# The Effectiveness of Technology in Schools: A Summary of Recent Research

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Throughout the 1980s, the United States experienced dramatic growth in the use of computer-based technology for instruction. The U.S. Office of Technology Assessment reported that the percentage of schools with one or more computers grew from approximately 18 percent in 1981 to 95 percent in 1987.(1) The Software Publishers Association estimated that as of December 1994 more than 18.1 million computers had been installed in various types of educational institutions in the United States, including 6.2 million units in the nation's more than 109,000 public and private K-12 schools.(2)

During the 1980s, studies demonstrated that using computer technology could motivate students, enhance instruction for special needs students, improve students' attitudes toward learning, and motivate teachers and free them from some routine instructional tasks. The Software Publishers Association's 1990 *Report on the Effectiveness of Microcomputers in Schools* presented studies that showed that the use of technology as a learning tool could make a measurable positive difference in student achievement, attitudes, and interaction with teachers and other students. These effects were related to a number of factors—such as subject area, characteristics of the student population, the teacher's role, patterns of student grouping, software design, and the level of access to technology.(3)

The 1996 report summarized here documents the growing research on the effectiveness of technology and extends the findings presented earlier.(4) It is based on 176 research reviews and reports of original research projects, from both published and unpublished sources, that appeared between 1990 and 1995. The 176 studies were chosen from an original set of over 1000; studies were excluded from the final set for such reasons as methodological weakness (e.g., lack of alternative treatments in comparative studies) and focus on extraneous issues (e.g., critiques of typical research methods, research on the attitudes of student teachers, research on the physical layout of technology-rich classrooms). Seventy of the final set appeared in professional journals, while 33 were doctoral dissertations.

The report itself is presented in four sections:

1. the effects of technology on students' achievement,
2. the effects of technology on student self-concept and attitudes about learning,
3. the effects of technology on interactions involving teachers and students in the learning environment, and
4. a complete bibliography of the work cited.

This article both surveys the general results presented in the report and highlights findings and issues that are especially important to library media specialists.

# Technology and Student Achievement

The bulk of the report—twenty-four of the thirty-eight pages it devotes to discussing particular findings—addresses the effects of technology on student achievement. In general, the studies reviewed in this section suggest that:

educational technology has demonstrated a significant positive effect on achievement. Positive effects have been found for all major subject areas, in preschool through higher education, and for both regular education and special needs students. Evidence suggests that interactive video is especially effective when the skills and concepts to be learned have a visual component and when the software incorporates a research-based instructional design. Use of online telecommunications for collaboration across classrooms in different geographic locations has also been shown to improve academic skills.(5)

The report focuses initially on several meta-analyses of the effects of technology-based instruction as compared to other instructional methods. A helpful (if somewhat controversial) methodology, meta-analysis is designed to provide general statements that summarize the findings of a number of studies on a particular topic. It uses statistical techniques to analyze and synthesize data from these studies in order to present the findings according to a common measurement known as an “effect size” (ES). The ES, which is represented as a decimal, shows the degree of difference between two points of comparison—in this case between technology-based and “other” instructional treatments. According to Kulik and Kulik, an ES of 0.30 constitutes “a moderate but significant effect”; Ryan notes that an ES of 0.30 is equivalent to approximately three months’ gain in student achievement.(6) Thus, an ES of 0.30 or better in favor of technology-based instruction suggests that such instruction is significantly effective because of the extent to which it accelerates student learning.

The results of the meta-analyses are quite encouraging to those who are interested in using technology to enhance student learning. Kulik and Kulik’s meta-analysis of 254 controlled studies of students from kindergarten through higher education found that computer-based instruction (CBI) had an average of ES of 0.30; for individual studies in which differences in achievement were statistically significant, the difference favored CBI in 94 percent of the cases.(7) In a follow-up analysis of 97 of these 254 studies, Kulik found an average ES of 0.38 for CBI involving drill-and-practice and tutorial software.(8) Ryan’s meta-analysis of 40 comparative studies of the use of computers in elementary schools yielded an average ES of 0.309 and demonstrated that the amount of technology-related teacher training was significantly related to the achievement of students receiving CBI.(9) Another meta-analysis—Bangert-Drowns’s work on word-processing in writing instruction—is supported by Valeri-Gold and Deming’s and Snyder’s reviews of similar research in suggesting that the incorporation of word processing into writing instruction can help students produce higher-quality writing.(10)

In addition to its discussion of word processing, the report addresses a variety of curriculum areas—notably language arts, mathematics, and science—through descriptions of individual studies. While it would be inappropriate to generalize on the basis of the individual studies cited, it is important to recognize that the research generally supports earlier work in suggesting that the appropriate use of technology can foster student learning in a variety of subject areas.

Language arts is a particularly important area for library media specialists, and it has been a frequent focus of educational technology research in recent years. Overall, the recent studies in this area indicate that using technology can enhance students' language development as well as their achievement in reading, writing (as noted above), and spelling. Specifically, the studies show that the use of technology can help students gain a variety of language skills:

- understanding the relationships among the parts of the English language, classification, and reading comprehension;
- sound discrimination, sound-symbol correspondence, listening comprehension, decoding in context, and creating oral narratives;
- phonological awareness;
- reading achievement; and
- spelling.(11)

Recent comparisons of traditional mathematics instruction to its computer-assisted counterpart also yielded positive learning results related to the use of technology, including commercially available problem-solving software.(12) Similarly, studies by the Cognition and Technology group at Vanderbilt University of their video series entitled "The Adventures of Jasper Woodbury" showed positive results.(13) This series itself is of particular interest to library media specialists: each "adventure" is a fifteen- to twenty-minute story that embeds all the information students need to solve a particular mathematical problem; students need not only mathematical skills but skills in identifying, evaluating, and using information to reach their solutions. The series thus provides a strong example of the ways in which information skills are inherent in the contemporary curriculum and can be linked to achievement in curricular areas.(14) This link is underscored by the findings of a more recent study that suggests supplementing the Jasper videos with a variety of contextual tools and follow-up activities will help students apply their learning to new situations.(15)

Positive results have also been reported for technology-based science learning—for example, in a comparison between high school biology students who used only a videodisc-based simulation of frog dissection and those who performed a dissection but did not use the videodisc. On a test of anatomical identification, there was no significant difference between the two groups, suggesting that learning at least some kinds of information by simulation can be as effective as learning it through hands-on experience. Perhaps more importantly, a group of students who used the simulation as preparation for an actual dissection significantly outperformed those who did the dissection only, suggesting once again the value of the library media specialist's role in urging teachers to incorporate instructional media carefully and appropriately into their lessons.(16)

The report also describes positive learning effects of technology for young children and for special needs students. Since effective instruction for any population involves a number of interacting elements, it is not surprising that research on these special populations looks at a complex of factors rather than only at the comparative effects of technology-based and traditional instruction. Much of the research in these areas thus focuses on instruction that is supplemented with computer experiences, and the results suggest the utility of technology-based enrichment for these populations.

Similar results were discussed in the report's review of four of the more recent applications of technology to education: telecommunications, videodisc, hypermedia, and adaptive testing. While the studies related to hypermedia and to adaptive testing did not address issues of direct concern to library media specialists, several studies related to telecommunications and interactive videodiscs are particularly relevant because they suggest the relationship of information literacy to student achievement. An evaluation of National Geographic's Kids Network, for example, indicated that fourth and fifth graders who had engaged in telecommunications-based science activities made significant gains in such skills as the use of graphs for organizing observations, the interpretation of data, and the identification of map locations.(17) Results of several of the studies related to interactive video-discs—and particularly one that investigated students' abilities to extract relevant information for problem solving—also underscore the link between information use and student achievement.(18) As students engage more and more frequently with these information-rich technologies, their abilities to identify, evaluate, and use information will become increasingly important to their achievement.

## Software Design Characteristics and Student Achievement

Among the most useful of the report's findings for library media specialists is a discussion of specific software design characteristics that seem to make a difference in the amount and quality of student learning. While each of the six individual characteristics was gleaned from comparatively few studies—the report itself covers a comparatively short period—the group generally reinforces findings from years of earlier research. Library media specialists, who play an important role in selecting and evaluating new media products for learning, will find the list a helpful addition to our existing knowledge base.

**1. In general, offering students some control over the amount, review and sequence of instruction can result in higher achievement than having the software control all instructional decisions. However, low-achieving students and students with little prior content knowledge are likely to require more structure and instructional guidance than other students.**(19)

Several studies demonstrated the importance of having learners exercise some level of control over the pace and sequence of their instruction. For example, fifth and sixth graders who controlled the amount of time they spent on each screen of an interactive video on comets significantly outscored a comparison group who used the same software but did not control its pace.(20) Similarly, high-school students who used versions of basic geometry software that allowed them to add or bypass example, practice, and review screens demonstrated significantly greater achievement than students who used versions of the same software that offered no such control.(21) Other studies suggest caution before exposing some students to software that offers a high degree of learner control: while high-achieving students seemed to profit from software that places few restrictions on learner control, low-achieving students and those with little prior knowledge of the content seemed to achieve greater gains with programs that included guidance and structure.(22)

**2. In tutorial and practice software, programs with feedback providing knowledge of correct responses were found to be superior to programs that require students to answer until they are correct.**(23)

Not surprisingly, several studies have shown the value of software that guides students toward making correct answers rather than simply requiring them to persist until they respond correctly. While this research focused primarily on college and university students, the effect has been demonstrated with younger learners as well: low-ability eleventh graders who received knowledge-of-correct-response feedback during social studies reading comprehension practice were significantly more successful than students who had received only answer-until-correct feedback.(24)

**3. Software that includes embedded cognitive strategies provides students with a learning advantage. Helpful cognitive strategies include repetition and rehearsal of content, paraphrasing, outlining, cognitive mapping or diagramming, drawing analogies and inferences, generating illustrative examples, specific techniques for reading in the content areas, and using pictorial information.**(25)

Research on the effectiveness of embedded strategies is still limited, although interest seems to be growing in the ways such strategies can be provided directly within software to encourage learning. Two studies reviewed for this report examined the effects of embedded strategies with high school students. In one study, tenth graders who used an embedded-strategies version of a HyperCard biology stack significantly outperformed a group that used a stack without such strategies; the strategies that were embedded were similar to those noted above, and the learning task involved insect identification.(26) In the other study, learning disabled high school students used software in which they had to choose a correct diagram in response to a logic problem. The students who used a version of the software that instructed them to generate a diagram before choosing the correct one significantly outperformed students who used a version that did not include this embedded strategy. Furthermore, the embedded-strategy group also significantly outscored the others on more difficult logic tasks.(27)

**4. Animation and video can enhance learning when the skills or concepts to be learned involve motion or action.**(28)

Three studies addressed the contributions of animation and video for students in the age range served by library media specialists, and all three suggest that these characteristics can enhance learning. In one study, poor-reading second graders who used a program that included animated objects without spoken labels recalled significantly more of the objects' names than did similar students who used a version with labels but no animation.(29) Fourth graders who used an animated version of a program on Newton's laws of motion developed specifically for elementary students achieved at a significantly higher level than did students who used a version with still-frame graphics.(30)

Researchers who compared the effects of audio-only and computer controlled multimedia on the story-comprehension abilities of kindergarten students found that the students who had received the multimedia version made significantly more summary and inference statements and offered a wider variety of information than did the audio-only group. These students (including some who were at-risk) were also more likely to include the story's key components—the beginning, the problem, the attempt to resolve the problem, and the final resolution. The researchers concluded that the video included in the multimedia version helped students to form mental representations for stories and suggested that such representations might help students develop their general sense of story structure, an important pre-reading skill.(31)

**5. Students using hypermedia software can benefit from an interface that includes a graphical browser, or navigation map, that shows the links among the various screens of information.**(32)

This conclusion is based on only a single study—one that involved college students—but it suggests intriguing possibilities for research with the K–12 students served by library media specialists.

**6. Fantasy contexts may be advantageous to young children learning abstract concepts.**(33)

This conclusion, too, is based on only a single study but one that focused on students of immediate interest to library media specialists. It found that third graders who explored geometry concepts in a Logo program performed better when they worked within a story context than without one. Students who either chose or were assigned one of three contexts—a pirate looking for buried treasure, a detective hunting criminals, or an astronaut searching for new planets—outscored their peers on immediate and delayed tests of their understanding of Logo procedures.(34)

In general, then, recent research on the effects of technology on student learning consistently demonstrates the value of technology in enhancing achievement. It is important to note, however, that the studies reviewed were limited both in number and in design: the report's five-year span covers only a brief period in the history of instructional technology, and several of the studies tell us only that "more is better" because they evaluated technology-based approaches as additions to other instruction rather than as substitutes for it. Nevertheless, this latest cycle of research confirms the contribution of interactive media to student learning and suggests a number of avenues for further exploration of the nature and dimensions of this relationship.

# Technology and Student Self-Concepts

The findings in the report also reinforce years of findings about technology's positive effects on students' self-concepts and support the potential of educational technology to improve students' attitudes about themselves and about learning:

Educational technology has been found to have positive effects on student attitudes toward learning and on student self-concepts. Students felt more successful in school, were more motivated to learn, and had increased self-confidence and self-esteem when using computer-based instruction. This was particularly true when the technology allowed learners to control their own learning.(35)

Three studies provide evidence of the positive impact of educational technology on students' overall self-concepts. In one, CBI-using urban elementary students expressed stronger feelings of school success than peers in another school who did not use CBI.(36) In another, fourth graders grew in self-esteem and self-confidence when computers were placed in their homes and their school.(37) And in the third, high school mathematics students in a classroom-instruction-plus-CBI group gained significantly more on a measure of self-concept of academic ability than did their peers in a classroom-only-instruction group.(38) These findings are notable in light of what teachers and library media specialists have observed for years: students who view themselves as successful learners are more likely to enjoy school, to put forth their best efforts, and to achieve even more learning success.

Research related to technology and student attitudes in specific curriculum areas and with specific technologies reinforces these general findings. For example, a number of studies in language arts suggest that integrating computers into the curriculum can help improve student attitudes toward writing and spelling practice; studies in mathematics, science, and social science echo these positive findings.(39) Similarly, studies involving telecommunications projects, video-based technologies, and CD-ROM have documented positive effects of technology on student attitudes.(40) Newbold's CD-ROM study reflects what library media specialists have seen over the past decade: sixth graders reported more positive attitudes toward electronic encyclopedias than toward their print counterparts, and those who had actually used a CD-ROM encyclopedia were more positive toward writing and toward using the library.(41)

Individual studies within the group summarized above involved elementary, middle, and high-school students and often focused on at-risk groups (e.g., inner-city, rural, or learning- disabled students) for whom issues of self-concept and positive motivation are especially important. No research on learner control was reported with elementary students, but studies with high school students suggest the importance of this element to the development of positive attitudes.(42)

Library media specialists are responsible for working with teachers to evaluate and select much of the software that makes its way into classrooms, and one of the most intriguing paragraphs in this section of the report offers some guidance for the evaluation and selection process. It discusses the wide variety of software types that can positively affect students' attitudes through the fundamental step of helping students become more effective learners:

Well-designed tutorial and practice and "enhanced" hyper-textbooks can make challenging concepts and principles easier to understand. For example, students who are visual learners can benefit from still and motion graphics and video presentations included in instructional software. Tool software—software that makes it possible to accomplish a task more easily or effectively (e.g., a word processor or spreadsheet package)—can foster creativity and curiosity and make the task easier to accomplish. For instance, revising an essay on [a] computer means working on just the parts the student wants to change [rather than] rewriting the entire essay. Simulation software can offer students highly interactive, intrinsically rewarding experiences that textbooks cannot provide. For example, technology can allow students to role-play the president of the United States, an 18th-century American pioneer, or an international detective.(43)

Library media specialists are gatekeepers whose budgets—however limited—afford them the opportunity to purchase instructional media for use by an entire student body. This body of research suggests that it is important to address affective as well as cognitive factors in order to select materials that will truly meet students' learning needs.

# Technology in Context

The final—and shortest—segment of the report reviews research that

1. suggests characteristics of a desirable technology-based learning environment,
2. explores the effects of technology on teacher-student interactions and teachers' instructional behavior, and
3. examines students' interactions with one another in technology-based learning.

Although the report covers only classroom-based research and fails to discuss studies of the contributions of library media centers and programs to the creation and use of technology-rich learning environments, it offers useful insights into the role of technology in making education more student-centered, more interactive, and more of a stimulus for cooperative problem solving.

In her meta-analysis of the effects of CBI on elementary students' achievement, Ryan identified three characteristics of the most effective learning environments: personal interaction among the members of the class (both teacher-student and student- student interaction); integration of the technology into the curriculum by the teacher; and inclusion of activities that allow students to direct their own learning or to express themselves.(44) Teachers who orchestrate these and similar interactions are classified as "exemplary" by Becker, who pointed out that such teachers are considered their schools' leaders in technology and (1) have had considerable formal training in using and teaching with computers and (2) spend many hours at school working on computers for a variety of tasks.(45) Widely known for his tracking of computer use in schools over the years, Becker also identified a variety of other contextual factors that contribute to successful computer integration in schools: the existence of a social network of computer-using teachers, organizational support from both school and district administrations, and adequate resources to fund software acquisition and appropriate student grouping (i.e., smaller classes).(46)

Other studies, too, have documented the importance of teacher experience and attitudes and have described the ways in which patterns of interaction develop and can flourish in technology-rich and networked environments.(47) Of particular interest to library media specialists is the work of Ehman and others, who synthesized the results of eight case studies on the use of database software in social studies classrooms, concluded that instructors must provide structure for students engaging in complex problem-solving with such materials, and offered recommendations that parallel guidelines for school library media programs espoused by Eisenberg and Berkowitz, Kuhlthau, Neuman, and others:

Provide “clear expectations with a sequence of activities”; explain and model essential elements of the problem-solving process and offer students opportunities to practice these elements; and provide for “regular checking of student progress in accomplishing the milestone tasks of problem-solving.”(48)

Only a half-dozen studies reviewed for the report address the effects of technology on student-student interactions, and these are too scattered in specific focus to allow strong concluding generalizations. Nevertheless, the report suggests several important insights related to this dimension of technology and learning:

Greater student cooperation and sharing and helping behaviors occurred when students used computer-based learning that had students compete against the computer rather than against each other.

Small-group collaboration on computers is especially effective when students have received training in the collaborative process.(49)

In general, then, research on the contextual factors related to the use of technology in schools is beginning to outline a number of factors and interactions that contribute to effective technology-based learning environments. Library media specialists have a great deal of experience and expertise in creating and sustaining such environments, and these insights from classroom-based research support the theory and research emanating from the library media field.

# Conclusion

For decades, instructional technology researchers have sought to document the positive effects that technology can have on student learning. This report, which is the latest in this long line of attempts, addresses the effects of technology on student achievement, on student self-concept and attitudes about learning, and on interactions involving teachers and students in the learning environment.

Although the report focuses on classroom research and excludes studies conducted in library media centers, it provides useful insights for library media specialists and, indeed, for all school personnel who are concerned about using technology to promote student learning. Among its broader conclusions that offer such insights are the following:

Introducing technology into the learning environment has been shown to make learning more student-centered, to encourage cooperative learning, and to stimulate increased teacher/student interaction.

Positive changes in the learning environment brought about by technology are more evolutionary than revolutionary. These changes occur over a period of years, as teachers become more experienced with technology.

Courses for which computer-based networks were used increased student-student and student-teacher interaction, increased student-teacher interaction with lower-performing students, and did not decrease the traditional forms of communication used. Many students who seldom participate in face-to-face class discussions became more active participants online.(50)

These conclusions suggest the complexities of teaching and learning in the technology-rich environments that will be common in education in the next century. They offer both challenges and encouragement to educators who are committed to fostering learning—not just keystroking and mouse clicking—within those environments.

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