CHAPTER 6

Computer Technology and Reading Instruction

COMPUTER TECHNOLOGY AND READING INSTRUCTION

Executive Summary

Introduction

Although reading is based on the technology of writing and printing, the history of reading instruction reflects a recurrent interest in the application of other technologies, for example, reading pacers, tachistoscopes, and even television. The use of computers in reading instruction dates only to the mid-1960s with the work of Suppes, Atkinson, and their colleagues. For example, Atkinson and Hansen (1966-1967) published the first report of the use of computers in teaching reading. The current review was undertaken to examine research that used computers to deliver reading instruction to determine what the results have been, what the potential is, and what questions remain.

Background

Despite the current intense interest in computer technology, there has been relatively little systematic research into problems of involving computers or other technologies. Several factors seem responsible for the limited research on computers in literacy contexts. First, many reading researchers did not and do not consider technology to be a mainstream topic. That is, they often believe that reading instruction can be delivered *only* by a human. Others believe that technology must be considered in the overall context of reading instruction. Those in the latter category believe that other problems in reading instruction should be attended to before issues of technology are addressed. These general impressions are reinforced by some of the factors described in the following paragraphs.

Until recently, computers did not have all (or even most) of the capabilities that were needed to implement a complete program of reading instruction. A primary lack among these capabilities was the inability to comprehend oral reading and judge its accuracy. Another lack was the inability of computers to accept free-form responses to comprehension questions, leading to reliance solely on recognition tests such as multiple-choice formats. The situation is currently very different, with most new computers capable of speech recognition, as well as a host of multimedia presentation capabilities. Artificial intelligence is beginning to make inroads into software for instruction, and systems for text comprehension are fairly sophisticated, even on home computers.

The development of the Internet and the linking of schools and school computers to it have combined to provide a new interest in computer usage. The kinds of information resources available have provided a stimulus for renewed efforts to deliver instruction of all sorts, including reading, by computer. Coupled with the facts that computers have become much more capable and software has become much more advanced, interest in using the Internet has led to a dramatic new wave of interest in using computers in reading instruction.

Methodology

A database had previously been developed on this topic. That database covered the period from 1986 to 1996 and included all the studies on technology and literacy (e.g., writing as well as reading). Because this database had been developed by a combination of electronic and hand searching all of the journals, it was deemed expedient to use the database and update it with more recent work. Only those studies that met the criteria of the National Reading Panel were included.

Results and Discussion

There is a small body of research on the problems of computer technology and reading. The work that met the National Reading Panel requirements is substantially smaller. Many of the research studies that have been published are explorations of capabilities of computers, comparisons of computers with traditional tasks, word processing, and learning. Very few of these studies directly examined the effects of using computer technology for reading instruction.

A total of 21 studies was found, representing experimental manipulations of problems across the entire spectrum of reading instruction. As a first step to further analysis, the problems addressed by these studies were categorized. The largest group of studies (six) included those that studied the addition of speech to computer-presented text. There were two studies that examined the effects of vocabulary instruction, two more that

looked at word recognition instruction, and two that investigated comprehension instruction, broadly defined. One study examined spelling, and two studies examined the effects of broad programs on learning to read. These last studies looked at the delivery of reading instruction by comprehensive software that covered many, if not most, elements of reading instruction.

Conclusions

It is extremely difficult to make specific instructional conclusions based on the small sample of experimental research available. One conclusion is that it is possible to use computer technology for reading instruction. All the studies in the analysis report positive results. The six studies that examined the addition of speech to print presented on computers suggest that this may be a promising alternative, particularly in light of the powerful multimedia computers now available.

There are two other trends that should be examined more systematically. A small, but growing, body of research examines the use of hypertext in learning environments. Although this is technically not reading instruction, it is possible that hypertext might be used in instructional contexts to some advantage.

A second area outside the scope of the current review is that of using computers for word processing. Given that instruction in reading is most efficacious when combined with writing instruction, the use of word processing has the potential to make reading instruction more effective.

Implications for Reading Instruction

Although the Panel is encouraged at the reported successes in using computer technology for reading instruction, there are relatively few specific instructional applications to be gleaned from the research. It is clear that some students can benefit from the use of computer technology in reading instruction. In particular, studies on the addition of speech to print suggest that this may be a promising alternative, especially given the powerful multimedia computers now available and those being developed. In addition, the use of hypertext and word processing appear to hold promise for application to reading instruction.

Directions for Further Research

The reported successes to date in using computer technology for reading instruction indicate that this is an area that needs a great deal of additional exploration. There are many questions that still need to be addressed and many areas in which research does not exist. Particularly striking in its absence is research on Internet applications as they might be incorporated in reading instruction. Another area is the use of computer technology to perform speech recognition. Although great strides have been made in this technology, there have been no recent studies of speech recognition applied to reading instruction, despite its increasing use. Finally, the issue of multimedia presentations has not been addressed in the context of reading instruction. There are many questions that remain about the efficacy of multimedia incorporated in reading instruction.

Introduction

Reading is based on the technology of writing and printing. The history of reading instruction reflects a recurrent interest in the application of other technologies (Kamil & Lane, 1998; Kamil, Intrator, & Lane, 2000). (The "other technologies" include, for example, reading pacers, tachistoscopes, and television.) The use of computers in reading instruction dates only to the mid-1960s with the work of Suppes, Atkinson, and their colleagues. For example, Atkinson and Hansen (1966-1967) published the first report of the use of computers in teaching reading. This pioneering work in demonstrating the efficacy of using computers to deliver reading instruction set the way for much of the subsequent research. Although there were debates about whether or not they were really teaching reading at the time (Spache, 1968-1969; Atkinson, 1968-1969), such public debates no longer seem to exist.

Despite the current intense interest in computer technology, there has been relatively little systematic research in problems of involving computers or other technologies. Kamil and Intrator (1998) conducted an extensive review of the research in literacy and technology and found that between 1986 and 1996 there were only 350 published research journal articles that reported investigations of reading and writing. The yearly proportion of these technology studies was relatively constant over that time period, ranging from 2% to 5% of the total of all research articles on reading and writing. These totals reflect all research on computers and other technologies, not simply instructional research.

Several factors seem responsible for the limited research on computers in literacy contexts. First, many reading researchers did not and do not consider technology to be a mainstream topic. That is, many believe that reading instruction can be delivered only by a human. Others believe that technology must be considered in the overall context of reading instruction; they believe that other problems in reading instruction should be attended to before issues of technology. These general impressions were reinforced by some of the factors described in the following paragraphs.

Second, for much of the time since the initial reports of computerized reading instruction, computers did not have all (or even most) of the capabilities that were needed to implement a complete program of reading instruction. A primary lack among these capabilities was the inability to comprehend oral reading and judge its accuracy. Another lack was the inability of computers to accept free-form responses to comprehension questions, leading to sole reliance on recognition tests like multiple choice formats.

Lack of those capabilities meant that computer technology often was considered useful only as a supplement to conventional instruction, rather than as a primary delivery system. As a supplemental device, at best, it occupied a less prominent position in the problem space of reading researchers. Indeed, because computer software was relatively incapable of speech recognition or text comprehension, there were only a few activities that the computer seemed to be capable of handling independently. At least in the early history of computers and reading, this was reflected in the translation of things like paper and pencil worksheets to the computer screen. The situation is currently very different, with most new computers capable of speech recognition, as well as a host of multimedia presentation capabilities. Artificial intelligence is beginning to make inroads into software for instruction, and systems for text comprehension are fairly sophisticated, even on home computers.

A third consideration in the history of computers and reading has been the cost factor. With the introduction of microcomputers, the steady decline in prices, accompanied by a steady increase in capabilities, has produced computers that cost only a few hundred dollars. These machines can easily outperform the machines of a decade ago. Most new computers are capable of presenting audio and video, controlling external devices, and being expanded. They have substantial amounts of memory and a great deal of external storage capacity. In addition, there are low-cost printers, scanners, cameras, and a host of other peripherals that can be attached, typically for far less even a few years ago. All of these make unbelievable some of the original predictions that computers would never be cost effective in classrooms.

Finally, there was often resistance to the idea that a computer could deliver reading instruction. One important reason for this simply seems to be the age-old debate about whether teaching reading is an art or a science. Software, to match teacher performance, must be adaptable to a very broad range of responses from learners. It must be able to analyze responses to questions, separating correct from incorrect; respond to idiosyncratic responses in appropriate ways; and bring multiple methods to bear on pedagogical contexts. Computers are still unable to do many of these activities today, despite advances in hardware and software. This problem is not limited to the use of computers to deliver reading instruction. It is endemic to much current software. Despite dramatic developments in learning theory and software design, this seems to be the most serious impediment to progress. The rapid pace of technological innovation in both hardware and software, however, suggests that this issue is being addressed.

At the same time, a different sort of development has caused a renewed interest in computer technology. The development of the Internet and the linking of schools and school computers to it have combined to provide a new interest in computer usage. The kinds of information resources available have provided a stimulus for renewed efforts to deliver instruction of all sorts, including reading, by computer. Coupled with the much greater capability of computers and major advances in software, use of the Internet has led to a dramatic new wave of interest in using computers in reading instruction.

The current review was undertaken to examine the research that used computers to deliver reading instruction in an effort to determine what the results are, what the potential is, and what questions remain.

Methodology

Database

The Technology Subcommittee began its task by using a database that was assembled by Kamil and Intrator (1997). This database was deemed an appropriate starting point because it was assembled by a combination of electronic searches and exhaustive hand searches of all the journals that appeared in the electronic searches. The following paragraphs describe the methods used in the creation of the database in that study.

A review of the research on computer technology and reading was undertaken to document the trends in this area. To accomplish this task, the first step was to interrogate both the ERIC and PsycINFO databases. Any journal research article that matched the descriptors of technology, computers, reading, writing, or literacy was listed.

Queries were generated in the form of SUBJECT READ# and SINCE 1986 not YEAR = 1996 and DOCTYPE = research and DOCTYPE = journal article and S = technology. Other queries were composed to cover similar topics in reading, writing, speaking, listening, and literacy. Both “technology” and “computer” were used as qualifiers. The Panel decided that single descriptors would yield a more liberal sampling of articles, even though such a procedure yields more “false positives.” (For example, using literacy as a descriptor yielded many studies of science literacy and computer literacy that did not deal with reading or writing.) These queries yielded a total of 965 articles in 159 different journals.

In a preliminary hand search of the journals, evidence was found that there were articles that did not appear in the ERIC or PsycINFO databases. Consequently, each of the 159 journals was hand-searched for relevant articles that were missed or missing from the database interrogation. In addition, many of the articles in the original set did not meet the criteria of true research reports about literacy and technology. For example, some of the articles were mere speculation; others were about computer literacy rather than reading. Still others were commentaries arguing for or against the efficacy of technology interventions in literacy learning. The Panel applied a simple criterion to include or exclude articles. To be included, an article had to deal with the areas laid out above and had to be based on an empirical data collection. However, reviews of research studies based on empirical studies were included. Because the original search was conducted prior to the end of 1996, the Panel included any available 1996 issues of journals in the hand search.

Subsequent additions to the database were made by queries of the INSPEC database and hand-searching similar to that described above. This yielded an ultimate pool of 350 studies. Information on all relevant articles was entered into a Filemaker Pro database. Each

article was assigned a value for number of pages, literacy type, technology type, subject population, special population characteristics, problem, platform, methodology, findings, recommendations, and quality.

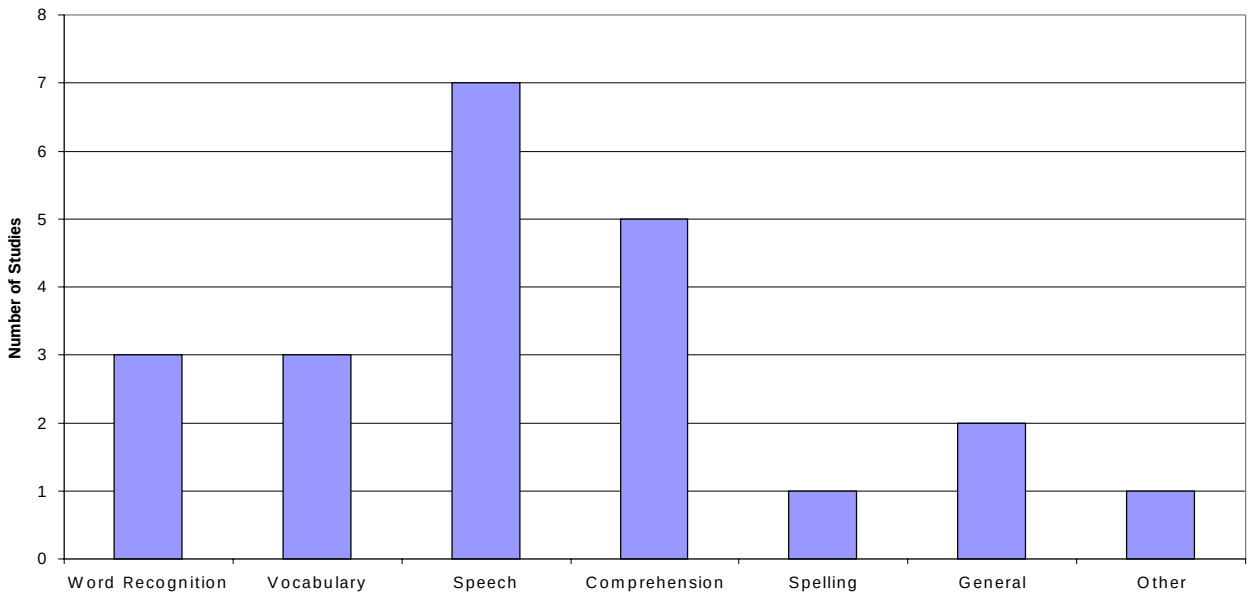
For the present analysis, the studies in the database were filtered to identify a subset of experimental or quasi-experimental instructional studies. Of the 350 studies, a total of 92 investigated reading using experimental or quasi-experimental methods. Of the 92, only 47 studies were instructional. Studies that merely compared computerized versions of a task with conventional versions were not counted as instructional. Studies that merely examined effects of the computer, unless attended by some instructional intervention, were also eliminated from the pool. What this last criterion did was to remove a few studies that simply translated existing materials for use in a computer presentation. Studies that did not deal with computer technologies were also eliminated. (In the original database, for example, there were studies that examined instructional uses of television.)

Studies that were about word processing were not considered further, because many or most of these did not involve any connection with reading. Finally, studies of special populations, non-native speakers of English, or adult readers were deemed inappropriate for further analysis. (A number of studies dealt with learning to read in a second language, for example, and fell outside the scope of the charge to the National Reading Panel.) This produced a final pool of only 21 studies.

Analysis

The 21 studies represent experimental manipulations of problems across the entire spectrum of reading. As a first step to further analysis, the problems addressed by these 21 studies were categorized. This procedure ultimately yielded seven categories. The largest group of studies (six) studied the addition of speech to computer-presented text. There were two studies that examined the effects of vocabulary instruction, two more that looked at word recognition instruction, and two that investigated comprehension instruction, broadly defined. One study examined spelling, and two studies examined the effects of broad programs on learning to read. The last studies looked at the delivery of reading instruction by comprehensive software that covered

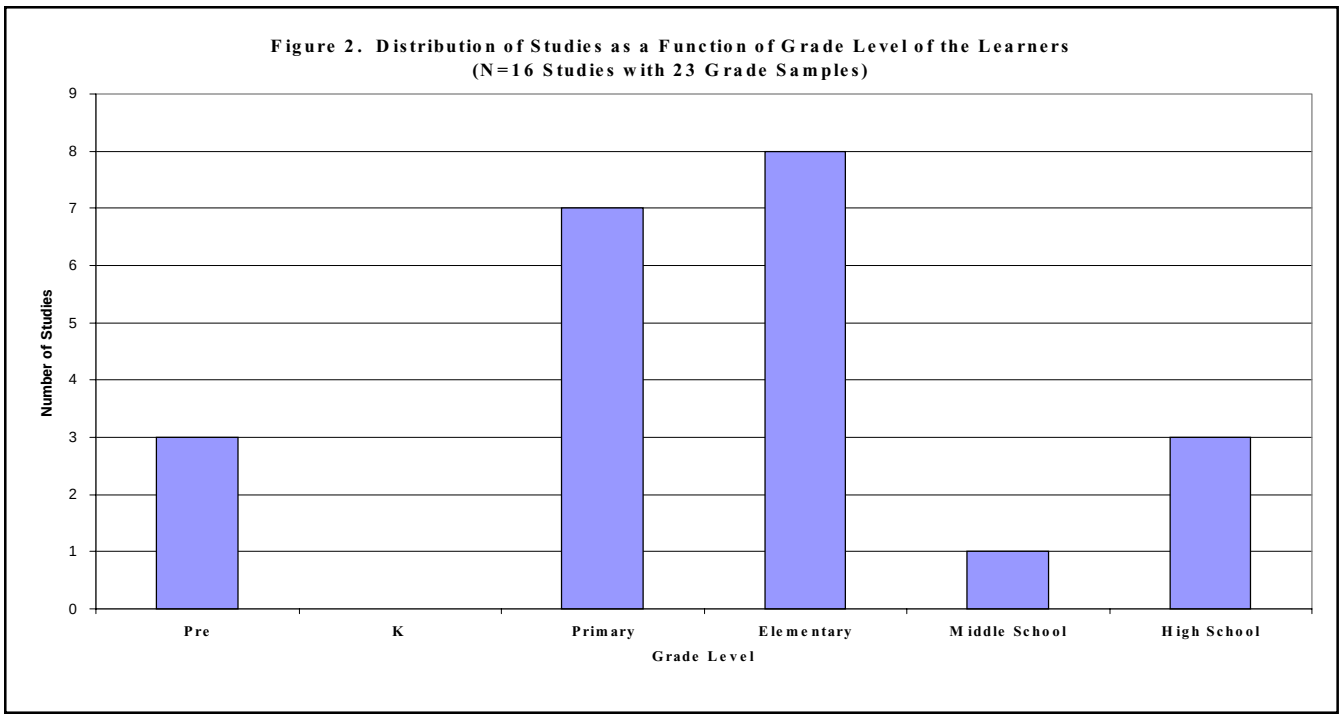
Figure 1. Number of Computer Technology Studies as a Function of Reading Problems (N = 22 Problems in 21 Studies)



many, if not most, elements of reading instruction. One study examined the learning of picture-word relationships and was not classified. Figure 1 presents these data graphically.

Consistency With NRP Methods

Meta-analysis was judged inappropriate because the 21 studies were spread across the entire spectrum of variables and across populations ranging from preschool to high school. The distribution of the final pool of studies as a function of grade levels is included as Figure 2. What is interesting about this distribution is that it is equally focused on primary and elementary students. The implication is that technology has been applied with equal emphasis to problems of early readers and of more experienced ones. Perhaps the anomaly is that there are so few studies at the high school level.



A striking feature of the entire pool of studies is the small proportion of studies that used experimental or quasi-experimental methods compared to the total number of instructional studies. Only 92 of the 350 studies, or 26%, used experimental methods. Moreover, fewer than 5% of the studies in the original data set met the criteria for inclusion established by the National Reading Panel. Even though these numbers are low, they are in agreement with the conclusions of Kamil and Intrator (1997), Kamil and Lane (1998), and Kamil, Intrator, and Kim (2000) that there has been a dearth of research on problems in technology and literacy. According to Kamil and Intrator (1997), there was no significant increase in published research on technology and literacy over the time span from 1986 to 1996.

Results

It is difficult to conclude much on the basis of the 21 studies. They all report successful uses of computer technology in one context or another. Kamil and Intrator (1997) classified the studies in their database according to whether the processes studied were old or new modes of instruction. For example, an "old" process might be completing a workbook page at the computer rather than with paper and pencil. A new one might be reading from hypertext.

They further classified the old modes as to whether they merely replaced an old form of instruction or augmented it. If, for example, the workbook page was merely completed and the student was given no feedback, this was a simple replacement. If, however, the student was given appropriate instruction, based on the answers, it was considered to be an augmented process.

In the final data set of instructional studies, there were no new processes studied. They were equally divided between the augmented or replacement categories. This seems to suggest that, for the experimental research, there are few examples of truly new uses for computer technology to date.

This is an important finding in that it suggests that there are few truly innovative uses of computer technology in literacy instruction, despite the great promise. There will almost certainly be more developments of new uses for technology in literacy instruction in the future. For now, the computer seems to be used as technology to either present or augment traditional instructional practices.

Discussion

There are threads in the research database that are worth noting even if the studies on which they are based do not meet the formal criteria established by the NRP. These findings are based on a limited amount of data, and not all of these studies are purely instructional. They are given here to indicate that there are factors not quite central to reading instruction that might be adapted for such use. Before strong recommendations could be made that these should be incorporated in reading, additional research would be needed. These trends include the potential benefits of computers in reading for word processing, use of computers as motivational devices, use of computers as assistive technologies, and the potential of hypertext as an alternative medium for reading and studying. These trends are consistent with the trends noted by Kamil, Intrator, and Kim (2000).

In particular, the database contains 131 studies (38%) that were about writing. Although not all of these were instructional studies, a number were. They were, however, excluded, as noted above, by the formal criteria established by the NRP. The exclusion of these studies is not meant to imply that the teaching of writing is unimportant. The Panel believes it can be integrated with beginning reading instruction in beneficial ways. What was missing from the published research was an explicit link to reading instruction. Consequently, these studies were not included.

There are reviews of the specific literature on word processing that already exist, and it was considered unproductive to duplicate them. The Panel suggests that the use of word processing in writing instruction could be an important and effective addition to the reading curriculum that can benefit immediately from the use of computer technology.

A second cluster of studies involved the use of computer technologies as motivational agents. The Panel judged that these studies were, again, not directly in the instructional charge but worth considering. It is probably the case that as computers become more familiar to students, their motivational value will diminish. For the present, though, this still seems to be a potent variable, although its precise application is far from clear. Again, reading instruction can probably make good use of the motivational aspects of computers and software.

The third trend is reflected in a set of studies that examines what Kamil, Intrator, and Kim (2000) have called *assistive* technologies. There were 114 studies in the original database (33% of the total) that dealt with special populations. While not all of these are experimental or quasi-experimental studies, they do point to an important cluster of research activities. There seems to have been less resistance to the adoption of computer technologies for these populations than for mainstream populations. Although less evidence is presented of the effectiveness of computers for use in mainstream instructional applications, the uses with special populations may point the way for the future.

Finally, the NRP looks to the promise of hypertext as an application for the future. A small, but steadily increasing, cluster of studies points the way toward potentially important applications revolving around hypertext and hypermedia. There were 12 studies that involved hypertext in the assembled database, but they do not adequately reflect the growing interest in the topic. Many of the studies do not meet the experimental or instructional criteria, but they will provide important data as researchers and practitioners conceptualize new ways to apply hypermedia in reading and learning to read. It will be those applications that must be researched and validated for use in reading instruction. Hypertext and hypermedia may also involve developing new modes of instruction for students to use them effectively. What is most exciting about this trend is that it represents truly new ways of applying computer technology to reading and reading instruction.

Implications for Reading Instruction

There are few implications for practice that can be drawn from the small set of instructional studies in the database. What is important is that there are uses for the computer that do impinge on reading instruction. The following is an attempt to draw some of these implications, with the caveat that the implications are clearly tentative and need to be verified by continued research.

- **Computers can be used for some reading instructional tasks.**

Although there are only a few experimental studies that are relevant to this point, they do report successes. What is clear is that as computer software becomes more capable, the opportunities for computers to be used in reading instruction will expand.

At the very least, computers can provide opportunities for students to interact instructionally with text for greater amounts of time than they can if only conventional instruction is provided. Although there was no research that provided a general rule for determining what works, careful selections from available software can provide additional instructional assistance in classrooms. Although there is a publication bias to report only positive differences, there were no instructional studies in which the computer did not provide a significant addition to the instructional context.

- **Word processing is a useful addition to reading instruction.**

A very large portion of the database involved studies of word processing. Because writing is often part of reading instruction, the findings concerning word processing are relevant, even though the studies fell outside the criteria for analysis. Word processing has many benefits for writing, particularly in its close match with process writing approaches. Although the implication has not been experimentally tested (in terms of its effect on reading instruction), this seems likely to occur in the future. One implication seems to be that word processing alone is unlikely to make a difference; it must be embedded in other instruction.

- **Multimedia computer software can be used for reading instruction.**

There are many unanswered questions about the efficacy of multimedia learning. All of the conditions under which multimedia learning is more effective than conventional learning are not known. However, there appear to be many students who benefit from the addition of multimedia instruction to a conventional curriculum. One example that was tested in several studies was the addition of speech (computerized or not) to the instructional context. When multimedia software is available and appropriate, it should be exploited.

- **Computers do have a motivational use in reading instruction.**

Although there were no experimental instructional studies that supported this implication explicitly, the motivational aspects of computers should not be overlooked. This effect may diminish as computers become ever more common. For the time being, they still retain some motivational advantage over conventional instruction.

- **Hypertext has a great deal of potential in reading instruction.**

There is a growing interest in hypertext because of its potential to allow the reader to control some of the presentation of text, determining what to read at various junctures in the text. Another potential is the use of hypertext to assist the reader who is having difficulty with a passage. Despite the fact that there were no experimental instructional studies on this topic that met

the NRP criteria, the application of hypertext concepts to reading and reading instruction seems to have a great deal of potential. The use of hypertext and hypermedia on the Internet almost mandates the need to address this issue in reading instruction. In the meantime, hypertext, particularly coupled with Internet access, seems to have been adopted in many classrooms, regardless of the lack of research.

Directions for Further Research

It is inappropriate to separate the applications of computer technologies to reading instruction into a set of issues about technology and a set about reading. The Panel believes that technology is not a problem to be studied in and of itself. The problem is, rather, how the technology is applied to specific problems in reading instruction. To that end, the following questions are offered as among the most important ones to be answered by future research. They are neither simple nor easily answered. Answering them will involve issues as complex as professional development for teachers and as simple as the utility of drill and practice exercises.

Research on these topics needs to be relatively independent of specific computer platforms and software because the rapidity of innovation makes specific choices obsolete in short time periods. One argument for not conducting more research has been that the technology outpaces the research. However, not all of the important questions are dependent on the state of technological innovation.

The Panel believes that the following list of questions represents relatively short-term needs for today and shortly beyond the horizon of current development. Some effort should be directed at conceptualizing new uses for computer technology—uses that will augment conventional reading instruction in beneficial ways. The list does not include questions that may become important in the future—such as the role of literacy in a much more graphically oriented world. These may not be researchable, but the implications of these developments need to be systematically explored by research.

One of the most striking findings of this analysis is that there is a surprising lack of published research. For whatever reason, the volume of published research has not kept pace with the interest in computer technology. Research is urgently needed to answer these and other questions that will affect the penetration of computer technology into conventional reading instruction.

1. What is the proper role for integration of computers in reading instruction? In what contexts can they be used to either replace or supplement conventional instruction?
2. What are the conditions under which multimedia presentation is useful or desirable in reading text?
3. What are the requisite characteristics of software to teach reading?
4. What is the appropriate mix of reading and writing instruction delivered by computer?
5. How can professional development programs be structured to help teachers effectively integrate computer solutions with instruction?
6. How are the effects of computer usage in pedagogy most effectively measured? Do conventional assessments measure all of the learning that takes place in computer environments?
7. What is the utility of hypertext in instructional contexts?
8. How can Internet resources be incorporated in reading instruction?

Overall Conclusions

The current analysis has found general agreement in the experimental literature that computer technology can be used to deliver a variety of types of reading instruction successfully. There has been relatively little research in this important area and, consequently, many unanswered questions remain.

The rapid development of capabilities of computer technology, particularly in speech recognition and multimedia presentations, promises even more successful applications in literacy for the future. To be certain that these new developments are incorporated in instruction as efficiently as possible, it is important that research be initiated to answer the questions that have not been addressed to date.

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Appendices

Appendix A

Studies Analyzed

Barker, A. B., & Torgeson, J. K. (1995). An evaluation of computer-assisted instruction in phonological awareness with below average readers. Journal of Educational Computing Research, 13, 89-103.

Bass, G., Ries, R., & Sharpe, W. (1986). Teaching basic skills through microcomputer assisted instruction. Journal of Educational Computing Research, 2, 207-219.

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