The Impact of Media and Technology in Schools

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Executive Summary

Introduction

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There are two major approaches to using media and technology in schools. First, students can learn "from" media and technology, and second, they can learn "with" media and technology. Learning "from" media and technology is often referred to in terms such as instructional television, computer-based instruction, or integrated learning systems. Learning "with" technology is referred to in terms such as cognitive tools and constructivist learning environments.

Regardless of the approach, media and technology have been introduced into schools because it is believed that they can have positive effects on teaching and learning. The purpose of this report is to summarize the evidence for the effectiveness and impact of media and technology in K-12 schools around the world. A limitation of this report is that the vast majority of the published research on the effectiveness of media and technology in schools was conducted in English-speaking countries such as Australia, Canada, the United Kingdom, and the United States of America.

For the purposes of this report, media is defined as "all means of communication, whatever its format." In this sense, media include symbol systems as diverse as print, graphics, animation, audio, and motion pictures. Technology is defined as "any object or process of human origin that can be used to convey media." In this sense, technology includes phenomena as diverse as books, films, television, and the Internet. With respect to education, *media* are the symbol systems that teachers and students use to represent knowledge; *technologies* are the tools that allow them to share their knowledge representations with others. Unfortunately, it is common to confound the meanings of media and technology in education, and they are often used synonymously.

One of the major reasons for the widespread attention focused on media and technology in education today is the enormous financial investment being made in media and technology in education around the world. For example, a recent Presidential report in the USA recommends that "at least five percent of all public K-12 educational spending in the United States (or approximately $13 billion annually in constant 1996 dollars) should be earmarked for technology-related expenditures."

Learning "From" Media and Technology

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The foundation for the use of media and technology as "tutors" in schools is "educational communications," i.e., the deliberate and intentional act of communicating content to students with the assumption that they will learn something "from" these communications. The instructional processes inherent in the “from” approach to using media and technology in schools can be reduced to a series of simple steps:

1) exposing students to messages encoded in media and delivered by technology,
2) assuming that students perceive and encode these messages,
3) requiring a response to indicate that messages have been received, and
4) providing feedback as to the adequacy of the response.

Television and the computer are the two primary technologies used in the “from” approach. The findings concerning the impact of television in education can be summed up as:

- There is no conclusive evidence that television stultifies the mind.
- There is no consistent evidence that television increases either hyperactivity or passivity in children.
- There is insufficient evidence that television viewing displaces academic activities such as reading or homework and thereby has a negative impact on school achievement. The relationship between the amount of time spent viewing television and achievement test scores is curvilinear with achievement rising with 1-2 hours of television per day, but falling with longer viewing periods.
- The preponderance of the research evidence indicates that viewing violence on television is moderately correlated with aggression in children and adolescents.
- Forty years of research show positive effects on learning from television programs that are explicitly produced and used for instructional purposes.
- Most studies show that there are no significant differences in effectiveness between live teacher presentations and videos of teacher presentations.
- Television is not widely in classrooms because teachers experience difficulty in previewing videos, obtaining equipment, incorporating programs into the curriculum, and linking television programming to assessment activities.

The findings concerning the impact of computer-based instruction (CBI) in education can be summed up as:

- Computers as tutors have positive effects on learning as measured by standardized achievement tests, are more motivating for students, are accepted by more teachers than other technologies, and are widely supported by administrators, parents, politicians, and the public in general.
- Students are able to complete a given set of educational objectives in less time with CBI than needed in more traditional approaches.
- Limited research and evaluation studies indicate that integrated learning systems (ILS) are effective forms of CBI which are quite likely to play an even larger role in classrooms in the foreseeable future.

- Intelligent tutoring system have not had significant impact on mainstream education because of technical difficulties inherent in building student models and facilitating human-like communications.

Overall, the differences that have been found between media and technology as tutors and human teachers have been modest and inconsistent. It appears that the larger value of media and technology as tutors rests in their capacity to motivate students, increase equity of access, and reduce the time needed to accomplish a given set of objectives.

Learning "With" Media and Technology

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Computer-based cognitive tools have been intentionally adapted or developed to function as intellectual partners to enable and facilitate critical thinking and higher order learning. Examples of cognitive tools include: databases, spreadsheets, semantic networks, expert systems, communications software such as teleconferencing programs, on-line collaborative knowledge construction environments, multimedia/hypermedia construction software, and computer programming languages.

In the cognitive tools approach, media and technology are given directly to learners to use for representing and expressing what they know. Learners themselves function as designers using media and technology as tools for analyzing the world, accessing and interpreting information, organizing their personal knowledge, and representing what they know to others

The foundations for using software as cognitive tools in education are:

- Cognitive tools will have their greatest effectiveness when they are applied within constructivist learning environments.
- Cognitive tools empower learners to design their own representations of knowledge rather than absorbing representations preconceived by others.
- Cognitive tools can be used to support the deep reflective thinking that is necessary for meaningful learning.
- Cognitive tools have two kinds of important cognitive effects, those which are *with* the technology in terms of intellectual partnerships and those that are *of* the technology in terms of the cognitive residue that remains after the tools are used.
- Cognitive tools enable mindful, challenging learning rather than the effortless learning promised but rarely realized by other instructional innovations.
- The source of the tasks or problems to which cognitive tools are applied should be learners, guided by teachers and other resources in the learning environment.

- Ideally, tasks or problems for the application of cognitive tools will be situated in realistic contexts with results that are personally meaningful for learners.
- Using multimedia construction programs as cognitive tools engages many skills in learners such as: project management skills, research skills, organization and representation skills, presentation skills, and reflection skills.
- Research concerning the effectiveness of constructivist learning environments such as microworlds, classroom-based learning environments, and virtual, collaborative environments show positive results across a wide range of indicators.

Conclusions and Recommendations

Overall, fifty years of educational research indicates that media and technology are effective in schools as phenomena to learn both *from* and *with*. Historically, the learning *from* or tutorial approaches have received the most attention and funding, but the *with* or cognitive tool approaches are the focus of more interest and investment than ever before. Media and technology have many other advantages in terms of repeatability, transportability, and increased equity of access. In addition, although the research evidence is sparse, the cost-effectiveness, cost-benefit, and return-on-investment of media and technology may be of great benefit under certain conditions, especially in developing countries.

Longitudinal studies such as the ten year investigation of the Apple Classrooms of Tomorrow (ACOT) Project show that pedagogical innovations and positive learning results do eventually emerge from the infusion of media and technology into schools, but the process takes longer than most people imagine.

Large investments in time and support for teachers are especially critical if the adoption of constructivist pedagogies accompany the infusion of media and technology. This is critical given that it is pedagogy that is most influential on learning, not media or technology. Media and technology, however, are integral to the implementation of innovative pedagogies.

The need for long-term, intensive research focused on the mission of improving teaching and learning through media and technology has never been greater. This research should be developmental in nature, i.e., focused on the invention and improvement of creative approaches to enhancing human communication, learning, and performance through the use of media and technology. The purpose of such research is to improve, not to prove. In the final analysis, the esoteric and complex nature of human learning may mean that there may be no generalizable best approach to using media and technology in schools. The most we may be able to hope for with respect to media and technology in education is creative application and informed practice.

Section 1: Introduction

"Learning From" and "Learning With" Media and Technology

There are two major approaches to using media and technology in schools: students can learn "from" media and technology, and they can learn "with" media and technology (Jonassen & Reeves, 1996). Learning "from" media and technology is often referred to in terms such as instructional television, computer-based instruction, or integrated learning systems (Hannafin, Hannafin, Hooper, Rieber, & Kini, 1996; Seels, Berry, Fullerton, & Horn, 1996). Learning "with" technology, less widespread than the "from" approach, is referred to in terms such as cognitive tools (Jonassen & Reeves, 1996) and constructivist learning environments (Wilson, 1996).

Regardless of the approach, media and technology have been introduced into schools because it is believed that they can have positive effects on teaching and learning. The purpose of this report is to summarize the evidence for the effectiveness and impact of media and technology in schools around the world. (A limitation of this report is that the vast majority of the published research on the effectiveness of media and technology in schools was conducted in English-speaking countries such as Australia, Canada, the United Kingdom, and the United States of America.) Research studies concerning the impact of these different approaches will be presented in the next two sections of this report. But first, it is necessary to clarify what is meant by the terms "media" and "technology" within the context of education.

The Challenge of Defining Media and Technology

Media has many definitions ranging from "a particular form of communication" as in "print versus video" to "the industry that provides news and entertainment" as in "the media." For the purposes of this report, media is defined as "all means of communication, whatever its format" (Reid, 1994, p. 51). In this sense, media include symbol systems as diverse as print, graphics, animation, audio, and motion pictures.

Similarly, technology has many definitions ranging from "the application of the scientific method to solve problems as in 'the technology of space exploration'" to "the things or processes which embody knowledge or craft within a culture as in 'the technology of writing'." Within this report, technology is defined as "any object or process of human origin that can be used to convey media." In this sense, technology includes phenomena as diverse as books, films, television, and the Internet.

With respect to education, *media* are the symbol systems that teachers and students use to represent knowledge; *technologies* are the tools that allow them to share their knowledge representations with others. Unfortunately, it is common for practitioners and experts alike to confound the meanings of media and technology in education, and they are often used synonymously. The following quote from the Fifth Edition of the *Encyclopedia of Educational Research* (Mitzel, 1982) illustrates the problem:

> *First, although most educators are comfortable enough to use the term "media" and expect others to understand its meaning, it lacks a commonly accepted definition. Instead, there is a general, somewhat vague understanding that it refers to various audio and/or visual communication technologies which have come to be used by educators. Books and other print materials are, of course, media too, yet it is usually understood from the context – including the present context – that they are not part of the topic under discussion. (Seibert & Ullmer, 1982, pp. 1190-1191)*

The confounding of media (a symbol system) with technology (a delivery system for media) is unlikely to go away in popular discourse about education any time soon, but the distinction between media and technology must be clarified as unambiguously as possible if their impact is to be understood. The following quote from the Sixth Edition of the Encyclopedia of Educational Research (Alkin, 1992) clarifies this distinction:

> *Computer-based technologies cannot be regarded as "media," because the variety of programs, tools, and devices that can be used with them is neither limited to a particular symbol system, nor to a particular class of activities...... In this light, "the computer" is in fact a "multifaceted invention" of many uses, a symbolic tool for making, exploring, and thinking in various domains. It is used to represent and manipulate symbol systems – language, mathematics, music – and to create symbolic products – poems, mathematical proofs, compositions. (Salomon, 1992, p. 892)*

Salomon's (1992) important distinctions between media as symbol systems and technologies as tools or vehicles for sharing media will be used throughout this report. However, many, if not most, of the research and evaluation studies that are cited in this report are not informed by this distinction, an inconsistency that is frustrating, but inevitable. Even people who prepare dictionaries are uncomfortable with the term "media." For example, the American Heritage College Dictionary contains this note:

> *The etymologically plural form* media *is often used as a singular to refer to a particular means of communication, as in* This is the most exciting new media since television*. This usage is widely*

regarded as incorrect; medium *is preferred. (Berube, 1993, p. 846)*

The Importance of Media and Technology in Education

Why is so much attention paid to media and technology in education? First, with respect to media, there are many issues of concern to students, parents, educators, governments, and society at large. For example, important questions are asked about the effects of different media on the cognitive and moral development of children. With respect to technology, people want to know whether various new technologies are more effective for teaching and learning than more traditional classroom approaches, whether some technologies are more motivating than others, or at the very least, whether technologies can be used to increase access or reduce costs within education. Questions about the impact of media and technology in terms of increasing access to education and reducing the costs of education are especially high on the agendas of politicians and government agencies around the world. In the USA, the Panel of Educational Technology of the President's Committee of Advisors on Science and Technology (1997) included as one of its six major strategic recommendations that technology be used to "Ensure equitable, universal access" (p. 5). Another part of the same report called for realistic budgeting for technology-related expenditures within schools, noting that the much-touted return-on-investment for educational technology was a long-term prospect.

Another reason for the attention being paid to media and technology in education reflects commercial or corporate interests. Although printed material continues to be "the dominant medium format" in schools (Molenda, Russell, & Smaldino, 1998, p. 3), a recent Presidential report in the USA recommends that "at least five percent of all public K-12 educational spending in the United States (or approximately $13 billion annually in constant 1996 dollars) should be earmarked for technology-related expenditures...." (President's Committee of Advisors on Science and Technology, 1997, p. 5). Similar investments are underway throughout the world, in both developed and developing countries. It is no wonder that global corporations such as AT&T and Sony are investing in large-scale educational technology initiatives.

Still another reason for the focus on media and education stems from sharp disagreements about the value of media and technology in education. Enthusiastic endorsements of new media and technologies in education are easy to find in news reports, political speeches, and other sources. Many of these proclamations seem overly-optimistic if not hyperbolic. Consider this quote from Lewis Perelman's 1993 book titled *School's Out*:

Because of the pervasive and potent impact of HL (hyperlearning) technology, we now are experiencing the turbulent advent of an economic and social transformation more profound than the

> *industrial revolution. The same technology that is transforming work offers new learning systems to solve the problems it creates. In the wake of the HL revolution, the technology called "school" and the social institution commonly thought of as "education" will be as obsolete and ultimately extinct as the dinosaurs. (p. 50)*

However, despite such rhetoric and other, more conservative, optimism expressed in the popular press and government documents, there are also many skeptics and a few outspoken critics of media and technology in education. A recent cover story of *The Atlantic Monthly* entitled "The Computer Delusion" illustrates a critical view of technology in education, beginning with this opening sentence:

> *There is no good evidence that most uses of computers significantly improve teaching and learning, yet school districts are cutting programs – music, art, physical education – that enrich children's lives to make room for this dubious nostrum, and the Clinton Administration has embraced the goal of "computers in every classroom" with credulous and costly enthusiasm. (Oppenheimer, 1997, p. 45).*

The controversy in the popular press is echoed in the educational research literature. Research examining the effectiveness of media and technology in schools can be traced back almost eighty years (Cuban, 1986), and yet many questions about the value and impact of these approaches remain unanswered. Indeed, the seemingly contradictory findings often reported in the educational research literature fan the flames of the ongoing controversy about media and technology in education. Consider the following two quotes:

> *Bringing the electronic media into the schools could capitalize on the strong motivation qualities that these media have for children. Many children who are turned off by school are not turned off by one or another of the electronic media; quite the opposite. An educational system that capitalized on this motivation would have a chance of much greater success...... Each medium has its own profile of cognitive advantages and disadvantages, and each medium can be used to enhance the impact of others. (Greenfield, 1984, p. 178)*

> *All in all, media's symbolic forms and computers' afforded activities often have skill-cultivating effects. However, to claim that these effects are specific to any one medium or media attribute is difficult...... There is growing consensus that past media comparison, media attribute, and motivation studies indicate that media do not influence whether someone learns from instruction. Learning seems to result from factors such as task differences, instructional methods, and learner traits (including attitudes) but not the choice of media for instruction. (Clark, 1992, p. 812)*

The two quotes above were written by highly respected scholars from two of the most esteemed research universities in the USA. Professor Patricia Marks Greenfield is in the Psychology Department at the University of California Los Angeles (UCLA), and Professor Richard E. Clark teaches Instructional Technology at the University of Southern California (USC). How can two such noted researchers, physically just a few miles distance from each other, be worlds apart in terms of their estimation of the importance of media in education? This report is an attempt to sort out the differences in these perspectives and present a synthesis of research findings that may help to resolve this and other controversies about media and technology in education.

Organization of the Report

This report is organized into four sections. Section One is an Introduction to the major issues underlying the growing interest in media and technology in schools around the world. Section Two addresses the impact of media and technology in schools when they are used in didactic or tutorial modes (the learning “from” approach). Section Three presents the evidence for the impact of media and technology in schools when they are used as cognitive tools or constructivist learning environments (the learning “with” approach). Section Four presents a critical analysis of what we know about the impact of media and technology in schools as well as a set of recommendations for an improved research agenda regarding these issues.

Summary

This first section has presented important distinctions between media and technology with the former defined as a means or symbol system for human communication and the latter as a vehicle or tool for the transmission or manipulation of media. This section has also described several major reasons for the widespread attention focused on media and technology in education today. These reasons include: 1) the importance of unresolved issues about educational media and technology to virtually all members of society, 2) the enormous financial investments being made in media and technology in education around the world, and 3) the often vehement disagreements that exist about the value and impact of media and technology in education that exist in both the popular press and the educational research literature.

Section 2: The Impact of Learning “From” Media and Technology in Schools

The Meaning of Media and Technology as Tutors

The foundation for the use of media and technology as “tutors” in schools is "educational communications," i.e., the deliberate and intentional act of communicating content to students with the assumption that they will learn something "from" these communications (Krendl, Ware, Reid, & Warren, 1996). In educational communications, information or knowledge is encoded visually or verbally in the symbol systems (media) that are enabled by various technologies. For example, animation is a form of media that can be delivered to students via a variety of technologies such as the World Wide Web. Within a web-based science tutorial, an animation of the movement of the moon around the earth might be shown to students so that they can visualize and learn about the lunar phases.

The instructional processes inherent in the “from” approach to using media and technology in schools usually can be reduced to a series of simple steps:

1) exposing students to messages encoded in media and delivered by technology,
2) assuming that students perceive and encode these messages,
3) requiring a response to indicate that messages have been received, and
4) providing feedback as to the adequacy of the response.

Interaction in the “from” approach, if present, is normally operationalized in terms of student input via the technology such as clicking a mouse button to indicate a response to a multiple-choice question, some form of answer judging, and feedback in the form of another message previously encoded in the media. Instructional technologies (e.g., films and teaching machines) were first introduced early in this century in the belief that they could “teach” in a similar sense that teachers or tutors are said to teach (Cuban, 1986). This section of this report focuses on the two most widely used forms of media and technology as tutors today, specifically television and computers.

Learning “from” Television

Popular Beliefs about TV

Since the first educational television broadcasts began in Iowa in 1933, there have been decades of research focused on the educational effects of television, and yet controversies about the impact of television in schools and society as a whole persist. For example, some well-known social critics (e.g., Postman, 1995, 1994, 1985; Winn, 1985) maintain that television viewing is cognitively debilitating. A review of the television research literature, however, indicates that such claims are largely based upon subjective observations rather than theory-guided investigations, and there is no conclusive evidence that television stultifies the mind (Seels, Berry, Fullerton, & Horn, 1996). There is also no consistent evidence that television increases either hyperactivity or passivity in children (Dorr, 1992).

Another popular belief is that television viewing is detrimental to the academic achievement of school-age children and teens. While some studies have reported a negative correlation between the amount of television viewing and scholastic performance, such statistics are susceptible to misinterpretations because of intervening variables such as intelligence and socioeconomic status (Seels et al., 1996). In a book titled *Literacy in the Television Age: The Myth of the TV Effect*, Susan Neuman (1995) provides an in-depth review of research examining the relationship between television and achievement. She concludes that there is insufficient support for the hypothesis that television viewing displaces academic activities such as reading or homework and thereby has a negative impact on school achievement. A competing analysis of the literature by Comstock and Paik (1991) concluded that the relationship between the amount of time spent viewing television and achievement test scores (primarily reading tests) is curvilinear with achievement actually rising with 1-2 hours of television per day, but gradually falling with longer daily viewing periods.

Undoubtedly, the most widespread belief about television is that it fosters violence and aggressive behaviors among children and adolescents (Winn, 1985). A survey of the literature indicates that there have been nearly 20 books published on this topic in the last decade alone, most of them condemning television as causing aggression. In addition, scores of research studies related to this topic are published around the world each year. There is little disagreement that in many, if not most, countries television provides a steady flow of violence ranging to as many as 25 violent acts per hour in children's programming (Donnerstein, Fairchild, Feshbach, Katz, & Huston, 1993). The preponderance of the quantitative research evidence indicates that viewing violence on television is moderately correlated with aggression in children and adolescents (National Institutes of Mental Health, 1982; Seels et al., 1996), but as with all such correlational research, the evidence for direct causality is weaker. Alternative explanations for the reported correlations are possible, e.g., those children with a tendency toward aggression may be more likely to watch violent television programs. Despite the weak evidence for causality, both the public in general and many politicians have come to accept the conclusion that television violence has negative effects on youth (Signorielli, 1991). As a result, legislation has recently been passed in the USA to compel television networks to provide violence ratings for their programs and to require manufacturers to install electronic blocking devices (such as the "V-chip") in new TV sets. Similar laws are already in place in other countries.

Less publicized than hypotheses about the negative effects of television on cognitive development, scholastic achievement, and social behavior are research investigations into the positive effects of television viewing on factors such as interest, creativity, and imagination (Leonard, 1997). Howard Gardner (1982, 1991, 1993), a well-known developmental psychologist at Harvard University, is a proponent of the idea that certain kinds of television stimulate creativity and imagination in young children. However, the research results supporting these types of positive hypotheses are modest at best (Seels et al., 1996).

Exemplary Programs

Two television shows that have been subjected to more educational research than any others in the USA are *Mister Rogers' Neighborhood* (Collins & Kimmel, 1996) and *Sesame Street* (Lovelace, 1990; Mielke, 1990), both shown on public television stations. *Sesame Street*, distributed in more than 90 countries, has also been studied internationally (Gettas, 1990).

The goals of *Mister Rogers' Neighborhood* are primary affective, and research has demonstrated positive effects on the self-esteem of children and their tendencies to value others (Seels et al., 1996). With emphasis on both socialization and cognitive development, *Sesame Street* has been shown to have positive outcomes in terms of school readiness as well as math, reading, and social skills (Seels et al., 1996). Interestingly, some researchers have focused on whether the slower-paced *Mister Rogers' Neighborhood* and the faster-paced *Sesame Street* have differential effects on children's attention spans, but such studies are inconclusive (Anderson & Collins, 1988; Seels et al., 1996).

Research Results

The most positive research news about learning "from" television can be found in the classroom where 40 years of research show positive effects on learning from television programs that are explicitly produced and used for instructional purposes (Dorr, 1992; Seels et al., 1996). In addition, most studies show that there are no significant differences in effectiveness between live teacher presentations and videos of teacher presentations (Seels et al., 1996).

More importantly, there is strong evidence that television is used most effectively when it is intentionally designed for education and when teachers are involved in its selection, utilization, and integration into the curriculum (Johnson, 1987). In the past, the biggest barrier to the integration of television programs into the classroom was the fixed-time limitation of instructional broadcasts, but the wide-spread availability of video cassette recorders (VCRs) has provided teachers with the ease-of-use and flexibility they require (Mielke, 1990).

Increasingly, television is coming into schools via cable and or satellite transmissions. The Star Schools Consortium in the USA is one of the largest such enterprises, providing scores of telecourses in thousands of schools across the nation (Moore & Kearsley, 1996). Most often, programs received via satellite dish or cable are recorded by media specialists or technology coordinators and subsequently made available for teachers when and how they choose. Flexibility of scheduling and ease of access to equipment and programs are the biggest factors promoting classroom use of television (Dorr, 1992; Seels et al., 1996)

A few programs are still intended for use at specific times. Perhaps the most controversial of these in the USA is *Channel One*, ten minutes of news and advertisements produced by Whittle Communications (www.channelone.com). This program is seen by an estimated eight million adolescents in 12,000 schools in the USA each day (De Vaney, 1994). CNN, NBC, and other networks broadcast news into American classrooms, but *Channel One* is best known for the contracts it arranges with school districts whereby Whittle donates TV monitors and satellite receivers to schools in return for guaranteed viewing time each school day. Whittle recovers its costs from the fees it charges corporations for product advertisements aimed at the captive teen viewers. Interestingly, what little research has been done indicates that students ignore the advertisements and that teachers are not integrating the news portions of the program into the curriculum (De Vaney, 1994).

Historically, studies of the large-scale implementations of instructional television have shown mixed results. Three major forms of utilization have been investigated: 1) instances where the total instructional program is delivered via televised teachers, 2) instances where there is an integration of teacher-directed instruction with television programming, and 3) instances where television is used to supplement teacher-centered instruction, either for enrichment or remedial purposes. Cuban (1986) reports that total instructional television programs in countries such as American Samoa and El Salvador have met with initial enthusiasm, but declined in popularity after the novelty wore off and both students and teachers demanded less television and a return to regular classroom activities. Some studies indicate that students in rural schools, where quality teachers were less likely to be available, benefited the most from televised instruction (Seels et al., 1996).

However, television has been rarely used to totally replace teachers in any country, and television is usually used in coordination with or to supplement the regular curriculum (Cuban, 1986). Here the results are much more positive. A large-scale survey of teachers in the USA conducted in 1991 by the Corporation for Public Broadcasting indicated that "instructional television is a firmly established teaching tool that is positively regarded by classroom teachers and increasingly well-supported with equipment and programming" (Seels et al., 1996, p. 356). Writing in the Encyclopedia of Educational Research, Dorr (1992) concluded: "There is no doubt that television is an effective means of achieving traditional instructional goals" (p. 1398).

Future Needs

Unfortunately, there is a paucity of developmental research focused on how teachers might best use television in the classroom to enhance academic achievement. We know that motivation is an important factor in gaining the most from any educational experience, but we don't know how teachers can effectively motivate students to attend to educational television. We know that feedback concerning the message received (or not received) from television is important, but we lack clear directions as to when and how teachers should provide that feedback. And even when recommendations for using television in the classroom do exist (Stone, 1997), there is little evidence that these guidelines are integral parts of the curriculum in most teacher preparation programs (Waxman & Bright, 1993).

Dorr (1992) indicates that most children in the USA view less than 30 minutes of television a week in school whereas their home televisions are on nearly seven hours per day! Why isn't television used more widely in education? The teacher plays the major role in deciding what happens in the classroom, and as long as teachers experience difficulty in previewing videos, obtaining equipment, incorporating programs into the curriculum, and linking television programming to assessment activities, television viewing will continue to be relatively rare in classrooms. It also seems likely that the widespread public belief that television has detrimental effects on development, learning, and behavior will continue to limit television integration within most classrooms beyond that of a relatively modest supplementary role.

Learning "from" Computers

Behavioral and Cognitive Foundations

The personal computer is the most common interactive technology used as a "tutor" today. Interactive instruction via personal computer is known by many names and acronyms such as computer-based instruction (CBI) (Alessi & Trollip, 1991), integrated learning systems (ILS) (Bailey, 1993), and intelligent tutoring systems (ITS) (Polson & Richardson, 1988). The personal computer as a tutor or surrogate instructor has been the subject for much research and evaluation since its development in the late 1970s (Coley, Cradler, & Engel, 1997; Hannafin, Hannafin, Hooper, Rieber, & Kini, 1996). Critics of computers as tutors have been around since their inception (Oettinger, 1969), and there are vocal opponents of computers in classrooms today (Baines, 1997; Oppenheimer, 1997).

One irony underlying research on learning from computers is that while everyone recognizes the amazing improvements in the features and capabilities of personal computers that have occurred in the past 20 years, few people outside the research community acknowledge that the nature of computer-based learning has also undergone enormous change (Baker-Albaugh, 1993; Coley et al., 1997). The earliest forms of computer-based instruction were heavily influenced by the behavioral psychology of B.F. Skinner (1968). These programs were essentially automated forms of programmed instruction. They presented information to the student in small segments, required the student to make overt responses to the information as stimulus, and provided feedback to the student along with differential branching to other segments of instruction or to drill-and-practice routines. Although this basic behavioral model continues to dominate mainstream educational applications of computers such as integrated learning systems (Bailey, 1992), interactivity in some of today's most innovative applications, such as constructivist learning environments (Wilson, 1996), is based upon advances in cognitive psychology and constructivist pedagogy (Coley et al., 1997) (see Section Three of this report).

Research Results

The good news is that even with a primarily behavioral pedagogy, computers as tutors have positive effects on learning as measured by standardized achievement tests, are more motivating for students, are accepted by more teachers than other technologies, and are widely supported by administrators, parents, politicians, and the public in general (Coley et al., 1997; President's Committee of Advisors on Science and Technology, 1997). These conclusions about the effectiveness of computers in classrooms in the USA are in agreement with the conclusions of similar reports in Australia (Directorate of School Education, 1994), Canada (Bracewell & Laferriére, 1996), and the United Kingdom (Department for Education and Employment, 1996, 1997). Regrettably, the impacts of CBI in countries such as Brazil (Chaves, 1993), Chile (Oteiza, 1993), China (Makrakis & Yuan-tu, 1993), and Malaysia (Shahdan, 1993) are less clear.

Meta-analyses of research examining the effectiveness of computers in schools have illuminated their advantages and limitations (Kulik & Kulik, 1987, 1991). Meta-analysis is a statistical procedure that allows researchers to synthesize the results of numerous research studies comparing different treatments (e.g., CBI versus teacher-centered instruction) by reducing the results to a common "effect size" (Hunt, 1997). Although some proponents of computer-based instruction have promised a 2.0 effect size (representing an improvement of two standard deviations between CBI and traditional instruction), a more reasonable expectation is in the range of 0.5 to 1.0. The results of meta-analyses for computer-based instruction show an interesting pattern, as illustrated in Table 1.

Table 1. Effect sizes for CBI computed from meta-analysis studies.

Academic Level	Effect Size	Source
Elementary School	0.47	(Kulik, Kulik, & Bangert-Drowns, 1985)
Secondary School	0.36	(Bangert-Drowns, Kulik, & Kulik, 1985)
College and University	0.26	(Kulik & Kulik, 1986)
Adult Basic Education	0.42	(Kulik, Kulik, & Schwab, 1986)

As indicated in Table 1, the effectiveness of CBI over traditional teacher-centered instructional methods appears to decline as the level of education increases with the exception of adult basic education, where CBI has an effect size between that of secondary and elementary school contexts. A variety of explanations have been offered for these differential effects ranging from the belief that teachers in lower grades are better at integrating CBI into the curriculum to the suggestion that there is less well-designed software available in the higher grades. Clark (1994a, b) maintains that media and technology are mere vehicles for instructional methods. He provides an alternative interpretation of the differential effect sizes by arguing that when the differences in pedagogy are factored out of the comparisons between CBI and teacher-centered instruction, the effect sizes virtually disappear.

A more robust finding for computer-based instruction is that students are able to complete a given set of educational objectives in less time with CBI than needed in more traditional approaches (Kulik & Kulik, 1991). The time savings factor was first identified in military training contexts where a consistent 25% to 50% reduction in time to train has been demonstrated when interactive technologies are employed (Fletcher, Hawley, & Piele, 1990). The pressure to save instructional time has not been as great in school contexts, a situation that may change if proponents of national assessments are successful, and teachers perceive the need to cover more content within the school year.

Given the overall positive results for the computer as tutor approach, some questions can be asked about the relative effectiveness of different approaches to instructional computing in classrooms. The next two subsections of this report provide research findings for two major tutorial approaches: integrated learning systems (ILS) and intelligent tutoring systems (ITS).

Integrated Learning Systems

Integrated learning systems (ILS) utilize computer networks to combine comprehensive educational “courseware” with centralized management tools. ILS are marketed by large commercial vendors such as Computer Curriculum Corporation (CCC) [www.cccnet.com] and Jostens Learning Corporation [www.jlc.com]. CCC’s programs are reported to be in use by millions of students in 16,000 classrooms in the USA, Canada, UK, Japan, Australia, and New Zealand. Jostens claims that its courseware is used by 9 million students in 13,000 schools around the world. There were approximately a dozen major ILS vendors in the early 1990s, although recent mergers indicate that a market shake-out is underway. In a special issue of *Education Technology* magazine devoted to ILS, Bailey (1992) asked two primary questions: “Why do they (ILS) continue to dominate the school technology market? Are they as effective as the vendors claim?” (p. 3).

Why are ILS so popular among educators, at least those with the power to make purchasing decisions? Bailey (1993) and Becker (1992b) describe some of the perceived advantages of integrated learning systems that help to explain why ILS dominate the school technology market:

- Networking allows centralized management by teachers and administrators.

- Diagnostic and prescriptive analysis techniques built into ILS provide the basis for more and better individualization of lesson materials for students.
- The logistical problems associated with software distribution and maintenance are eliminated by networking from centralized servers.
- Strong tutorials and extensive drill-and-practice opportunities are provided for students within a wide range of abilities.
- There is an obvious articulation between the content of ILS lessons and standardized assessment approaches used in most schools.
- Students and teachers can experience a common user interface across subjects and grades.

What about the question of their heavily advertised effectiveness? ILS are complex systems that involve the use of specific hardware and software to address large portions of the standard school curriculum, especially in areas such as mathematics, reading, and language arts. Funding for the development of early versions of these systems came from government resources targeted for “at risk” students, and they are sometimes criticized as having too much “drill and kill” materials in them (Bailey, 1992). Becker (1992c) provides evidence that ILS are most effective for those students with either low or high aptitude for regular classroom instruction, but that the 40% of students in the middle range experience no improvement from ILS over regular classroom instruction. Becker (1992b) uses meta-analysis techniques to examine the effectiveness of some of the ILS from major vendors. As illustrated in Table 2, most of the results are positive, but much more modest than promised by the vendors themselves.

Table 2. Effect sizes for ILS derived from Becker (1992b).

ILS Source	Effect Size	Number of Studies Included
Vendor #1	0.17	13
Vendor #2	0.40	4
Vendor #3	0.33	3

Despite the lack of evidence that ILS are as effective as the commercial interests behind them claim, they are quite likely to play an even larger role in classrooms in the foreseeable future (Bracey, 1992). For example, a January 1998 press release indicates that Jostens Learning has initiated a seven-year partnership with Addison-Wesley Longman, one of the world’s largest education publishers, to promote ILS in the United Kingdom where a new government initiative aims at increasing the use of technology in schools [www.jlc.com]. The collaboration predicts at least a 34 million dollar contract within the UK alone. In November 1997, Computer Curriculum Corporation inked a reported 50 million dollar agreement with Research Machines, the leading supplier of educational software in the UK [www.cccnet. com]. Investors in these companies are confident in a bright future for ILS.

To their credit, most of the ILS on the market have been redesigned in recent years to take advantage of multimedia capabilities and advances in instructional design. Unfortunately, the new versions of ILS have not been subjected to rigorous research and evaluation studies. The WWW sites associated with ILS vendors contain both testimonials and anecdotal evidence, but there is a complete lack of large-scale, externally conducted, rigorous research studies reported in the sites or obtainable through public information resources such as ERIC (Educational Resources Information Clearinghouse) [http://www.askeric.org]. In addition, there is evidence that vendors underestimate the training required for teachers to make effective use of ILS or other forms of software (Robinson, 1992; Wiburg, 1995).

Intelligent Tutoring Systems

The basic components of intelligent tutoring systems (ITS) were conceptualized 25 years ago (Hartley & Sleeman, 1973) as 1) knowledge of the domain, 2) knowledge of the learner, and 3) knowledge of teaching strategies. In ITS language, these are often referred to as the expert model, the student model, and the tutor (Larkin, 1991). Others trace the history of ITS all the way back to 1926 when Sidney L. Pressey built an “instructional machine” that presented a student with multiple-choice questions (Shute & Psotka, 1996), a device which could even dispense candy for correct answers. Advocates of ITS promote these systems as “the most promising approach to delivering individualized instruction” (Shute & Psotka, 1996, p. 571) because the “artificial intelligence” aspects of the program can allegedly diagnose and remedy student misconceptions with the precision of a human tutor.

Although much of the development of ITS has been done in the context of military and industrial training, there have been significant efforts to develop ITS for education, especially in challenging subjects such as algebra, calculus, and programming. For example, John Anderson (1993) is well known for his work building a geometry ITS. An evaluation of Anderson’s geometry tutor in an urban school setting indicated that the system had both positive learning outcomes and encouraged more cooperative problem-solving among students (Shute & Psotka, 1996). Unfortunately, despite a few positive evaluations in loosely controlled studies, few ITS have demonstrated the significant results promised by their developers.

ITS attracted much more attention, funding, and research a few years ago than they do today. One telling sign is that the *Journal of Artificial Intelligence in Education* recently changed its name to the *Journal of Interactive Learning Research*. Even those who have been most involved in research and development targeted at producing "intelligent tutors" have begun to acknowledge the lack of impact they have had on mainstream education (Lajoie & Derry, 1993). A major factor contributing to the lack of success of ITS is that the technical difficulties inherent in building student models and facilitating human-like communications have been greatly underestimated by proponents of this approach.

In the face of the disappointing results of ITS, some experts suggest that "...the appropriate role for a computer is not that of a teacher/expert, but rather, that of a mind-extension 'cognitive tool'" (Derry & Lajoie, 1993, p. 5). Cognitive tools, as described in the next section of this report, are *un*intelligent tools, relying on the learner to provide the intelligence, not the computer. This means that planning, decision-making, and self-regulation are the responsibility of the learner, not the technology. Cognitive tools can serve as powerful catalysts for facilitating these higher order skills if they are used in ways that promote reflection, discussion, and collaborative problem-solving (see Section Three of this report).

Future Needs

Research and evaluation of the effectiveness of CBI and other applications of computers as tutors have been plagued by flaws that render much of the existing literature little more than pseudoscience (Reeves, 1993). One reason for this deplorable state of affairs is that there has long been great disagreement about the purpose and value of educational research. For example, Nate Gage, a past president of the American Educational Research Association (AERA), has been a staunch defender of the notion that the goal of basic research in education is simply "more valid and more positive conclusions" (Farley, 1982, p. 12) whereas another past president of AERA, Robert Ebel, proclaimed:

> *....the value of basic research in education is severely limited, and here is the reason. The process of education is not a natural phenomenon of the kind that has sometimes rewarded scientific investigation. It is not one of the givens in our universe. It is man-made, designed to serve our needs. It is not governed by any natural laws. It is not in need of research to find out* how *it works. It is in need of creative invention to* make *it work better. (Farley, 1982, p. 18, Ebel's italics).*

Should educational research seek to establish immutable laws akin to those found in the harder sciences? Or should educational researchers be focused on finding out how to improve education with different types of students in specific places at particular times of their development? These questions reflect an on-going struggle between those who favor basic research and those who call for applied research. Despite the increased acceptance of qualitative alternatives to the experimental methods that dominated educational research in the past, there are signs that some powerful policy-makers are pushing for more classically empirical approaches. For example, the Panel of Educational Technology of the President's Committee of Advisors on Science and Technology (1997) listed as one of its six major strategic recommendations that the government "initiate a major program of experimental research....to ensure both the efficacy and cost-effectiveness of technology use within our nation's schools" (p. 5). A wiser course would be to support both development research (aimed at making CBI work better) and empirical (aimed at determining how CBI works) using both quantitative and qualitative methods.

Summary

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This second section has presented evidence for the effectiveness of the learning “from” media and technology approach. Focusing on television and computer-based instruction, evidence was provided that media and technology can be effective tutors in K-12 schools, although the question of whether media and technology enable learning more than traditional classroom methods remains unresolved. Differences that have been found between technology as tutors and teachers have been modest and inconsistent. It appears that the larger value of media and technology as tutors rests in their capacity to motivate students, increase equity of access, and reduce the time needed to accomplish a given set of objectives.

With its firm foundation in behavioral psychology, the learning “from” or tutorial approach to using media and technology in schools is well-established in the minds of many educators and the public at large. In fact, if the commercial success of integrated learning systems and many other tutorial programs is good evidence, many regard this approach as a sufficient way of introducing media and technology into the school curriculum. However, cognitive psychologists and constructivist educators have created quite different models. In the next section, we turn our attention to the learning “with” or cognitive tools approach.

Section 3: The Impact of Learning “With” Media and Technology in Schools

The Meaning of Media and Technology as Cognitive Tools

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Cognitive tools have been around for thousands of years, ever since primitive humans used piles of stones, marks on trees, and knots in vines to calculate sums or record events. In the broadest sense, cognitive tools refer to technologies, tangible or intangible, that enhance the cognitive powers of human beings during thinking, problem-solving, and learning. Something as complex as a mathematical formula or as simple as a grocery list can be regarded as a cognitive tool in the sense that each allows humans to “off-load” memorization or other mental tasks onto an external resource.

Today, computer software programs are examples of exceptionally powerful cognitive tools (Jonassen, 1996a; Lajoie & Derry, 1993). Also referred to as "cognitive technologies" (Pea, 1985), "technologies of the mind" (Salomon, Perkins, & Globerson, 1991), and “mindtools” (Jonassen, 1996a), they will be referred to as “cognitive tools” in this report (Kommers, Jonassen, & Mayes, 1992). As computers have become more and more common in education, researchers have begun to explore the impact of software as cognitive tools in schools (Jonassen & Reeves, 1996).

Computers as cognitive tools represent quite a different approach from media and technology as vehicles for educational communications (see Section Two of this report). Computer-based cognitive tools have been intentionally adapted or developed to function as intellectual partners to enable and facilitate critical thinking and higher order learning. Examples of cognitive tools include:

- databases,
- spreadsheets,
- semantic networks,
- expert systems,
- communications software such as teleconferencing programs,
- on-line collaborative knowledge construction environments,
- multimedia/hypermedia construction software, and
- computer programming languages.

In the cognitive tools approach, information is not encoded in predefined educational communications which are then used to transmit knowledge to students. Indeed, with cognitive tools, the need for formal instructional systems design processes are reduced. Instead of specialists such as instructional designers shaping students' learning via prescribed communications and interactions, media and technology are given directly to learners to use for representing and expressing what they know. Learners themselves function as designers using media and technology as tools for analyzing the world, accessing and interpreting information, organizing their personal knowledge, and representing what they know to others.

Productivity Tools and Cognitive Tools

It is necessary to highlight differences between this new conception and earlier perspectives of using computers and other technologies to support learning that have not been as successful as promised. In 1980, Taylor described the three major roles of computers in education as “tutor, tool, and tutee.” The tutor role (see Section Two of this report) has enjoyed some success, and promises to be even more successful as cognitive learning theories increasingly guide the design of integrated learning environments and other forms of CBI.

The computer as productivity tool in the sense defined by Taylor (1980) has enjoyed some success, especially when used to support writing (Becker, 1992a; Bruce & Rubin, 1993). However, other software tools such as spreadsheet, database, and computer-aided design (CAD) programs have failed to improve teaching and learning as much as promised by proponents of the technology as tool approach because they have been largely used in the context of traditional "instructivist" pedagogy. Goodlad (1984) described the teacher-directed, text-dominated, curriculum that characterizes most instructional practice in American schools. Ironically, software tools have often been regarded as objects for study in themselves and subjected to the same instructivist pedagogy that limits intellectual growth by students in areas such as science, mathematics, and social studies.

For example, although computer-aided design (CAD) software has revolutionized professional practices and dramatically increased productivity in engineering, architecture, and other design fields, it has had little impact in education. Industrial arts teachers (now called "technology educators" in the USA) have enthusiastically adopted CAD software into their classrooms and labs, but instead of engaging students in authentic tasks, they often "teach" students the command sets for the software outside of meaningful contexts. Students end up failing to perceive the relevance and value of CAD programs within the design professions or how to apply the software within their own design projects. As pointed out by Salomon, Perkins, and Globerson (1991), "No important impact can be expected when the same old activity is carried out with a technology that makes it a bit faster or easier; the activity itself has to change" (p. 8).

Embraced with almost religious fervor in some circles (cf. Papert, 1980), the *tutee* role for computers in education has also delivered less than promised. According to the “tutee” approach, students develop higher order thinking skills and creativity by teaching computers to perform tasks, e.g., draw a picture, using "friendly" programming languages such as Logo (Papert, 1980) and microworlds such as Karel the Robot (Popyack, 1989). Unfortunately, studies aimed at investigating the effects of Logo have failed to demonstrate the cognitive advantages promised by Logo enthusiasts (Pea & Kurland, 1987). Defenders of the "tutee" approach would maintain that the Logo implementations investigated in most studies were too brief and unfocused. Indeed, many applications of Logo described in the literature lack the "mindful engagement" that Salomon and Globerson (1987) argue is necessary for learning. More intensive Logo implementations where students are engaged in meaningful tasks over longer periods of time have demonstrated more impressive cognitive effects (cf. Harel, 1991; Papert, 1993).

Constructivist Learning Theory

In recent years, learning theory has gone through what can be called a “paradigm shift.” Constructivist learning theory is gradually gaining the same respect and attention long accorded to behavioral learning theory (Duffy & Jonassen, 1992). Constructivism concerns the process of how students create meaning and knowledge in the world as well as the results of the constructive process. How students construct knowledge depends upon what they already know, their previous experiences, how they have organized those experiences into knowledge structures such as schema and mental models, and the beliefs they use to interpret the objects and events they encounter in the world. Cognitive tools help learners organize, restructure, and represent what they know.

For constructivists, the ultimate nature of reality does not matter as much as its local nature, i.e., learners’ unique and shared constructions of reality (von Glaserfeld, 1989). According to constructivism, a teacher cannot map his/her own interpretations of the world onto learners because they do not share a set of common experiences and interpretations. “Reality” resides in the mind of each knower who interprets the external world according to his/her own experiences, beliefs, and knowledge. Learners are able to comprehend a variety of interpretations and to use them in arriving at their own unique interpretations of the world. The mind filters input from the world in making its interpretations, and therefore each learner conceives of the external world somewhat differently.

Whereas instructivists emphasize the transmission of standardized interpretations of the world by teachers and the educational media and technology they use as well as standardized assessments to test the degree to which students' understandings match accepted interpretations, constructivists seek to create learning environments wherein learners use cognitive tools to help themselves construct their own knowledge representations. Cognitive tools and the goals, tasks, pedagogies, resources, and human collaboration integral to their use enable learners to engage in active, mindful, and purposeful interpretation and reflection.

Learners as Designers

Following the maxim that the surest way to learn something is to teach it to others, the process of designing instructional materials enables instructional designers to understand content much more deeply than the students whose thinking will be constrained and controlled by the very materials they are developing (Jonassen, Wilson, Wang, & Grabinger, 1993). It follows that empowering learners to design and produce their own knowledge representations and educational communications can be a powerful learning experience.

Langer (1989) reminded us of the importance of mindfulness in learning. Students learn and retain the most from thinking in meaningful (mindful) ways. Representing knowledge is a mindful task that can be enabled by cognitive tools such as multimedia construction software or electronic spreadsheets. Cognitive tools require students to think in meaningful ways about how to use an application's capabilities and features to represent what they know. Students not only learn deeply and mindfully with cognitive tools, their opportunities for reflection are also enhanced (Norman, 1983). There is considerable evidence that reflective thinking is under-utilized in education by both teachers and their students (Good & McCaslin, 1992), a problem that cognitive tools may help to ameliorate.

The Effects of Learning *with* and *of* Technology

Salomon, Perkins, and Globerson (1991) make an important distinction between the effects of learning *with* and *of* technology:

> *First, we distinguish between two kinds of cognitive effects: Effects* with *technology obtained during intellectual partnership with it, and the effects* of *it in terms of the transferable cognitive residue that this partnership leaves behind in the form of better mastery of skills and strategies. (p. 2)*

Cognitive tools are important in both respects. Salomon et al. (1991) maintain that "the cognitive effects with computer tools greatly depend on the mindful engagement of learners in the tasks afforded by these tools" (p. 2), and that educators should empower learners with cognitive tools and assess their abilities in conjunction with the use of these tools. Such a development will entail a new conception of ability as an intellectual partnership between learners and the tools they use. Although some worry that this partnership makes learners too dependent upon the technology, many performances (e.g., instrumental music) are meaningless without the technologies which enable them. Allowing students to demonstrate learning in collaboration with cognitive tools may be attacked by parties invested in existing assessment systems. However, who would assess the ability of an artist without allowing the use of brushes, paint, and other media? Contemporary intellectual abilities should not be assessed without cognitive tools, including books and computers (Salomon et al., 1991). The very conception of knowledge is changing with a move from a conception of knowledge as possession of facts and figures to one of knowledge as the ability to retrieve information from databases and use it to solve problems (Simon, 1987).

Of course, there are many important intellectual abilities that should be performed and assessed without the aid of cognitive tools. This is where Salomon et al.'s (1991) delineation of the learning effects *of* technology become so important:

Until intelligent technologies become as ubiquitous as pencil and paper – and we are not there yet by a long shot – how a person functions away from intelligent technologies must be considered. Moreover, even if computer technology became as ubiquitous as the pencil, students will still face an infinite number of problems to solve, new kinds of knowledge to mentally construct, and decisions to make, for which no intelligent technology would be available or accessible. (p. 5)

Easy Learning?

Many instructional innovations falsely promise to make learning fun and teaching easy (Cuban, 1986). Cognitive tools make no such promises, either for learners or teachers. Instead, cognitive tools activate complex cognitive learning strategies and critical thinking. These tools not only extend the mind, they have the potential to reorganize mental functioning (Pea, 1985) and engage learners in high level generative information processing (Wittrock, 1974). In generative processing, deeper information processing results from activating appropriate mental models, using them to interpret new information, assimilating new information back into those models, reorganizing the models in light of the newly interpreted information, and using the enhanced mental models to explain, interpret, or infer new knowledge (Norman, 1983). Knowledge acquisition and integration is a constructive process involving "mindful" cognitive effort (Langer, 1989; Salomon & Globerson, 1987). When using cognitive tools, learners engage in knowledge construction rather than knowledge reproduction.

Cognitive tools are learner-controlled, not teacher-controlled or technology-driven. For example, when students build databases, they are also constructing their own conceptualization of the organization of a domain of knowledge. Cognitive tools are not designed to reduce information processing, that is, make a task easier, as has long been the goal of instructional systems design as a field. Learners can't use cognitive tools effortlessly because they require learners to think harder about the subject matter being studied or the task being undertaken with the goal of generating original thoughts that would be impossible without these tools (Perkins, 1993).

The nature and source of the task or problem is paramount in applications of cognitive tools. Past failures of "tool" approaches to using computers in education can be attributed largely to the relegation of the tools to traditional academic tasks set by teachers or the curriculum. Cognitive tools are intended to be used by students to represent knowledge and solve problems while pursuing investigations that are relevant to their own lives. These investigations are ideally situated within a constructivist learning environment (Duffy, Lowyck, & Jonassen, 1993). Cognitive tools won't be effective when used to support teacher-controlled tasks alone.

The Foundations for Using Cognitive Tools

The following principles sum up the foundations for using cognitive tools:

- Cognitive tools will have their greatest effectiveness when they are applied within constructivist learning environments.
- Cognitive tools empower learners to design their own representations of knowledge rather than absorbing representations preconceived by others.
- Cognitive tools can be used to support the deep reflective thinking that is necessary for meaningful learning.
- Cognitive tools have two kinds of important cognitive effects, those which are *with* the technology in terms of intellectual partnerships and those that are *of* the technology in terms of the cognitive residue that remains after the tools are used.
- Cognitive tools enable mindful, challenging learning rather than the effortless learning promised but rarely realized by other instructional innovations.
- The source of the tasks or problems to which cognitive tools are applied should be learners, guided by teachers and other resources in the learning environment.
- Ideally, tasks or problems for the application of cognitive tools will be situated in realistic contexts with results that are personally meaningful for learners.

Multimedia as a Cognitive Tool

Space does not allow full revelation of the effectiveness of a wide range of cognitive tools, and therefore this report focuses on multimedia construction programs as intellectual partners to enable and facilitate critical thinking and higher order learning. Although there are many different types of computer-based cognitive tools, including databases, spreadsheets, semantic networks, expert systems, multimedia/hypermedia construction software, computer-based conferencing, collaborative knowledge construction environments, computer programming languages, microworlds, and interactive learning environments (Jonassen, 1996a), multimedia construction software programs such as *HyperStudio* (Milton & Spradley, 1996) are tools increasingly available in K-12 schools, and therefore deserve special attention.

Multimedia is the integration of more than one medium into some form of communication or experience delivered via a computer. Most often, multimedia refers to the integration of media such as text, sound, graphics, animation, video, imaging, and spatial modeling into a computer system (von Wodtke, 1993). Employing relatively inexpensive desktop computers, users are now able to capture sounds and video, manipulate audio and images to achieve special effects, synthesize audio and video, create sophisticated graphics including animation, and integrate them all into a single multimedia presentation. Individuals with very little experience are becoming their own multimedia artists, producers, and publishers. Multimedia presentations are engaging because they are multimodal. In other words, multimedia can stimulate more than one sense at a time, and in doing so, may be more attention-getting and attention-holding.

In the cognitive tools approach, multimedia is not a form of instruction to learn *from*, but rather a tool for constructing and learning *with*. Learners may create their own multimedia knowledge representations that reflect their own perspectives on or understanding of ideas. Or learners may collaborate with other learners to develop a classroom or school multimedia knowledge base.

Research Results

Ideally, tasks or problems for the application of multimedia construction software as a cognitive tool should be situated in realistic contexts with results that are personally meaningful for learners. Beichner (1994) reports on a project where these conditions were met in a unique way. The subjects in this study were seventh and eight grade students enrolled in a middle school located on the grounds of a large, metropolitan zoo. The school is a magnet school emphasizing the study of science to which students are admitted based upon a lottery. A primarily qualitative, observational investigation was conducted over a two-year period while the students worked cooperatively to create interactive displays for a touch-sensitive multimedia kiosk for the zoo.

Several categories emerged out of the qualitative analysis of the data which included extensive videotapes, interviews, observations, and student-created materials. The students' strong appreciation that they were preparing multimedia materials for a real audience emerged as the core category in the analysis. Related findings were:

1) students demonstrated great concern for accuracy in their displays,
2) students quickly assumed the major responsibility for content and editing decisions despite the fact that the original task of designing the displays had been structured for them by the teacher,
3) students accessed wide ranges of science materials and sources to find the content they desired, and
4) their commitment to and enthusiasm for the project remained very high.

On the negative side, the project failed to integrate its activities into the larger curriculum in the school or to attract the participation of teachers other than the computer coordinator. The bottom line was that by establishing an environment where creative thinking about content is combined with real-world assignments, students learned the content, enjoyed the learning process, and recognized that they had created something worthwhile.

Lehrer (1993) describes the development, use, and results of a hypermedia/ multimedia construction tool called *HyperAuthor* that was used by eighth graders to design their own lessons about the American Civil War. This study exemplifies the principle that: "Cognitive tools empower learners to design their own representations of knowledge rather than absorbing knowledge representations preconceived by others." As Perkins (1986) maintains, knowledge is a process of design and not something to be transmitted from teacher to student. Thus, students should be engaged in “HyperComposition” by designing their own hypermedia. The process requires learners to transform information into dimensional representations, determine what is important and what is not, segment information into nodes, link the information segments by semantic relationships, and decide how to represent ideas. This is a highly motivating process because authorship results in ownership of the ideas in the multimedia presentation.

Students in the Lehrer study were high and low ability eighth graders who worked at the multimedia construction tasks for one class period of 45 minutes each day over a period of several months. The students worked in the school media center where they had access to a color Macintosh computer, scanner, sound digitizer, *HyperAuthor* software, and numerous print and non-print resources about the American Civil War. An instructor was also available to coach students in the conceptualization, design, and production of the hypermedia programs. Students created programs reflecting their unique interests and individual differences. For example, they created programs about the role of women in the American Civil War, the perspectives of slaves toward the war, and "not-so-famous people" from that period.

According to Lehrer (1993), "The most striking finding was the degree of student involvement and engagement" (p. 209). Both high and low ability students became very task-oriented, increasingly so as they gained more autonomy and confidence with the cognitive tools. At the end of the study, students in the hypermedia group and a control group of students who had studied the Civil War via traditional classroom methods during the same period of time were given an identical teacher-constructed test of knowledge. No significant test differences were found. Lehrer conjectured that "these measures were not valid indicators of the extent of learning in the hypermedia design groups, perhaps because much of what students developed in the design context was not anticipated by the classroom teacher" (p. 218).

However, a year later, when students in the design and control groups were interviewed by an independent interviewer unconnected with the previous year's work, important differences were found. Students in the control group could recall almost nothing about the historical content, whereas students in the design group displayed elaborate concepts and ideas that they had extended to other areas of history. Most importantly, although students in the control group defined history as “the record of the facts of the past,” students in the design class defined history as “a process of interpreting the past from different perspectives.” In short, the "design approach lead to knowledge that was richer, better connected, and more applicable to subsequent learning and events" (p. 221).

Lehrer, Erickson, and Connell (1994) conducted another study with ninth grade students who were using *HyperAuthor* to develop hypermedia about topics such as World War I, lifestyles between 1870 and 1920, immigration, and imperialism. They found similar results to the aforementioned Civil War project:

1) students' on-task behavior increased over time,
2) students perceived the benefits of planning and transforming stages of development, and

3) they developed generalizable skills such as taking notes, finding information, coordinating their work with other team members, writing interpretations, and designing presentations.

The Highly Interactive Computing Environments (HI-CE) Group at the University of Michigan has developed a multimedia composition tool called *MediaText* (Hays, Weingard, Guzdial, Jackson, Boyle, & Soloway, 1994). They believe that rather than using media to deliver instruction to learners, learners should use the media to generate their own instruction, and in so doing, learn more about the content. The HI-CE group has studied high school students creating *MediaText* stories, biographies, or instructional aids, as well as multimedia essays. Students have learned to use techniques such as mentioning, directives, titling, and juxtaposition in their documents. They have found that as students' experiences with *MediaText* increase, their documents become more integrated rather than merely annotated text. Students have been very enthusiastic about being "constructionists" (Papert, 1993), believing that they are learning more because they understand the ideas better.

The ACCESS (American Culture in Context: Enrichment for Secondary Schools) Project (Spoehr, 1994; Spoehr & Shapiro, 1991) focuses on the subjects commonly taught in high school, such as United States History, American Literature, and American Studies. The project began with teachers assembling a collection of textual, pictorial, audio, and video materials to supplement their courses. Initially, students simply used the materials for information retrieval. Students who made more extensive use of the conceptual organization built into the system benefited more than the students who used the system like a linear electronic book. Eventually, the project orientation shifted from teacher-created hypermedia materials to student-generated hypermedia documents. To make it easier for students to create interactive projects, the ACCESS user interface was improved. Students produce several small hypermedia documents of increasing size and complexity early in the school year to become familiar with the authoring process. Later, they generally take on one or more major research projects.

According to Spoehr (1994), the structures that students impose on their hypermedia knowledge vary. A few students (5 - 10%) typically underutilize the power of the programs and use a linear format (i.e., one overview card followed by a linear series of screens). Most students produce more interesting organizational types, including the "star" in which the entry point is an overview containing buttons to two or more sub-topics, each of which appears as a linear sequence, and the "tree" in which one or more main branches off the initial overview in the program are subdivided into further sub-topics which are then organized as linear sequences or divided into sub-sub-topics. Students utilizing the "tree" organization (about 25% of the students) generally show more sophisticated understanding of the topic than students using the "star" structure.

There are many ways that the ACCESS Project students appear to benefit from their experiences as interactive authors, most of which fall into the category of superior knowledge representation and higher-order thinking skills. Spoehr

(1993) reports that students who build and use hypermedia apparently develop a proficiency in organizing knowledge about a subject in a more expert-like fashion. They are able to represent multiple linkages between ideas and organize concepts into meaningful clusters. In turn, these superior knowledge representations support more complex arguments in written essays. These studies indicate that the conceptual organization skills acquired through building hypermedia/multimedia are sufficiently robust to allow students to generalize these skills to content that they acquire from other sources.

The studies reviewed above support the conclusion that designing multimedia is a complex process that engages many skills in learners. Carver, Lehrer, Connell, and Ericksen (1992) list some of the major thinking skills that learners learn and use as multimedia designers:

<u>Project Management Skills</u>

- Creating a timeline for the completion of the project.
- Allocating resources and time to different parts of the project.
- Assigning roles to team members.

<u>Research Skills</u>

- Determining the nature of the problem and how research should be organized.
- Posing thoughtful questions about structure, models, cases, values, and roles.
- Searching for information using text, electronic, and pictorial information sources.
- Developing new information with interviews, questionnaires and other survey methods.
- Analyzing and interpreting all the information collected to identify and interpret patterns.

<u>Organization and Representation Skills</u>

- Deciding how to segment and sequence information to make it understandable.
- Deciding how information will be represented (text, pictures, movies, audio, etc.).
- Deciding how the information will be organized (hierarchy, sequence) and how it will be linked.

<u>Presentation Skills</u>

- Mapping the design onto the presentation and implementing the ideas in multimedia.
- Attracting and maintaining the interests of the intended audiences.

<u>Reflection Skills</u>

- Evaluating the program and the process used to create it.

- Revising the design of the program using feedback.

The Need for More and Better Research

A search of the ERIC database indicates that there were at least 250 publications related to the use of multimedia in schools in 1997. But perusal of these articles indicates that the vast majority are based upon the perception that multimedia is something that students learn "from" rather than "with." There are very few schools where multimedia construction software is consistently used as cognitive tools, and even fewer research and evaluation studies of the type described above. Research focused on multimedia seems to be stuck in the traditional comparative paradigm. To give but one example, White and Kuhn (1997) compared elementary school students' ability to recall stories about historical figures presented to them via text, oral reading, and multimedia presentations. No significant differences were found, a finding typical of the last 50 years of media comparison research. A more fruitful investigation might have examined the effects of having students create their own multimedia representations of stories.

Ironically, while using multimedia as a cognitive tool remains on the fringe of mainstream K-12 education, most school systems are rushing to hook themselves up to the Internet to provide teachers and students with access to multimedia information on the World Wide Web. What are they going to do with access to all that multimedia? One hopeful development is taking place in the form of "constructivist learning environments" described in the next subsection of this report.

Constructivist Learning Environments

Wilson (1996) offers a definition of a constructivist learning environment:

> *[a constructivist learning environment is] a place where learners may work together and support each other as they use a variety of tools and information resources in their guided pursuit of learning goals and problem-solving activities. (p. 5)*

Table 3 presents Grabinger's (1996) list the major changes in assumptions about learning that guide the development of constructivist learning environments:

Table 3. Old versus new assumptions about learning (Grabinger, 1996, p. 667)

Old Assumptions	New Assumptions
1. People transfer learning with ease by learning abstract and decontextualized concepts.	1. People transfer learning with difficulty, needing both content and context learning.
2. Learners are receivers of knowledge.	2. Learners are active constructors of knowledge.
3. Learning is behavioristic and involves the strengthening of stimulus and response.	3. Learning is cognitive and in a constant state of growth.

4. Learners are blank slates ready to be filled with knowledge. 5. Skills and knowledge are best acquired independent of context.	4. Learners bring their own needs and experiences to learning situations. 5. Skills and knowledge are best acquired within realistic contexts. 6. Assessment must take more realistic and holistic forms.

Constructivist learning environments encompass many different applications of media and technology in education, including:

1) computer microworlds such as LEGO/Logo (Resnick & Ocko, 1994; Rieber, 1992),

2) classroom-based learning environments such as the Jasper Woodbury problem-solving programs (Cognition and Technology Group at Vanderbilt, 1992), and

3) open, virtual environments such as the CoVis project (Edelson, Pea, & Gomez, 1996).

For the cognitive scientists, learning theorists, instructional designers, and teachers involved in creating constructivist learning environments, learning refers to the development of mental states and abilities of all types including conceptual knowledge, technical skills, automatic rules, mental models, and problem-solving. Forms of higher-order outcomes such as motivation, intellectual curiosity, and the habits of lifelong learning are especially relevant because these are the most challenging types of learning to teach and learn. According to Honebein (1996), to meet these ambitious learning outcomes, developers of constructivist learning environments adhere to seven goals:

1. Provide students with experience with the knowledge construction process.
2. Provide experience in and appreciation for multiple perspectives.
3. Embed learning in realistic and relevant contexts.
4. Encourage ownership and voice in the learning process.
5. Embed learning in social experience.
6. Encourage the use of multiple modes of representation.
7. Encourage self-awareness of the knowledge construction process.

The next three subsections of this report present the research findings associated with different types of constructivist learning environments, specifically, a microworld called LEGO/Logo, a classroom-based learning environment called Jasper Woodbury, and an open, virtual environment called CoVis.

LEGO/Logo

Logo was created by Seymour Papert (1980, 1993). Early investigations of Logo as a programming language that would enable students to develop generalizable problem-solving skills were not as successful as Papert and others predicted (Pea & Kurland, 1987). More recently, new versions of Logo have been developed that involve real objects that children can program with Logo instructions. The best known of these is LEGO/Logo, which integrates a popular building block toy set with computer-controlled devices such as motors (Resnick & Ocko, 1990). With two to four students per group, children in grades 3-5 tackle design problems such as creating a LEGO walking machine. In addition to physical tasks (building robots) and mental tasks (programming actions), the students keep "Inventors Notebooks."

Early qualitative studies of children engaging in the LEGO/Logo projects yielded positive results (Lai, 1993). Resnick and Ocko (1990) summarize the results:

> *Our work has shown that Constructionist design activities offer rich learning opportunities. Far from obscuring mathematical and scientific concepts, design projects can actually give mathematical and scientific concepts a new relevance in the minds of children. Moreover, such projects can provide students with a new appreciation of how real mathematicians and scientists (not to mention architects and engineers and writers) go about their work. (pp. 127-128)*

An extension of the LEGO/Logo work has led to the development of a "programmable brick" and other objects that students can use in constructionist design projects (Resnick, 1997). Research continues at the M.I.T. Media Lab and local schools in the Boston area to test these and other microworlds (Kafai & Resnick, 1996).

Jasper Woodbury

The Cognition and Technology Group at Vanderbilt University is well known for the development of a rich set of classroom-based learning environments that address a wide range of curriculum goals including mathematics and problem-solving (Cognition and Technology Group at Vanderbilt, 1992). The most heavily researched versions of these programs are known as the Jasper Woodbury Problem-Solving Series. Available in both linear video and interactive videodisc formats, these programs are based around interesting vignettes that present middle school-age students with challenging problems to solve. For example, in one episode, a hiker finds a wounded eagle in a remote mountain site that can only be reached by personal aircraft. The students must figure out the best route to fly while dealing with variables such as wind conditions and fuel capacity. Students work in small teams to solve these problems. There are multiple possible solutions, and conditions such as wind speed can be changed to create analog and extension problems.

A year-long research project was conducted with Jasper in 16 schools in 9 states (Cognition and Technology Group at Vanderbilt, 1991). Comparing students in Jasper classes with those in traditional math classes, the researchers investigated effects in terms of mathematical problem-solving and reasoning skills, specific mathematical knowledge and skills, standardized achievement test scores, and attitudes toward mathematics. The study used both quantitative and qualitative methods.

The results were generally favorable for the Jasper students. With respect to problem-solving, the Jasper students were more skilled in identifying problems and breaking them down into smaller components that would lead to solutions. Regarding specific knowledge and skills, the Jasper students outperformed the control students in areas such as decimals, fractions, and calculations of area, perimeter, and volume. The Jasper students also were better in solving three different types of word problems. Results were less positive in the attitude and achievement areas. Although the Jasper students had more positive attitudes toward mathematics at the end of the school year, they expressed no greater desire to study math than the control students. On standardized achievement tests, Jasper students tended to perform better than the others, but the results were not statistically significant. A more recent study (Young, Nastasi, & Braunhardt, 1996) investigated the effects of immersing fifth grade students in Jasper Adventures for three months. The results were equally positive, with the Jasper students outperforming the control students in mathematical and scientific knowledge, higher level problem-solving skills, learning skills, and even creativity.

The CoVis Project

With funding from the National Science Foundation (NSF) in the USA, researchers at Northwestern University (Edelson, Pea, & Gomez, 1996) have been developing the "CoVis Collaboratory," a learning environment that combines the objects and tools of constructivism with communication and visualization tools that enable communication and collaboration among learners in a sociocultural context. Working in 40 high school science classrooms, CoVis has three key components:

1. project-based science learning pedagogy,
2. scientific visualization tools for open-ended inquiry, and
3. networked environments for synchronous and asynchronous communication and collaboration.

Projects can be designed in a variety of scientific disciplines (Edelson, 1997). Some of the most interesting involve atmospheric sciences examining issues such as "global warming." CoVis is currently undergoing extensive research and evaluation, and early results indicate that students spend their time productively, prefer CoVis activities over traditional science labs, and learn both content and scientific inquiry skills (Gomez & Gordin, 1996). Additional research is focusing on teachers' roles in the Collaboratory.

Future Needs

Up until now, most research focused on forms of computer-based learning systems has investigated how to use the limited capabilities of the computer to present information and judge learner input (neither of which computers do especially well) while asking learners to memorize information and later recall it on tests (which computers do with far greater speed and accuracy than humans). The cognitive tools and constructivist learning environment approaches described above assign cognitive responsibility to each part of the learning system that does it best. The learner is responsible for recognizing and judging patterns of information, organizing it, and representing knowledge, while the computer performs calculations, stores information, and retrieves it upon the learner's command. Nonetheless, helping people to change their mental models of computers as something that students learn “from” to something they learn “with” remains a great challenge. This probably has a great deal to do with the constructivist pedagogy that ideally guides the adaptation of cognitive tools in schools. Many teachers are uncomfortable with moving from a teacher-centered to student-centered classroom environment, and such a transformation takes considerable time and support (Fisher, Dwyer, & Yocam, 1996)

Summary

This third section has presented research concerning the effectiveness of one type of cognitive tools, i.e., multimedia construction software. In addition, research concerning the effectiveness of constructivist learning environments such as microworlds, classroom-based learning environments, and virtual, collaborative environments was reviewed. Emphasizing “learning by design,” these approaches to learning “with” media and technology show positive results across a wide range of indicators. However, longer-term research using both quantitative and qualitative methods is needed to advance the development of these approaches as well as to provide evidence of their impact.

Section 4: The Future of Media and Technology in Schools

What We Know

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Overall, fifty years of educational research indicates that media and technology are effective in schools as phenomena to learn both *from* and *with*. Historically, the learning *from* or tutorial approaches have received the most attention and funding, but the *with* or cognitive tool approaches are the focus of more interest and investment than ever before. Preliminary findings suggest that in the long run, constructivist approaches to applying media and technology may have more potential to enhance teaching and learning than instructivist models. In other words, the real power of media and technology to improve education may only be realized when students actively use them as cognitive tools rather than simply perceive and interact with them as tutors or repositories of information.

At the same time, there is a paucity of empirical evidence that media and technology are any more effective than other instructional approaches. This is because most research studies confound media and methods. Fifteen years ago, Richard E. Clark, a professor of instructional technology at the University of Southern California, ignited a debate about the impact of media on learning with the provocative statement that “media do not influence learning under any conditions” (Clark, 1983, p. 445). He clarified this challenge by explaining that media and technology are merely vehicles that deliver instructional methods. It is instructional methods, the teaching tasks and student activities, that account for learning. Clark maintained that as vehicles, media and technology do not influence student achievement any more than the truck that deliver groceries changes our nutrition. He concluded that media and technology could be used to make learning more efficient (enable students to learn faster), more economical (save costs), and/or more equitable (increase access for those with special needs).

Robert Kozma, Principal Scientist at the Center for Technology in Learning, SRI International, has challenged Clark in the debate about the impact of media and technology on learning. He argued that Clark’s separation of media and methods creates “an unnecessary and undesirable schism between the two” (Kozma, 1994, p. 16). He recommended that we move away from the questions about whether media and technology impact learning to questions concerning the ways can we use the capabilities of media and technology to influence learning for particular students with specific tasks in distinct contexts. This recommendation supports the call for more applied research described earlier in this report.

Both Clark and Kozma present important ideas. It is evident that the instructional methods students experience and the tasks they perform matter most in learning. The search for unique learning effects from particular media and technologies is ultimately futile because fifty years of media and technology comparison studies indicate no significant differences in most instances. Whatever differences are found can usually be explained by differences in instructional design, novelty effects, or other factors (Clark, 1992).

However, even though media and technology may lack unique instructional effects, some educational objectives are more easily achieved with media and technology than in other ways (Kozma, 1991). For example, certain symbol systems can only be experienced with specific technologies, e.g., slow motion is a medium afforded by film and video. A teacher could try to describe the flight of a bumble bee for hours without enabling students to perceive its mystery, whereas a slow motion video reveals the wonder of the bee's flight in seconds. A teacher could try to motivate children to appreciate the bumble bee's flying feats with words and pictures, but playing an orchestral recording of Rimsky-Korsakov's "Flight of the Bumblebee" could be far more powerful.

Media and technology have many other advantages in terms of repeatability, transportability, and increased equity of access. In addition, although the research evidence is sparse, the cost-effectiveness, cost-benefit, and return-on-investment of media and technology may be of great benefit under certain conditions, especially in developing countries (Reeves, Harmon, & Jones, 1993).

The Importance of Design and Implementation

Media and technology can be more or less well-designed depending on the talents, resources, and timelines available for the development effort. There are numerous scientific principles to guide design (Moore, Burton, & Myers, 1996; Ragan & Smith, 1996), but every instructional development effort involves large amounts of creativity and hard work. There are no comprehensive or infallible instructional design formulas (Gustafson & Branch, 1997). In fact, the design of media and technology for education retains as many aspects of a craft as it does a science. Evaluation has an especially important role in the instructional design process, but it is often underutilized (Reeves, 1997).

Implementation at the local level is as important as instructional design. In most instances, the conditions under which students actually experience and use media and technology in schools are decided within the confines of single classrooms by individual teachers. While some educational technologists have recommended that media and technology innovations should be "teacher-proof" to ensure fidelity in implementation (Winn, 1989), teacher empowerment is more likely to have positive effects than attempts to limit the prerogatives of teachers to implement media and technology as they wish (Glickman, 1997).

The Apple Classroom of Tomorrow (ACOT) Project (Fisher, Dwyer, & Yocam, 1996) illustrates the enormous importance of implementation in efforts to infuse media and technology into classrooms. In 1985, Apple Computer, Inc. began a long-term collaboration with several widely-separated school districts around the USA. Students and teachers were provided with computers and software for both school and home use, and research has been conducted in the participating schools for over a decade. The ambitious research program focused on six major questions:

1. What kinds of collaborative environments and tools are most helpful in inquiry-based classrooms?
2. What happens when teachers and students have access to rich on-line resources and remote experts?
3. How can the computer's power to represent knowledge in multiple media support learning?
4. How can the computer be used to support students in problem-solving?
5. What happens to motivation and learning when students have the same access to the sophisticated tools that experts use?
6. How can the learning and competencies accomplished in a technology-rich environment be assessed?

Coley et al. (1997) summarize the results of the first decade of ACOT research:

> *ACOT students:*
>
> *– Explored and represented information dynamically and in many forms*
>
> *– Became socially aware and more confident*
>
> *– Communicated effectively about complex processes*
>
> *– Used technology routinely and appropriately*
>
> *– Became independent learners and self-starters*
>
> *– knew their areas of expertise and shared that expertise spontaneously*
>
> *– Worked well collaboratively*
>
> *– Developed a positive orientation to the future (p. 37)*

Some of the most interesting findings from the ACOT research concern teachers and implementation. ACOT researchers found that teachers had strong beliefs about their roles and efficacy as teachers which changed very slowly as their classrooms moved toward child-centered rather than textbook-driven education (Sandholtz & Ringstaff, 1996). Teachers had to make significant changes in their classroom management styles, giving up more control to technology and students. This also changed slowly. Initially, media and technology were primarily used within the context of traditional pedagogical methods, and most teachers required years of experience before they adopted more innovative strategies such as project-based learning. Finally, teachers struggled with fundamental incongruities between traditional assessment measures and the kinds of learning occurring in their classrooms. In fact, assessment problems proved to be the most resistant to solutions and many remained unresolved (David, 1996).

The bottom line of the ACOT Project is that pedagogical innovations and positive learning results do eventually emerge from the infusion of media and technology into schools, but the process takes longer than most people imagine. Educational administrators who imagine that a summer workshop or after-school seminars by consultants will enable teachers to implement media and technology in their classrooms are mistaken. Huge investments in time and support for teachers will be especially critical if the adoption of constructivist pedagogies accompany the infusion of media and technology (Duffy & Cunningham, 1996).

The Need for Mission-Focused, Development Research

The fact that educational research is not highly valued by educational practitioners is widely recognized. A large part of the problem can be attributed to the fact that the interests of academics who conduct research and those of administrators, teachers, students, parents, and others involved in the educational enterprise are often quite different. Tanner (1998) reminds us that educational research should be focused on the mission of enhancing educational opportunities and outcomes:

> *Unfortunately, much that is taken for social research serves no social purpose other than to embellish reputations in the citadels of academe and sometimes to even undermine the democratic public interest.... Early in this century, John Dewey warned that educational practices must be the source of the ultimate problems to be investigated if we are to build a science of education. We may draw from the behavioral sciences, but the behavioral sciences do not define the educational problems. The faculties of the professional schools draw on the basic sciences, but their mandate is mission-oriented, not disciplined centered. (p. 348-349)*

This report reveals that students learn both *from* and *with* media and technology. Instructional television, computer-based instruction, and integrated learning systems have all been demonstrated to be effective and efficient tutors. There is considerable evidence that learners develop critical thinking skills as authors, designers, and constructors of multimedia or as active participants in constructivist learning environments. Further research on whether media and technology are as effective as teachers and other methods is no longer needed.

At the same time, the need for long-term, intensive research focused on the mission of improving teaching and learning through media and technology has never been greater. This research should be developmental in nature, i.e., focused on the invention and improvement of creative approaches to enhancing human communication, learning, and performance through the use of media and technology. The purpose of such research is to improve, not to prove. Further, developmental research is not limited to any one methodology. Any approach, quantitative or qualitative, is legitimate as long as the goal is to enhance education.

The recommendation to engage and invest in developmental research overlaps with advice emanating from policy-makers in the USA where the Panel of Educational Technology of the President's Committee of Advisors on Science and Technology (1997) established three priorities for future research:

> *1. Basic research in various learning-related disciplines and fundamental work on various educationally relevant technologies.*
> *2. Early-stage research aimed at developing new forms of educational software, content, and technology-enabled pedagogy.*
> *3. Empirical studies designed to determine which approaches to the use of technology are in fact most effective. (p. 38)*

The second of these priorities reflects the call for development research issued above. At the same time, the President's Committee of Advisors on Science and Technology (1997) may be guilty of placing too much faith in the ability of large-scale empirical studies to identify the most effective approaches to using media and technology in schools. In the final analysis, the esoteric and complex nature of human learning may mean that there may be no generalizable best approach to using media and technology in schools. The best we may be able to hope for is creative application and informed practice.

Summary

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This fourth and final section has summarized what we know about the impact of media and technology in schools. It works. It also points out the difficulty of answering questions about whether media and technology work better than other approaches or which applications of media and technology will have the most impact. The importance of instructional design and implementation were highlighted. This section concluded with a call for development research focused on the mission of enhancing teaching and learning through media and technology.

References

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Alessi, S. M., & Trollip, S. R. (1991). *Computer-based instruction: Methods and development*. (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall.

Alkin, M. C. (Ed.). (1992). *Encyclopedia of educational research (6th Ed.)*. New York: Macmillan.

Anderson, D. R., & Collins, P. A. (1988). *The impact on children's education: Television's influence on cognitive development* (ERIC Document Reproduction Service No. ED 295 271). Washington, DC: Office of Educational Research and Improvement.

Anderson, J. R. (1993). *Rules of the mind*. Hillsdale, NJ: Lawrence Erlbaum.

Bailey, G. D. (Ed.). (1993). *Computer-based integrated learning systems*. Englewood Cliffs, NJ: Educational Technology.

Bailey, G. D. (1992). Wanted: A road map for understanding integrated learning systems. *Educational Technology, 32*(9), 3-5.

Baines, L. (1997). Future schlock: Using fabricated data and politically correct platitudes in the name of educational reform. *Phi Delta Kappan, 78*(7), 492-498.

Baker-Albaugh, P. (1993). Definitions of interactive learning: What we see is not what we get. *Journal of Instructional Delivery Systems, 7*(3), 36-39.

Bangert-Drowns, R., Kulik, J. A., & Kulik, C.-L. (1985). Effectiveness of computer-based education in secondary schools. *Journal of Computer-Based Instruction, 12*(3), 59-68.

Becker, H. J. (1992a). Computer education. In M. C. Alkin (Ed.), *Encyclopedia of educational research* (pp. 232-235). New York: Macmillan.

Becker, H. J. (1992b). Computer-based integrated learning systems in the elementary and middle grades: A critical review and synthesis of evaluation reports. *Journal of Educational Computing Research, 8*(1), 1-41.

Becker, H. J. (1992c). A model for improving the performance of integrated learning systems. *Educational Technology, 32*(9), 6-15.

Beichner, R. J. (1994). Multimedia editing to promote science learning. *Journal of Educational Multimedia and Hypermedia, 3*(1), 55-70.

Berube, M. S. et al. (1993). *The American Heritage college dictionary*. (3rd ed.). Boston, MA: Houghton Mifflin.

Bracewell, R., & Laferriére, T. (1996). *The contribution of new technologies to learning and teaching in elementary and secondary schools* (www.tact.fse.ulaval.ca/fr/html/impactnt.html). Montreal, Quebec, Canada: Laval University and McGill University.

Bracey, G. W. (1992). The bright future of integrated learning systems. *Educational Technology, 32*(9), 60-62.

Bruce, B., & Rubin, A. (1993). *Electronic quills: A situated evaluation of using computers for writing in classrooms*. Hillsdale, NJ: Lawrence Erlbaum.

Carver, S. M., Lehrer, R., Connell, T., & Ericksen, J. (1992). Learning by hypermedia design: Issues of assessment and implementation. *Educational Psychologist, 27*(3), 385-404.

Chaves, E. O. C. (1993). The impact of computing on education in Brazil. *Educational Technology, 33*(9), 16-20.

Clark, R. E. (1994a). Media will never influence learning. *Educational Technology Research and Development, 42*(2), 21-29.

Clark, R. E. (1994b). Media and method. *Educational Technology Research and Development, 42*(3), 7-10.

Clark, R. E. (1992). Media use in education. In M. C. Alkin (Ed.), *Encyclopedia of Educational Research* (pp. 805-814). New York: Macmillan.

Clark, R. E. (1983). Reconsidering research on learning with media. *Review of Educational Research, 53*(4), 445-459.

Cognition and Technology Group at Vanderbilt. (1992). The Jasper experiment: An exploration of issues in learning and instructional design. *Educational Technology Research and Development, 40*(1), 65-80.

Cognition and Technology Group at Vanderbilt. (1991). *Assessing the outcomes of an innovative instructional program: The 1990-91 implementation of the "Adventures of Jasper Woodbury"* (Tech. Report No. 91-1). Nashville, TN: Vanderbilt University, Learning Technology Center.

Coley, R. J., Cradler, J., & Engel, P. K. (1997). *Computers and classrooms: The status of technology in U.S. schools* (Policy Information Report). Princeton, NJ: Educational Testing Service.

Collins, M., & Kimmel, M. M. (Eds.). (1996). *Mister Rogers Neighborhood: Children, television, and Fred Rogers*. Pittsburgh, PA: University of Pittsburgh Press.

Comstock, G., & Paik, H. (1991). *Television and the American child*. San Diego, CA: Academic Press.

Cuban, L. (1986). *Teachers and machines: The classroom use of technology since 1920*. New York: Teachers College Press.

David, J. L. (1996). Developing and spreading accomplished teaching: Policy lessons from a unique partnership. In C. Fisher, D. C. Dwyer, & K. Yocam (Eds.), *Education and technology: Reflections on computing in the classroom* (pp. 237-250). San Francisco, CA: Jossey-Bass.

Department for Education and Employment. (1997). *Excellence in schools* . London, UK: Department for Education and Employment.

Department for Education and Employment. (1996). *The national curriculum for information technology* . London, UK: Department for Education and Employment.

Derry, S. J., & Lajoie, S. P. (1993). A middle camp for (un)intelligent instructional computing: An introduction. In S. P. Lajoie & S. J. Derry (Eds.), *Computers as cognitive tools* (pp. 1-11). Hillsdale, NJ: Lawrence Erlbaum.

De Vaney, A. (Ed.). (1994). *Watching Channel One" The convergence of students, technology, and private business*. Albany, NY: SUNY Press.

Directorate of School Education, Victoria. (1994). *Technologies for enhanced learning: Current and future uses of technologies in school education* . Melbourne, Victoria, Australia: Directorate of School Education.

Donnerstein, E., Fairchild, H., Feshbach, N., Katz, P., & Huston, A. C. (1993). *Big world, small screen: The role of television in American society*. Lincoln, NE: University of Nebraska Press.

Dorr, A. (1992). Television. In M. C. Alkin (Ed.), *Encyclopedia of educational research (6th Ed.)* (pp. 1397-1400). New York: Macmillan.

Duffy, T. M., & Cunningham, D. J. (1996). Constructivism: Implications for the design and delivery of instruction. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 170-198). New York: Macmillan.

Duffy, T. M., & Jonassen, D. H. (Eds.). (1992). *Constructivism and the technology of instruction: A conversation*. Hillsdale, NJ: Lawrence Erlbaum.

Duffy, T. M., Lowyck, J., & Jonassen, D. H. (Eds.). (1993). *Designing environments for constructive learning*. Berlin, German: Springer.

Edelson, D. C. (1997). Realizing authentic scientific learning through the adaptation of scientific practice. In K. Tobin & B. Fraser (Eds.), *International Handbook of Science Education* . Dordrecht, NL: Kluwer.

Edelson, D. C., Pea, R. D., & Gomez, L. (1996). Contructivism in the collaboratory. In B. Wilson (Ed.), *Constructivist learning environments* (pp. 151-164). Englewood Cliffs, NJ: Educational Technology.

Farley, F. H. (1982). The future of educational research. *Educational Researcher, 11*(8), 11-19.

Fisher, C., Dwyer, D. C., & Yocam, K. (Eds.). (1996). *Education and technology: Reflections on computing in the classroom*. San Francisco, CA: Jossey-Bass.

Fletcher, J. D., Hawley, D. E., Piele, P. K. (1990). Costs, effects and utility of microcomputer assisted instruction in the classroom. *American Educational Research Journal, 27*(4), 783-806.

Gardner, H. (1993). *Multiple intelligences: The theory in practice*. New York: Basic Books.

Gardner, H. (1991). *The unschooled mind: How children think and how schools should teach*: New York: Basic Books.

Gardner, H. (1982). *Art, mind and brain: A cognitive approach to creativity*. New York: Basic Books.

Gettas, G. J. (1990). The globalization of Sesame Street: A producer's perspective. *Educational Technology Research and Development, 38*(4), 55-63.

Glickman, C. (Ed.). (1997). *Revolutionizing America's schools*. San Francisco, CA: Jossey-Bass.

Gomez, L. M., & Gordin, D. N. (1996). *Establishing project-enhanced classrooms through design.* Proceedings of the International Conference on Computers in Education, Charlottesville, VA: Association for the Advancement of Computing in Education.

Good, T. L., & McCaslin, M. M. (1992). Teaching effectiveness. In M. C. Alkin (Ed.), *Encyclopedia of educational research (6th Ed.)* (pp. 1373-1388). New York: Macmillan.

Goodlad, J. I. (1984). *A place called school: Prospects for the future*. New York: McGraw-Hill.

Grabinger, R. S. (1996). Rich environments for active learning. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 665-692). New York: Macmillan.

Greenfield, P. M. (1984). *Mind and media: The effects of television, video games, and computers*. Cambridge, MA: Harvard University Press.

Gustafson, K. L., & Branch, R. M. (1997). *Survey of instructional development models*. (2nd ed.). Syracuse, NY: ERIC Clearinghouse on Information & Technology.

Hannafin, M. J., Hannafin, K. M., Hooper, S. R., Rieber, L. P., & Kini, A. S. (1996). Research on and research with emerging technologies. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 378-402). New York: Macmillan.

Harel, I. (Ed.). (1991). *Children designers: Interdisciplinary constructions for learning and knowing mathematics in a computer-rich school*. Norwood, NJ: Ablex Publishing.

Hartley, J. R., & Sleeman, D. H. (1973). Towards more intelligent teaching systems. *International Journal of Man-Machine Studies, 2*, 215-236.

Hays, K. E., Weingard, P., Guzdial, M., Jackson, S., Boyle, R. A., & Soloway, E. (1994). Students as multimedia composers. *Computers and Education, 23*(4), 301-317.

Honebein, P. C. (1996). Seven goals for the design of constructivist learning environments. In B. Wilson (Ed.), *Constructivist learning environments* (pp. 11-24). Englewood Cliffs, NJ: Educational Technology.

Hunt, M. M. (1997). *How science takes stock: The story of meta-analysis*. New York: Russell Sage Foundation.

Johnson, J. (1987). *Electronic learning: From audiotape to videodisc*. Hillsdale, NJ: Lawrence Erlbaum.

Jonassen, D. H. (1996a). *Computers in the classroom: Mindtools for critical thinking*. Englewood Cliffs, NJ: Prentice-Hall.

Jonassen, D. H. (Ed.). (1996b). *Handbook of research for educational communications and technology*. New York: Macmillan.

Jonassen, D. H., & Reeves, T. C. (1996). Learning with technology: Using computers as cognitive tools. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 693-719). New York: Macmillan.

Jonassen, D. H., Wilson, B. G., Wang, S., & Grabinger, R. S. (1993). Constructivistic uses of expert systems to support learning. *Journal of Computer Based Instruction, 20*(3), 86-94.

Kafai, Y., & Resnick, M. (Eds.). (1996). *Constructionism in practice: Designing, thinking, and learning in a digital world*. Hillsdale, NJ: Lawrence Erlbaum.

Kommers, P., Jonassen, D. H., & Mayes, T. (Eds.). (1992). *Cognitive tools for learning*. Berlin: Springer Verlag.

Kozma, R. B. (1994). Will media influence learning? Reframing the debate. *Educational Technology Research and Development, 42*(2), 7-19.

Kozma, R. B. (1991). Learning with media. *Review of Educational Research, 61*(2), 179-212.

Krendl, K. A., Ware, W. H., Reid, K. A., & Warren, R. (1996). Learning by any other name: Communication research traditions in learning and media. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 93-111). New York: Macmillan.

Kulik, C.-L., & Kulik, J. A. (1991). Effectiveness of computer-based instruction: An updated analysis. *Computers and Human Behavior, 7*(1/2), 75-94.

Kulik, C.-L., & Kulik, J. A. (1986). Effectiveness of computer-based education in colleges. *AEDS Journal, 19*(2/3), 81-108.

Kulik, C.-L., Kulik, J. A., & Schwab, B. J. (1986). Effectiveness of computer-based adult education: A meta-analysis. *Journal of Educational Computing Research*, *2*(2), 235-252.

Kulik, J. A., & Kulik, C-L. (1987). Review of recent research literature on computer-based instruction. *Contemporary Educational Psychology, 12*, 222-230.

Kulik, J. A., Kulik, C.-L., & Bangert-Drowns, R. (1985). Effectiveness of computer-based education on elementary pupils. *Computers in Human Behavior, 1*(1), 59-74.

Lai, K.-W. (1993). LEGO-Logo as a learning environment. *Journal of Computing in Childhood Education*, *4*(3/4), 229-245.

Lajoie, S. P., & Derry, S. J. (Eds.). (1993). *Computers as cognitive tools*. Hillsdale, NJ: Lawrence Erlbaum.

Langer, E. J. (1989). *Mindfulness*. Reading, MA: Addison-Wesley.

Larkin, J. (Ed.). (1991). *Computer assisted instruction and intelligent tutoring systems: Shared goals and complementary approaches*. Hillsdale, NJ: Lawrence Erlbaum.

Lehrer, R. (1993). Authors of knowledge: Patterns of hypermedia design. In S. P. Lajoie & S. J. Derry (Eds.), *Computers as cognitive tools* (pp. 197-227). Hillsdale, NJ: Lawrence Erlbaum.

Lehrer, R., Erickson, J., & Connell, T. (1994). Learning by designing hypermedia documents. *Computers in Schools, 10*(1-2), 227-254.

Leonard, J. (1997). *Smoke and mirrors: Violence, television, and other American cultures*. New York: New Press.

Lovelace, V. (1990). *Sesame Street* as a continuing experiment. *Educational Technology Research and Development, 38*(4), 17-24.

Makrakis, V., & Yuan-tu, L. (1993). Informatics, development, and education: The case of China. *Educational Technology, 33*(9), 31-37.

Mielke, K. W. (1990). Research and development at the Children's Television Workshop. *Educational Technology Research and Development, 38*(4), 7-16.

Milton, K., & Spradley, P. (1996). A renaissance of the renaissance: Using HyperStudio for research projects. *Learning and Leading with Technology, 23*(6), 20-22.

Mitzel, H. E. (Ed.). (1982). *Encyclopedia of educational research (5th Ed.)*. New York: Macmillan.

Molenda, M., Russell, J. D., & Smaldino, S. (1998). Trends in media and technology in education and training. In R. M. Branch & M. A. Fitzgerald (Eds.), *Educational media and technology yearbook* (Vol. 23, pp. 2-10). Englewood, CO: Libraries Unlimited.

Moore, D. M., Burton, J. K., & Myers, R. J. (1996). Multiple-channel communication: The theoretical and research foundations of multimedia. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 851-875). New York: Macmillan.

Moore, M. G., & Kearsley, G. (1996). *Distance education: A systems view*. Belmont, CA: Wadsworth.

National Institutes of Mental Health (NIMH). (1982). *Television and behavior: Ten years of scientific progress and implications for the eighties* (DHHS Publication No. 82-1195). Rockville, MD: National Institutes of Mental Health.

Neuman, S. B. (1995). *Literacy in the television age: The myth of the TV effect.* (2nd ed.). Norwood, NJ: Ablex.

Norman, D. A. (1983). Some observations on mental models. In D. Gentner & A. L. Stevens (Eds.), *Mental models* . Hillsdale, NJ: Lawrence Erlbaum.

Oettinger, A. G. (1969). *Run, computer, run: The mythology of educational innovation*. New York: Collier Books.

Oppenheimer, T. (1997, July). The computer delusion. *The Atlantic Monthly*, pp. 45-62.

Oteiza, F. L. (1993). The impact of computer technology on schools in Chile. *Educational Technology, 33*(9), 25-31.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer*. New York: Basic Books.

Papert, S. (1980). *Mindstorms: Children, computers and powerful ideas*. New York: Basic Books.

Pea, R. D. (1985). Beyond amplification: Using the computer to reorganize mental functioning. *Educational Psychologist, 20*(4), 167-182.

Pea, R. D., & Kurland, D. M. (1987). On the cognitive effects of learning computer programming. In R. D. Pea & K. Sheingold (Eds.), *Mirrors of minds: Patterns of experience in educational computing* (pp. 147-177). Norwood, NJ: Ablex Publishing.

Perelman, L. J. (1992). *School's out: Hyperlearning, the new technology, and the end of education*. New York: William Morrow.

Perkins, D. N. (1993). Person-plus: A distributed view of thinking and learning. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 88-110). Cambridge, UK: Cambridge University Press.

Polson, M. C., & Richardson, J. J. (Eds.). (1988). *Foundations of intelligent tutoring systems*. Hillsdale, NJ: Lawrence Erlbaum.

Popyack, J. L. (1989). *Karel* (Computer software). Santa Barbara, CA: Intellimation.

Postman, N. (1995). *The end of education: Redefining the value of school*. New York: Alfred A. Knopf.

Postman, N. (1994). *The disappearance of childhood*. New York: Vintage Books.

Postman, N. (1985). *Amusing ourselves to death: Public discourse in the age of show business*. New York: Penguin Books.

President's Committee of Advisors on Science and Technology. (1997, March). *Report on the use of technology to strengthen K-12 education in the United States* (http://www.whitehouse.gov/WH/EOP/OSTP/NSTC/PCAST/k-12ed.html). Washington, DC: The White House.

Ragan, T. J., & Smith, P. L. (1996). Conditions-based models for designing instruction. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 541-569). New York: Macmillan.

Reeves, T. C. (1997). Established and emerging evaluation paradigms for instructional design. In C. Dills & A. Romiszowski, (Eds.), *Instructional development paradigms* (pp. 163-178). Englewood Cliffs, NJ: Educational Technology.

Reeves, T. C. (1993). Pseudoscience in computer-based instruction: The case of learner control research. *Journal of Computer-Based Instruction, 20*(2), 39-46.

Reeves, T. C., Harmon, S. W., & Jones, M. G. (1993). Computer-based instruction in developing countries: A feasibility assessment model. *Educational Technology, 33*(9), 58-64.

Reid, R. L. (1994). Reading, using, and creating media: The development of a definition of media education and guidelines for media use. In Bertelsmann Foundation (Ed.), *Media as a challenge - Education as a task* (pp. 49-55). Gütersloh, Germany: Bertelsmann Foundation.

Resnick, M. (1997). *Turtles, termites, and traffic jams: Explorations in massively parallel microworlds*. Cambridge, MA: M.I.T. Press.

Resnick, M., & Ocko, S. (1994). LEGO/Logo: Learning through and about design. In S. Papert (Ed.), *Constructionism* (pp. 141-150). Norwood, NJ: Ablex.

Resnick, M., & Ocko, S. (1990). LEGO/Logo: Learning through and about design. In I. Harel (Ed.), *Constructionist learning* (pp. 121-128). Boston, MA: MIT Press.

Rieber, L. P. (1992). Computer-based microworlds: A bridge between constructivism and direct instruction. *Educational Technology Research and Development, 40*(1), 93-106.

Robinson, S. (1992). Integrated learning systems: Staff development is the key to implementation. *Educational Technology, 32*(9), 40-43.

Salomon, G. (1992). New information technologies in education. In M. C. Alkin (Ed.), *Encyclopedia of educational research (6th Ed.)* (pp. 892-903). New York: Macmillan.

Salomon, G., & Globerson, T. (1987). Skill may not be enough: The role of mindfulness in learning and transfer. *International Journal of Educational Research, 11*, 623-638.

Salomon, G., Perkins, D. N., & Globerson, T. (1991). Partners in cognition: Extending human intelligence with intelligent technologies. *Educational Researcher, 20*(3), 2-9.

Sandholtz, J. H., & Ringstaff, C. (1996). Teacher change in technology-rich classrooms. In C. Fisher, D. C. Dwyer, & K. Yocam (Eds.), *Education and technology: Reflections on computing in the classroom* (pp. 281-299). San Francisco, CA: Jossey-Bass.

Seels, B., Berry, L. H., Fullerton, K., & Horn, L. J. (1996). Research on learning from television. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 299-377). New York: Macmillan.

Seibert, W. F., & Ullmer, E. J. (1982). Media use in education. In H. E. Mitzel (Ed.), *Encyclopedia of educational research (5th Ed.)* (pp. 1190-1202). New York: Macmillan.

Shahdan, T. S. T. (1993). Computers in Malaysian schools: Current developments and future plans. *Educational Technology, 33*(9), 48-57.

Shute, V. J., & Psotka, J. (1996). Intelligent tutoring systems: Past, present, and future. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 570-600). New York: Macmillan.

Signorielli, N. (1991). *A sourcebook on children and television*. Westport, CT: Greenwood Press.

Simon, H. A. (1987). Computers and society. In S. B. Kiesler & L. S. Sproul (Eds.), *Computing and change on campus* (pp. 4-15). New York: Cambridge University Press.

Skinner, B. F. (1968). *The technology of teaching*. New York: Appelton-Century-Crofts.

Spoehr, K. T. (1994). Enhancing the acquisition of conceptual structures through hypermedia. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* . Cambridge, MA: MIT Press.

Spoehr, K. T. (1993, April,). *Profiles of hypermedia authors: How students learn by doing.* Paper presented at the Annual Meeting of the American Education Research Association, Atlanta, GA.

Spoehr, K. T., & Shapiro, A. (1991). *Learning from hypermedia: Making sense of a multiply-linked database* (ERIC Document ED333864).

Stone, R. (1997). *New ways to teach using cable television: A step-by-step guide*. Thousand Oaks, CA: Corwin Press.

Tanner, D. (1998). The social consequences of bad research. *Phi Delta Kappan, 79*(5), 345-349.

Taylor, R. (Ed.). (1980). *The computer in the school: Tutor, tool, tutee*. New York: Teachers College Press.

von Glaserfeld, E. (1989). An exposition of constructivism: Why some like it radical. In R. B. Davis, C. A. Maher, & N. Noddings (Eds.), *Constructivist views on the teaching and learning of mathematics* . Athens, GA: JRME Monographs.

von Wodtke, M. (1993). *Mind over media: Creative thinking skills for electronic media*. New York: McGraw-Hill.

Waxman, H. C., & Bright, G. W. (Eds.). (1993). *Approaches to research on teacher education and technology*. Charlottesville, VA: Association for the Advancement of Computing in Education.

White, S. H., & Kuhn, T. (1997). A comparison of elementary students' information recall on text documents, oral reading, and multimedia presentations. *Journal of Computing in Childhood Education*, *8*(1), 15-21.

Wiburg, K. (1995). Integrated learning systems: What does the research say? *The Computing Teacher*, *22*(5), 7-10.

Wilson, B. G. (Ed.). (1996). *Constructivist learning environments: Case studies in instructional design*. Englewood Cliffs, NJ: Educational Technology.

Winn, M. (1985). *The plug-in drug/ Television, children, and the family*. New York: Viking Press.

Winn, W. (1989). Toward a rationale and theoretical basis for educational technology. *Educational Technology Research and Development, 37*(1), 35-46.

Wittrock, M. C. (1974). Learning as a generative activity. *Educational Psychologist, 11*, 87-95.

Young, M. F., Nastasi, B. K., & Braunhardt, L. (1996). Implementing Jasper immersion: A case of conceptual change. In B. Wilson (Ed.), *Constructivist learning environments* (pp. 121-133). Englewood Cliffs, NJ: Educational Technology.