities are able to meet the demands of rigorous curricula and will benefit from more explicit cognitive strategy instruction, thus enabling access to the curriculum in inclusive social studies classrooms. It is interesting to note, however, that general education students outpaced students with disabilities in knowledge acquisition despite the cognitive strategies and structuring that were integrated into the instructional approach.

A different research approach was taken in an ethnographic study of the use of anchored instruction in an integrated 8th grade language arts and social studies curriculum over the course of one year's time with nine students with LD and or MR and 10 non-disabled (Glaser, Rieth, Kinzer, Colburn, & Peter, 2000). The research focus was on instructional interactions and student participation in classrooms using anchored instruction. A different theme was selected for each semester for implementing a well-prescribed anchored instruction procedure. The phases included:

1. baseline for video and audio taping the students;
2. watching the video anchor;
3. retelling and segmenting the video anchor;
4. characterization from the video anchor; and
5. student research in small groups, resulting in multimedia presentations.

The ethnographic design included extensive coding of classroom interactions, teacher interviews, and student interviews. Observational data established that the overall number of daily interactions increased and students became more active participants. Teachers spent less time on management issues and task direction. The quality of teacher questions changed from fewer factual questions to more interpretive questions asked during instruction. In post interviews, students reported they enjoyed the format of instruction and felt they learned more. Likewise, teachers perceived that students were successful, enthusiastic, and engaged in class. Class and school attendance reportedly increased.

Taken as a whole, these studies demonstrate a trend in research in the content areas for studying the use of CMI nested within effective instructional approaches. With recent emphases in general education on constructivist learning paradigms and core curriculum standards, it is clear that some researchers in special education technology are attempting to address the intersection of effective instructional strategies for students with disabilities with new instructional paradigms in inclusive classrooms. The few studies reported in this review only "scratch the surface" of critical research issues in the field. It is surprising that no research has been forthcoming related to the use of Internet resources in student inquiry and the dismal level of information-seeking skills of mildly handicapped students as previously reported (Edyburn, 1991). Ethnographic studies and comparison designs without control or contrast groups demonstrate that students with disabilities can learn with computers and technology-support tools and enjoy new instructional approaches. There are limitations in these research approaches, however, in that they fail to discern what variables support successful learning or effective methods for integrating strategy instruction and computer usage within the overall instructional approach. This line of research needs to be expanded with an empirical focus on variables that predict learning.

DISCUSSION AND RESEARCH DIRECTIONS

Our conclusion after this review is that research in the past decade contributed little to advance our knowledge regarding effective uses of computer-mediated materials to assist learners with mild disabilities. In general, the research shows that students with mild disabilities learn using well-designed software in computer-mediated applications (Englert et al., 2004; Marston et al., 1995; Solomonidou et al., 2004). They are able to learn and use explicit strategies on computers and in classrooms, although transfer and maintenance are not automatic (Lee & Vail, 2005; Mastropieri et al., 1997). Software containing scaffolds and customizable features support better learning (Englert et al., 2004). Overall, students enjoy computer-mediated learning (Bahr et al., 1996; Bottge et al., 2003; MacArthur, 1998). Some studies found gains in learning from video anchors that situate learning and problem solving (Bottge et al., 2003; Hasselbring & Moore, 1996) although the integration of video anchors was not sufficient to enable students with disabilities to perform at equivalent levels with general education students (Koury, 1996). Ways have been found to use CMI to enable students to learn more complex curriculum content and to demonstrate knowledge acquisition in alternative ways (Ferretti et al., 2001; Okolo & Ferretti, 1996a).

The studies also show that students with mild disabilities learn less efficiently and do not make as much progress as their general education peers (Ferretti et al., 2001; Higgins et al., 1996; Howell et al., 2000; Koury, 1996). There is little evidence that any of the uses of CMI reported in this review, even when combined with effective instructional approaches, narrowed the gap in achievement for students with mild disabilities and in fact, general education students may show superior learning improvement using computer-supported materials (Lewis et al., 1999). CMI or technology applications do not eliminate performance differences and the expectation that they might is unrealistic (Okolo, Bahr, & Rieth, 1993). Many of the studies provided interesting information about teacher and student behavior during the use of CMI applications that was gained from qualitative methods (Glaser et al., 2000; Solomonidou et al., 2004) or use of extant disciplinary data (Blankenship et al., 2005).

Although most of the studies established that CMI supported learning, they failed to isolate predictive variables operating in naturalistic environments. As we continue to research computer-mediated instruction, we must remember the caution set forth by Woodward and Reith (1997) that our results will be subject to scrutiny due to the presence of confounding variables of conducting research in naturalistic settings like the classroom. Inadequate control and contrast groups, short duration of interventions, neglect of single case design rules, and failure to triangulate qualitative data suggest poor research designs. We know that small sample group analysis compromises generalizations about significant results. We also know that single subject design research, as well as case study research, provide strong results that are undeniable, but results may not transfer.

We are charged, then, to design better studies, intervene with strong pedagogy, select participants carefully, and conduct studies in naturalistic environments. Better description of participants—particularly their documented disabilities—will aid practitioners in understanding and using research results. In 1992, Ann Brown described the theoretical and methodological approaches that are useful in the study of complex interventions in classroom/naturalistic settings. She wrote:

> As a design scientist, it is necessary to tease apart the major features of enticing learning environments: the role of teachers, students and researchers; the actual contribution of curricula and computer support; methods for distributed expertise and how shared meaning is engineered, and so forth. There is a constant tension between designing an exciting classroom for happy campers and maintaining research standards of control and prediction (p. 173).

Future research efforts need to improve by combining both qualitative and quantitative methodologies (Brantlinger, Jimenez, Klingner, Pugach, & Richardson, 2005; Odom et al., 2005), by expanding our focus from the child to the instructional ecology within which the use of technology is nested (Odom et al., 2005; Woodward et al., 2001), and by taking on the challenge of using computer-mediated instruction to enhance learning in school and to prepare special learners for an ever-changing technological world.

Tomorrow's learning environments will offer wireless technology, integrated information systems, online digital learning materials, virtual reality applications, global communication, distributed learning requirements, and 24/7 access to education and training (Levin & Darden, 1999; Means, 2001). Research in special education to date has failed to address these emerging trends in the sophistication of technologies in education for students with high incidence disabilities. As a field, it is still struggling with questions of software design, embedded scaffolds for performance support, curricular integration, and instructional pedagogies for computer-mediated materials. As Ted Hasselbring recently stated (2001) "we cannot predict the future of special education technology, but we can invent it" (p. 15). It is time to invent a new research agenda that positions us to teach tomorrow's skills today, so that students with high incidence disabilities can learn and succeed with new and emerging technologies.

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