DOCUMENT RESUME

ED 411 365 UD 031 900

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TITLE Learning Technologies in the Classroom: Review of the Literature.
INSTITUTION Metropolitan Educational Research Consortium, Richmond, VA.
SPONS AGENCY Virginia State Dept. of Education, Richmond.
PUB DATE 1993-02-26
NOTE 301p.
PUB TYPE Information Analyses (070)
EDRS PRICE MF01/PC13 Plus Postage.
DESCRIPTORS *Computer Uses in Education; *Curriculum Development; Educational Environment; *Educational Technology; Elementary Secondary Education; Inservice Teacher Education; Program Implementation; *School Restructuring; Teacher Attitudes; Teaching Methods; Training

ABSTRACT

This literature review focuses on the application of technology (primarily the computer) to education. No single vision drives the infusion of technology into the schools, although social, vocational, pedagogic, and catalytic rationales have been proposed. Technology has a role in school restructuring by standardizing and automating procedures. When the goal of restructuring is to bring about a learning environment that emphasizes complex problem solving and decision making, technology has much to offer the restructuring movement. It can help create a richer learning environment and can support either traditional or learner-centered instructional philosophies. Computers can have a significant impact on teaching style as they empower the teacher to serve as a facilitator of learning rather than a transmitter of information. There seems to be a sequence from teaching without technology to becoming an accomplished integrator of technology into the classroom. Although instructional use and technology applications and resource applications differ according to grade level, teacher use seems to be quite similar across instructional levels. Any plan to implement computer use in the schools must feature teacher training and work to solve issues of student access to hardware and software. Although it has been demonstrated that educational technology can do the things it promises, there is still a lack of systematic implementation models. Appendixes present tables and figures illustrating the review and the focus questions that guided the review. (Contains numerous references.) (SLD)

LEARNING TECHNOLOGIES IN THE CLASSROOM:
Review of the Literature

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LEARNING TECHNOLOGIES IN THE CLASSROOM:
Review of the Literature

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February 26, 1993

EXECUTIVE SUMMARY

The literature review focuses on the application of technology (primarily the computer) to education. It is organized to present background information to familiarize the reader with basic issues relevant to teaching with technology, the restructuring of American schools, and the performance one could expect from the infusion of technology into schools and classrooms. Furthermore, it summarizes findings regarding access and equity, inservice and preservice education, and funding and facilities.

THE TECHNOLOGY RATIONALE

After a decade of enthusiasm, there still is no single compelling vision driving the infusion of technology into the schools; four have been projected.

1. **The Social Rationale.** Policy makers want to be sure that all children are "aware and unafraid of how computers work". They should be prepared to understand computers and be aware of their role in society because computers are pervasive in industrialized countries.

2. **The Vocational Rationale.** There will be employment opportunities for individuals who have the proper computer skills. Therefore, it's an important competency to develop.

3. **The Pedagogic Rationale.** Students can learn from computers. There are advantages over other traditional methods in using computers to learn.

4. **The Catalytic Rationale.** Computers are catalysts to change schools for the better. They can facilitate change. They are symbols of progress. They encourage learning (Hawkridge, 1990).

TECHNOLOGY AND RESTRUCTURING

Technology by itself cannot restructure schools, however, schools cannot reach excellence for all children without it. The conclusion drawn by many is that technology has an essential -- though not independent -- role to play in boosting educational productivity.

The role of technology in support of restructuring is an evolving one. It can support traditional models by standardizing and automating procedures. Applications such as CAI, mastery learning curriculum, and programmed skill packages make existing practice better.

However, it is believed that only certain learning tasks can be routinized. If the goal of restructuring is to move to a learning environment that emphasizes complex problem solving, decision making and value judgments that are not easily codified, then technology has much to offer the restructuring movement.

In fact, there is a growing consensus that any major investment of time and effort in technology can only be justified if teachers use the technologies as tools, in ways that emphasize application, word processing, simulation, and program problem solving.

The pace of technology makes assimilation difficult, but there seems to be a natural progression in teacher use of technology. Firstly, observers believe you change the way people think about teaching and learning, and then apply technology. You cannot apply technology first and expect to change the way people think because they will just apply the technology in old ways.

Secondly, as teachers become more familiar with technology, they use it less for drill and practice and more for word processing and databases. Restructuring schools can use this natural progression by organizing for it, putting technology into the hands of teachers, integrating it into the curriculum, allowing experimentation by teachers, inferring knowledge about possible uses after teachers have reached a comfort level with the technology, providing adequate time to learn and develop, providing sufficient amounts of hardware, keeping success stories in front of teachers and removing the classroom from isolation.

TECHNOLOGY AND INSTRUCTION

Technology can help create a rich learning environment. This potential depends upon the teacher's ability to integrate the technology into everyday classroom activities. Integration requires a great deal of effort by the teacher. However, used appropriately, it can reinforce, supplement and extend student skills.

Technology can also support either the **traditional or learner centered instructional philosophies.** Traditional teachers use it as a medium for drill and practice and tutorials. Learner centered teachers use it as a tool for problem solving, taking advantage of the word processing, database, spread sheet, graphics and telecommunication applications. Technology enables teachers to reinforce their instructional philosophy or transform it.

If adopted, technology can have an impact on teaching style, instructional philosophy and goals at each grade level, resource allocation and on instructional materials.

One of the most significant impacts of the computer is on **teaching style**, even though most observers feel there is no "best way" to teach or learn. While some people think both the teacher and learner-centered approaches have their places, the technology empowers the teacher to function as a facilitator of learning rather than acting in the traditional role as transmitter of ready made information.

It is generally acknowledged that teachers are **critical to integrating technolog**y into the learning process. They make the decision to integrate the technology, make it an internal part of their technique or use it as an add-on, a "treat" or reward. The general consensus is that as a result of the adoption of technology, the **teacher's role** changes from presenter to coordinator of learning resources and frees the teacher to work individually with students. They move from being the "sage on the stage" to the "guide on the side."

There seems to be a sequence from teaching without technology and becoming an **accomplished integrator**. Teachers adopt innovations in light of their own goals, accustomed practice, culture of their community and school, and their own interpretations of the information they receive about new approaches. Therefore, it is appropriate to find uses of technology that support the instructional philosophies teachers have identified.

Teachers vary the use of technology based on their curriculum goals, assessment of student need, and preferred teaching approach. Technology-using teachers use technology in different ways: drill and practice, tutorials, simulations, problem solving and productivity tools. The types of instructional decisions they make are dependent on their knowledge of possible uses, availability and ease of use of the technology, and their instructional philosophy. As their philosophies change, as in restructured schools, the technologies and applications they use will change also. For example, teachers generally start with drill and practice and move to applications.

There are grade level differences in the use of technology. For example, **instructional use differs** by grade level. In elementary, drill and practice and tutorials are emphasized. Middle schools and high schools emphasize word processing, discovery, problem solving and productivity tools. Its potential is to not only reinforce lessons, but as a tool to support the development of minds from pre-adolescent through adolescent phases.

Technology applications are also emphasized at different graded levels. At the elementary and middle schools, one finds more use of integrated learning systems (ILSs) than at the high schools. And, in the high schools, there is more use of video disc, CD ROM and database than the elementary and middle schools.

Teachers' use, on the other hand, is similar across all three levels, except that high school teachers don't use it to create banners for room decorations as do elementary and middle school teachers.

Curricular emphases also differ by grade level. In elementary, computers are used in math and language arts. Middle school use is more in general math and sciences. Mathematics and science are the focus in high schools. One of the most difficult barriers in **curriculum reform** has been the reluctance to drop existing content. Yet, technology using teachers are four times more likely to introduce new topics and five times more likely to de-emphasize certain topics than non-technology using teachers.

Resources also appear to be allocated differently across grade levels. For example, elementary schools seem to prefer to distribute their computers. In 1986, only seven percent of the K-6 schools had at least eight computers linked while high schools had linked twenty-four percent of the high schools.

Finally, the impact of technology on **instructional materials** has not been fully felt as of yet. However, several incidents portend future developments. The definition of the textbook is beginning to change. For example, the technology to produce customized textbooks exists, but it is not being utilized on a large scale. Most recent trends include the following activities. In Texas the word "textbook" means any instructional material that meets curriculum requirements. In California it means textbooks and video discs. Florida law allows the state board of education to adopt technology in the textbook process (Mageau, 1991). The 1992 New Grolier Multimedia Encyclopedia is a CD ROM based multimedia encyclopedia containing 33,000 articles. It has new multimedia elements such as digitized video segments of historical events, famous people, and automation sequences.

TECHNOLOGY AND STUDENT PERFORMANCE

In general, student **performance can be improved** through the use of learning technologies. Specifically, a meta analysis of 184 studies of learning technologies concluded that, on average, a student performing at the 50th percentile will perform at the 62nd percentile on the standard normal curve.

It is also clearly evident that **performance varies**. Therefore, strengthening implementation protocols and processes will produce substantially better results. For example, the fluctuation of results by type of achievement measure indicates that teachers must address alignment and assessment issues prior to assessing the results of their instruction.

Purchase decisions can also be improved when based on a clear description of the educational problem the user is trying to solve or the opportunity they are trying to provide students through learning technologies.

The following points illustrate the **impact of technology on performance**:

- CAI and ILS applications are effective for teaching mathematics and language arts. There is preliminary evidence that multimedia may produce similar results in science.
- Newer technology applications are more effective than older applications.
- The technology in mathematics, language arts, and science proved to be educationally significant in terms of results.
- The effect of technology on at-risk students is promising.
- Learning technologies raised scores 1) substantially on locally developed teacher/researcher district developed examinations; 2) moderately on state/regionally developed criteria referenced tests; and 3) moderately on standardized norm referenced tests.
- The write to read results were negligible and not educationally significant for reading, and substantially and educationally significant for writing.
- ILSs demonstrated educationally significant results on standardized tests; and with at-risk students.
- There were few studies found that examined the effectiveness of the use of technology as a tool. In fact, these applications require that new assessment strategies be developed.

Finally, if technology is to demonstrate its potential value, then there needs to be a movement away from standardized test evaluations and toward authentic assessments.

TECHNOLOGY AND ACCESS

Computers are pervasive in the schools. If progress is judged on the amount of hardware and number of students using it, then progress has been made. For example, in 1989, the ratio of students of computers to schools was 6/1 at the elementary level and 21/1 at the high school level. However, **access** continues to be an important issue regarding equity, gender, location of the computers and disparity.

The findings on **equity** are mixed and somewhat confusing. On the one hand, the ratio of students to computers was found to be nearly twice as favorable for schools containing low SES students. Yet, others report that students with high minority enrollment have less than one-half the computer access compared to students with majority enrollments. Socioeconomic factors play a disturbing role in low SES student access to computers, particularly at the elementary school level. This trend disappears at middle school and high schools, but it may be too late by then.

Equity in school computer use must involve not only equal access, but also consideration of the learning needs of poor, minority and female students. This means that equity must be a priority, a part of every policy decision and every classroom action.

Gender differences are also of concern. It has been reported that instruction based upon cooperative modes rather than competition is preferred by females. If this is the case then the move from traditional uses of technology to more contemporary use as tools has the potential to reduce gender bias and make the technology more attractive.

Some observes feel that **placement of the computers**, rather than the total number, is the key variable in defining access. The literature portrays some doubt as to where the computers belong in the schools. But it is clear that student utilization depends on organization of computers in labs or classrooms and the availability of appropriate software.

Other problems exist with **connectivity** beyond the school day. The futurists say it won't be a problem because in the future, every student will have a lap top with a modem to access whatever information or tools they need. Though not considered a serious problem by most observers, it is a concern today.

Telecommunications is linking education to the world. It is being used in education to increase information access and reduce **disparity** through television, satellites and distance education. These technologies are eliminating barriers of time, geography or local expertise. Rural students are using them for meeting graduation requirements and urban students use them for low cost field trips. Minnesota and Memphis demonstration sites use them for distance tutoring. Several states use it to deliver courses to meet graduation requirements. Others use it to enrich the classroom through programs such as CNN Newsroom and World Classroom.

Finally, what does seem to be related to exemplary uses of technology is **administrative leadership**. Administrative actions to insure equity in access to different categories of students such as sex, ability, and ethnic group are three times as likely to be found in schools where exemplary technology-using teachers are found.

TECHNOLOGY AND TRAINING

Any plan to make greater use of technology must include teacher training. Yet, relatively little scholarly attention has been paid to changes in the role of the teacher due to technology intensive classrooms. However, the research is clear on two points: 1) the process by which teachers appropriate technology is more complex than that by which they adopt other changes, and therefore it takes time -- five to six years -- to master teaching with computers, and 2) the lack of teacher training is perceived as an issue most likely to impede the advancement of educational technology, second only to funding in importance.

It takes about five years to become an accomplished technology user. It requires the teacher's motivation and support from colleagues, schools, school districts, colleges and departments of education.

Teacher training and preservice education can both be improved by understanding the characteristics of the five percent of the teaching force who are considered exemplary technology-users. For example, they had 1) more formal training in using computers and teaching with computers, 2) more specific training on how to integrate software into existing lessons, how to organize class activities to allow computer use during class time, and word processing and other computer applications, 3) learned applications through self instruction and spent twice as many hours personally working on computers at school, and 4) progress from applications that directly reinforce what is being taught, such as drill and practice, to those that are more expansive, such as tools.

The **types of training** required are: 1) skills needed to work with technology, 2) education that promotes vision and understanding of the possibilities of state of the art applications of technology, and 3) skills to revise and modify courseware. A three-tier approach to training is recommended. The first tier involves the minimum expertise needed to operate the technology. The second tier involves new educational skills: classroom management and the integration of technology into the curriculum. The third tier involves annually skill updates to allow for new developments. Exemplary technology-using teachers recommend that training start with one application that is easily used and quickly adopted.

The literature identified colleges of education, school districts, regional service centers, professional organizations and private corporations, including vendors of hardware and software as potential deliverers of technology training. Regional centers are playing a growing role in training. In fact, seventy-five percent of the states sponsor training through centers, and twenty-two states use electronic networks to provide training.

With regard to **preservice education**, the perception is that prospective teachers are: 1) not being educated to integrate technology into the classroom, 2) being taught by instructors who lack expertise with the computer,3) ill-prepared to teach with computers, and, 4) attribute less value to using computers than business school majors.

However, in 1988, ten of the fifteen largest teacher training instruction programs included a computer literacy requirement for graduation. Two years later, the number had risen to twelve. There is a trend among colleges to start with separate classes before proceeding to offer more comprehensive approaches.

Several conditions must be met if colleges can produce teachers who are knowledgeable and comfortable with teaching with technology. For example, students and faculty must have access to hardware and software equivalent to what they will find in the classrooms they will enter. Expanded activity requires expanded capacity.

Prospective teachers should be immersed in an environment that requires them to use technology to improve communications, increase productivity and enhance the teaching/learning process. Several models appear in the findings that are worth investigating.

Based on the existing research, it is difficult to predict the effects of technology on the skills required for teaching. A basic premise is that teachers will need to possess all the skills currently required in addition to the new skills made necessary by technology. There are few explicit pedagogical models existing for teachers to emulate when trying to integrate technology and teaching. This condition has led school districts to establish the operational criterion for selection as "interested, experienced, and appropriately educated."

However, year 2000 educators (whether they are classroom teachers, central office, or state department personnel) will have to be engaged in a range of functions rather than perform only specialized tasks. Instead of increasing specialization, all members of an organization must possess a core set of knowledge skills and attitudes that are redundant in all organizational members such as collaborator, mentor/mentee, planner, researcher, and seeker.

TECHNOLOGY AND FUNDING, FACILITIES AND EQUIPMENT

Funding has been and still is the most important issue in the advancement of educational technology. At the current rate of investment, states can expect broad experimentation, continuing equity questions and slow but steady improvement in access and software.

The state has a special role in funding to provide equal access within schools and within classrooms. State funding is mixed with funding from the federal government, business and industry, software publishers, hardware vendors, and private foundations. Currently, the major sources are 30% state, 10% federal, and the majority (60%) from local funds. There is a general consensus that all potential sources need to be encouraged to participate because the size of the investment is large. More importantly, what is needed is a steady funding source that can provide a steady base funding source.

Several **funding options** have been suggested to get a more steady funding base at the legislative level such as: adjustments in the foundation program, earmarking permanent school funds, and short-term bond financing. Creative financing strategies such as grants and contributions from the private sector, using the textbook fund to purchase software, low interest loans, and special innovation funds have also been suggested.

The most widely held **justification for state funding** is to improve access and support integration of technology into the everyday life of students and teachers. State funding priorities have been distance learning, software and video preview centers, electronic bulletin boards, and development of instructional TV. School districts are using federal and local funds for technology hardware.

Telecommunication and computers are merging. This fact is putting pressure on current **facilities** and requires design changes in new schools. The most noticeable changes will be in the classrooms and laboratories. More space and flexibility of costly equipment will be needed such as science and language laboratories and closed circuit television.

The **equipment** most commonly associated with the modern classroom are instructional television, the video cassette recorder, the microcomputer, and the interactive computer based video disk machine.

TECHNOLOGY AND PLANNING, IMPLEMENTATION AND EVALUATION

Planning for the use of technology should be focused on four key concepts that characterize the direction of educational technology. First, educational technology will be **interactive and controlled by the learner.** It will engage the student and enhance decision making and problem solving. This fact alone will revolutionize the classroom and the place we call school.

Secondly, educational technology will make **resources more accessible**, changing the place of schooling, the role of the teacher, and the relationship between teacher and learner. With massive data bases, with visual images immediately available, the teacher will no longer be the holder and dispenser of information and the trainer of skills. Teachers will be more like coaches, mediating technology, diagnosing learning styles and proficiencies, and facilitating a variety of strategies.

Thirdly, educational technology will be **more affordable**. It will be in reach of all learners, both in and outside the school.

Finally, educational technology will be **integrated**, bringing together may tools in an exiting and creative fashion. The merging of computers and video technologies with telecommunications is already in the current system (Farley, 1992).

Planning for technology is an **important state role**. The justification for state involvement revolves around equity of access to resources, coordination of resources, and developing infrastructures that allow information sharing and alleviate disparities. The planning model chosen by a state is generally dependent on tradition and the manner in which they handle major reform efforts.

States use a variety of mechanisms to develop state technology plans. They can be conceived through a task force structure composed of key constituents who develop a consensus around the components of a master plan. These constituents would be external to the department of education and would include businesses, the legislature, professional associations and members of the general public. The task force is responsible for presentation of the plan to the appropriate decision making bodies. In this model, the department of education acts as staff to the task force, providing information and being responsible for the mechanics of putting the plan together. Secondly, once the decision-making bodies (such as the State Board of Education) review the plan, they are responsible to amend the plan in accordance with the decision-making body's recommendations. Finally, under this model, the Department reverts to its managerial role of implementing the plan through budget requests, and if successful, through implementing decisions and tactical plans to implement the components that survive the decision-making process.

A second model used is to develop the Master Plan in-house. While this committee is generally composed of department members, it also includes members of professional associations and the professional community. This model generally has some public input and review process such as public comment periods in the drafts that are forthcoming from this process. At the conclusion of the work, the plan is submitted to the executive level of the organization who recommends changes, and then to the public decision makers for review and prioritization of components of the plan. After producing the first draft of the plan, the department's role is similar to the task force model.

No matter which overall planning structure is utilized, the process will generally use an adoption, political market place, a concern based strategy, or some combination of the three, such as strategic planning process. Each strategy has its strengths and weaknesses and they are detailed in the findings.

The **state master plans have focused** on hardware acquisition, software acquisition, evaluation, distribution, staff training and development, electronic linking of agencies and sources, integrating technology into instruction, encouraging local school divisions to plan for the use of technology prior to the purchase of equipment, and providing financial incentives and cooperative purchasing agreements.

Distance learning has become a staple of state efforts and is evident in nearly all state plans. Some leading states have created centers for research, development, dissemination, demonstration and evaluation of technology and software. Others have created demonstration schools. The emphasis there is to marshall all the resources for integrating technology into the daily life of a school. Others have focused on creating electronics networks to connect the schools to the world. Others have moved to establishing a statewide administrative management information resource.

State plans generally require or encourage school district planning. If there are state funds available for technology, they require it prior to the release of funds. Some may even help school districts write informal, appropriate plans on the use of technology and help determine needed software.

It has been demonstrated that **technology can do the things it promised**. A majority of states have developed plans. Many school districts have developed plans. However, judging from the incomplete diffusion of technology in the schools, it is apparent that either the best uses of technology have not been reached or there has been insufficient funding for its installation.

The lack of **systematic implementation models** to follow, incentives for individual teachers, limited amounts of equipment and the unsystematic use of software, primarily at the lower grades, have been identified as barriers. The facilitators of technology implementation are seen as the attitudes of teachers and administrators toward the innovative uses of technology, a good understanding of user perceptions, communication of possibilities and successes, and allowing sufficient time for a consensus to be established. Most essential is the existence of a core of enthusiastic technology-using teachers and a dynamic supportive administration that, together, provide the leadership to design and implement the plan.

The **role of evaluation** is nothing less than to provide: 1) policy makers with the information they require to contribute to their decisions to enhance or expand technology, and 2) designers' and users' information which will contribute to improvement, continuance or expansion of their programs. As important as evaluation is the state role that has been limited.

Most progress has been made by learning by doing. A few states require that the components of their master plans be evaluated periodically. Some require an evaluation component for every technology project they fund. California has been a leader in this area. They require formative evaluations of each of their demonstration schools. Cost-effectiveness has been much proposed and advocated, but there is little evidence that rigorous studies have been conducted or utilized.

Technology
Review of the Literature

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PREFACE

This review was commissioned by the Virginia Department of Education during the development of the state master plan for Technology. Fifty-one questions were posed to guide the review (see Appendix B). The information found in this review and its supportive annotated bibliography makes it possible to approach technology decisions with a healthy blend of informed instinct and analytical deliberation.

This review focuses on the application of technology (primarily the computer) to education. It is organized to present background information to familiarize the reader with basic issues relevant to teaching with technology, the restructuring of American schools and the performance one could expect from the infusion of technology into the schools and classrooms. It summarizes findings regarding access and equity, inservice and preservice education, and funding and facilities.

Considerable research has been conducted on the effects of technology, access to technology, gender bias, and surveys of teacher use, but little scholarly attention has been paid to the changing role of the teacher in a technology intensive classroom or to technology's relationship to restructuring. It is in these two sections that this review extends the research and makes its major contribution.

The project team was composed of research assistants Jeanne Schlesinger, Amanda Parks and John Pisapia, project director. Ms Judy Scardina provided able assistance in document formulation and editing.

John Pisapia
Project Director

INTRODUCTION

The children of our society will never again know schools without computers.
(Roblyer, 1988)

The 1980s recorded an impressive record of growth in the number of computers placed in the schools. Becker (1986) in his national survey reported there was limited access to computers in 1985. But by 1987, ninety-five percent of American schools had computers used for instruction (U.S. Congress, OTA, 1988 cited hereafter as "Power on!", 1988). This growth is being shaped more by external forces than technology's potential contributions to teaching and learning, or than the internal influences of its educational professionals. It has been the pressure of vendors, media, legislators and some educators as an essential and easy-to-use key to educational excellence that has sustained the growth. Today the use of traditional media has become routine in most elementary and secondary schools.

Despite technology's promise, its potential to transform and customize America's classrooms remains largely unrealized (NGA, 1990). The problems were predictable: limited student access to computers (Becker, 1987), little teacher interest in having computers in their classrooms (Norris & Lumsden, 1984 cited in Baker, 1987) and few strong indicators describing the effectiveness of using instructional technology.

For these and other reasons, some observers fear that a public and professional backlash fueled by the unsubstantiated claims made by some advocates will gather steam. They claim there is little evidence that the computer has made major contributions to learning in the classroom other than to help learners know how to use it. They also note that educational innovations are prone to wither in the face of public and professional backlash.

PRESSURE FOR ADOPTION

Congress, governors, states, learned societies and the work place have all pressed for the infusion of technology.

In the early 80s, only a handful of states were actively involved in education technology. Today nearly every state is involved. State activities vary based on tradition, priorities, resources and needs. Some states have imposed mandates and/or controls on teachers, schools and divisions. Others have focused on building local capacity and have encouraged local decision-making.

In 1988, the United States Congress directed its Office of Technology Assessment to determine if further federal involvement was warranted. In a landmark study they found: a) technology's potential is largely unexploited, b) the role of the classroom teacher is critical, c) most teachers want to learn technology, d) adapting technology is complex, and e) technology makes teaching more challenging before it makes it easier (Power on!, 1988).

Learned societies have also applied pressure. In 1988, Information Power; Guidelines for School Library Media Programs was published. And the International Society for Technology in Education (ISTE) described the potential technology offers education to help decision-makers identify steps they must take to respond to the charge given them by the President and the Governors (Braun, 1990).

The adult work environment has also applied pressure. For example, Sheingold (1991) reports that computer-based technology has been brought into schools during the past decade largely because the technology was seen as important in and of itself, because it was an increasingly central component of the world of adult work.

Even this quickened involvement has not had the effect desired by governors. In fact, they noted that little progress was made to use state powers to help schools reorganize using technology and other means, so that they become more efficient and effective (NGA, 1990). Many believe the state must play a more active role if technology achieves its potential for improving education, a role they say is supported by societal needs for educated citizens and workers and traditional concern for access/equity.

THE TECHNOLOGY RATIONALE

After a decade of enthusiasm, there still is no of a single compelling vision driving the infusion of technology into the schools; four have been projected.

1. **The Social Rationale**. Policy makers want to be sure that all children are "aware and unafraid of how computers work". They should be prepared to understand computers and be aware of their role in society because computers are pervasive in industrialized countries.
2. **The Vocational Rationale**. There will be employment opportunities for individuals who have the proper computer skills. Therefore, it's an important competency to develop.
3. **The Pedagogic Rationale**. Students can learn from computers. There are advantages over other traditional methods in using computers to learn.
4. **The Catalytic Rationale**. Computers are catalysts to change schools for the better. They can facilitate change. They are symbols of progress. They encourage learning (Hawkridge, 1990).

The rhetoric supporting these visions is supported by the following several lines of thought:

- Learning technologies eliminate routine tasks which are characteristic of technological change. Computers offer new approaches, not just more efficient ways of doing the same thing. Freed of excessive mechanics, students can pursue more challenging and creative projects (Marshall et al., 1988).

- Or, learning technologies will help produce a more effective education for the citizens of a modern information society (Roblyer, 1988).
- Or, learning technologies are a cost-effective way to deliver an array of services tailored to needs of rural schools and handicapped, disadvantaged, or otherwise at-risk students.
- Or, learning technologies are tools to enhance teaching methodology, making lessons more effective, interesting and accessible. Technology at its best allows us to stimulate and explore.
- Or, learning technologies transform schools into places where knowledge is created rather than place where knowledge is transferred.
- Or, learning about technology itself is an imperative simply because it is a major force in the world economy.
- Or, more and more offices depend on their employees to work cooperatively on every aspect of a project (Hoctor, 1991).
- And, while not heard often, the application of technology has potential to enhance attractiveness of teaching profession (Marshall et al., 1989).

The critics counter that despite the increasing number of computers in schools, there has been minimal significant impact in the revitalization and transformation of teaching and learning. They say:

- Technology is still regarded as a reluctantly accepted in-law in the education family, not an asset but an add-on.
- In many cases, educational lecture-based practice is at odds with the best applications of technology
- Technology has been reactive rather than proactive.
- We know it's important; we struggle to find ways to use it.
- Finally, it costs a lot and few people use it. For example, computer acquisition and software utilization continue to command a significant fraction of institutional budgets. Yet, a small minority of teachers and

students are said to be computer users. Becker (1992) reports that only five percent of America's teachers are considered heavy users of technology.

DIRECTIONS

Even with their detractors, it is likely that we are at the start of a steady and significant rate of growth in use of learning technologies. Eight factors support this prediction:

1. Research evidence supporting effectiveness is quite strong and continues to grow.
2. Declining hardware costs make learning technologies more cost-effective.
3. There is a trend towards individualization of instruction.
4. Learning technologies can increase productivity of students and teachers.
5. There is a growing software infrastructure.
6. Learning technologies are improvable; newer software means better software.
7. The average level of teacher computer literacy will continue to grow steadily for many years even though it will remain lower than what might be desired (Mourasand & Ricketts, 1988).
8. Computers contribute to a hidden curriculum: a) mastery over technology, b) development of a problem-solving attitude or approach toward academic disciplines, and c) raising standards for results (Mourasand & Ricketts, 1988).

For three years, 1989, 1990 and 1991, Donald Ely has tracked trends in educational technology. He predicts we can expect to see that:

1. computers will be present in almost all public schools.
2. there will be a heightened concern for design and development of educational products.
3. there will be an increasingly important role for the evaluation of instruction.

4. there will be an increase in the use of research and development to solve current teaching and learning problems.
5. interactive video will gain acceptance as an R & D product, but not in the schools.
6. distance learning will become established as a major vehicle of instruction/training at all levels.
7. there will continue to be a preoccupation among practitioners with professional education in the field.
8. telecommunication will become a link connecting education to world.
9. the teacher role will change dramatically.

THE REVIEW OF LITERATURE

The trends identified above are explored in this review of the literature from 1987 to 1992. The a list of questions to focus the review was prepared by the Virginia Department of Education (see Attachment B).

Sources of Information. The collection process was conducted by computer search of three data bases through Lockheed's DIALOG Online Information Service, ERIC: Research in Education and Current Index to Journals in Education; Comprehensive Dissertation Abstracts International (DAI), Psychological Abstracts, and the Government Printing Office. The references are found in Appendix B. In addition an annotated bibliography and resource file were prepared and are available form the Virginia Department of Education to accompany this review.

Meta-analytic and empirical studies retrieved in these computer searches were the primary sources of data. A second source was the supplementary set of studies located by branching from the bibliographies in articles retrieved by computer searches. A third source was unpublished evaluation documents, acquired by a direct mailing of 3000 requests for studies using mailing lists of the Association for Educational Communications and Technology, American Association of School Administrators and the Chief State School Officers. A fourth source was reviews of literature previously conducted.

Selection and Characteristics of the Databases. The bibliographic search produced over 940 titles, 240 of which were discarded based on a review of the abstracts. The remaining 700 articles and their bibliographies were examined. Another 60 pieces were discarded after reviewing the articles because the articles were unsubstantiated opinions, contained design flaws, or did not have relevance to the focus questions. The studies and literature found in this search demonstrate the depth of information available for this review. (A separate annotated Reference List is found in the companion piece to this document).

The Review Process. The literature gathered was divided into primary and secondary sources and substantiated opinion pieces. The primary sources were reviewed first. Themes were teased out and facts were extracted. Initial drafts were written and then the secondary sources were reviewed to supplement and verify the review of primary sources.

ORGANIZATION OF THE REPORT

The review is organized in seven sections: technology and instruction, technology and restructuring, technology and student performance, access and equity, teacher training, funding, facilities and equipment, and planning, implementation and evaluation.

In each section a summary is presented first. The summary is constructed to first answer the focus questions, followed by the findings that support the summary statements. Information about what we know and what we do not know about technology is displayed in the findings.

Section 1. **Technology and Restructuring**

The purpose of this section is to examine the potential of technology to further the goals of restructuring America's schools. Is it essential? What new curricular offerings are possible? What new instructional strategies does it enhance? Does the use of technology change as restructuring becomes more established?

Section 2. **Teaching and Instruction**

The purpose of this section is to examine the impact of technology on educational philosophies, goals, and curricula, instructional roles, materials, strategies, and decision-making.

Section 3. **Technology and Student Performance**

The purpose of this section is to examine the results of using technology in instruction. Do they work? Are there more cost-effective technologies? Does assessment have to change to promote an outcome focused education? Secondly, the section examines alternate methods of evaluating technology based learning to insure that administrative, teacher, parent and student information is captured along with test results.

Section 4. **Access**

The purpose of this section is to examine student, teacher, and community access to technology. Secondly, the equity issues related to allocation of resources across grades, building areas, program areas, schools and school divisions will be examined. Finally, technology's potential to eliminate disparity and increase information access through telecommunications will be discussed.

Section 5. **Training**

The purpose of this section is to examine the strategies being utilized to enhance preservice and inservice technology skills of teachers and administrators. The characteristics of the teaching force will be described and competencies of the year 2000 educator will be projected. The status of current inservice training models and preservice education models will be examined to determine if there are effective ways of teaching prospective teachers about technology in the content area and ideology. Finally, a discussion of the state's options such as certification, and demonstrations and centers to support technology will be reviewed.

Section 6. **Funding, Facilities, and Equipment**

The purpose of this section is to examine the relationship of technology and funding options. Secondly, the implications technology presents for design of new schools, renovation of existing schools, and the operating, capital and maintenance costs are reviewed. Finally, the acquisition and disposal cycle for disposal of hardware and software are discussed.

Section 7. **Planning**

The purpose of this section is to identify the need for state planning, determine the models currently being utilized and the components, implementation and evaluation of those plans. A specific focus will be the relationship of state and district plans.

SECTION 1
TECHNOLOGY AND RESTRUCTURING

**"If you always do what you've always done,
you'll always get what you always got."**
(Unknown)

The purpose of this section is to examine the potential of technology to further the goals of restructuring America's schools. A summary centered on the focus questions is presented first, followed by the supportive findings.

SUMMARY

Technology by itself cannot restructure schools; however, schools cannot reach excellence for all children without it. The conclusion drawn by many is that technology has an essential -- though not independent -- role to play in boosting educational productivity.

The role of technology in support of restructuring is an evolving one. It can support traditional models by standardizing and automating procedures. Applications such as CAI, mastery learning curriculum, and programmed skill packages make existing practice better.

However, it is believed that only certain learning tasks can be routinized. If the goal of restructuring is to move to a learning environment that emphasizes complex problem-solving, decision-making and value judgments that are not easily codified, then technology has much to offer the restructuring movement.

In fact, there is a growing consensus that any major investment of time and effort in technology can only be justified if teachers use the technologies as tools in ways that emphasize application, word processing, simulation, and program problem-solving.

The pace of technology makes assimilation difficult. But there seems to be a natural progression in teacher use of technology. Firstly, observers believe you change the way people think about teaching and learning, then you apply technology. You cannot apply technology first and expect to change the way people think because they will just apply the technology in old ways.

Secondly, as teachers become more familiar with technology, they use it less for drill and practice and more for word processing and databases. Restructuring schools can use this natural progression by organizing for it, putting technology into the hands of teachers, integrating it into the curriculum, allowing experimentation by teachers, inferring knowledge about possible uses after teachers have reached a comfort level with the technology, providing adequate time to learn and develop, providing sufficient amounts of hardware, keeping success stories in front of teachers and removing the classroom from isolation.

FINDINGS

Three agendas of the educational reform movement in the United States have been promoted in the literature: 1) a push on reorganizing school processes, 2) a constructivist and cognitive/information processing view of learning and the effect of this view on teaching, and 3) a movement towards well-integrated uses of technology in the school curriculum (Sheingold, 1991; Bagley & Hunter, 1992). The three agendas can be integrated under the flag of restructuring America's schools.

THE ROLE OF TECHNOLOGY IN RESTRUCTURING

The role of technology in support of restructuring is an evolving one. The National Task Force on Education Technology (1986) reported to the U.S. Secretary of Education that today's schools need to gear up to improve traditional delivery to the maximum that technology based education helps make possible. They need to prudently acquire hardware and software and apply them effectively. The report states that one work station for every ten students is an achievable goal and an important step in the right direction.

The **traditional** model of education has been under constant attack. Al Shanker summarized the charge as: "The rigid and confining structure of the traditional model of education ... does not enable even the majority of our children to be educated -- and it never did.... [O]ur persistent educational crisis shows that we've reached the limits of our traditional model of education" (Shanker, 1992).

The nation's mood seemed to shift in 1988. This shift was recognized in The Office of Technology Assessment's national study presented to Congress and bridged the **traditional** and **restructuring** thrusts. They concluded that technology should be an integral part of the newly structured schools to help create new learning environment and help minimize administrative burdens on teachers and staff. They say schools must change in fundamental ways to insure success, made possible with technology.

On the one hand, they agreed with the 1986 Task Force recommendations. They said technology with its ability to standardize and automate procedures can further 'risk' goals. Applications such as CAI, mastery learning curriculum and programmed skill packages make existing practices better (Power on!, 1988).

They went on to add a new role for technology to play in restructuring America's schools. It is believed, they said, that only certain learning tasks can be routinized. Promoting the wholesale use of learning technologies for these purposes, such as breaking computation into sets of step by step procedures and packaging them as discrete lessons to be mastered, would mean schools would settle for the lowest level of instruction, having students learn superficial information. On the other hand, answering complex problem-solving, decision-making and value judgments are not easily codified for use in a computer lab. They concluded that technology has much to offer the restructuring movement (Power on!, 1988)

TECHNOLOGY AND RESTRUCTURING

Lewis J. Perelman's Technology and the Transformation of Schools, published by the National School Board Association, is perhaps the most lucid and indepth report on how technology and restructuring may be linked. He concludes ".... merely injecting electronic tools into classrooms, while leaving the basic design of education systems unaltered offers little hope for the major improvements in educational productivity that a nation 'at risk' requires ... Technological change and social change are interdependent and inseparable" (Perelman, 1987).

He goes on to say in a companion piece that technology by itself cannot restructure schools, but schools cannot restructure successfully in the direction of the visions described above without it. Conversely, the restructuring of schools is essential to the effective use of technology (Perelman, 1988).

Many observers besides Perelman feel technology has an essential, though not independent, role to play in boosting educational productivity (see Sheingold, 1991; Newmann, 1993). To accomplish this role, technology must be viewed broadly, not just as an add on to an established and unalterable educational infrastructure (Perelman, 1988). In fact, there is a growing consensus that the time and effort invested in computers can only be justified if teachers use technology in ways that emphasize application, word processing, simulation and program problem-solving (Cleborne Maddan, preface to Robyler et al., 1988).

Yet, discussion of restructuring is difficult because there is has been little agreement in the definition of the word. While agreement can only be determined at the local school level several concepts summarized in Tables 1, and 2 (see Appendix A) appear to have general agreement and help us to understand the characteristics restructuring schools have adopted. These notions are narratively described below to help us develop an understanding of the restructuring the transformations taking place in American schools.

Concepts. Some very similar concepts appear to undergird these new educational and organizational directions.

- Restructuring schools provide a learner-centered environment that goes beyond lecture and textbooks.
- Restructuring schools believe learning is more than assimilating knowledge; it is constructing it.
- Restructuring schools are between two educational paradigms and two organizational paradigms. On the one hand, they are reconsidering and reexamining the content and method of instruction, and at the same time they are attempting to democratize decision-making in the school, flatten the hierarchy, improve communications and share the responsibilities among all the stakeholders. (Sheingold, 1991; Newmann, 1993).

Additionally, the concepts illustrated in Table 1, Paradigms of Teaching, (see Appendix A) highlight the traditional and restructuring visions of schools and draw our attention to the direction restructuring schools are taking. These directions are summarized below:

- From knowledge transferred from faculty to students, to knowledge being jointly constructed by students and faculty,
- From students being seen as passive vessels to be filled by faculty's knowledge, to students being seen as active, constructors, discoverers and transformers of their own knowledge,
- The purpose of instruction from classifying and sorting students to developing student competence and talents,
- From working with the whole class to small group instruction,
- From lecture and recitation to facilitation and coaching,
- From working with better students to working with all students,
- From assessment based on test performance to assessment based on products, progress and effort,
- From all learners learning the same things to different students learning different things,

- From verbal thinking to integration of visual and verbal thinking.
- From impersonal relations among students and between faculty and students to personal transactions among students and between faculty and students,
- From a competitive individualistic context to cooperative classroom learning and cooperative faculty teams, and
- From assuming that any expert can teach to a belief that teaching is complex, requiring considerable training (Bagely and Hunter, 1992).

Vision. Technology has an important role to play in furthering the efforts of restructuring schools. It can be a catalyst for systemic change or the support of such change. Yet, it cannot drive change; school reform must be driven by vision. This role of technology and restructuring is best described through the concept of **Learner Center Environments** which are flexible and activity based. As alluded to above current theory views learning as the active engagement of learners in the construction of their own knowledge and understanding of facts, processes and concepts. This learning occurs through interaction with and support of the world of people and technologies. It is supported by a process orientation rather than a skill orientation.

In the school, block scheduling replaces standard fixed periods. There is increased parental and community involvement. In the classroom, the student is an active learner. The teacher is facilitator, counselor, research associate, mentor and resource person. Instruction changes to team teaching to support interdisciplinary curricular efforts. Cooperative learning, peer-learning and sharing of ideas replaces isolationism. The administration emphasizes a continuous process of renewal, reassessment and readjustment. Decisions are shared (Vision: Test, 1990).

Additionally, technology can support the concepts undergirding the learner-centered environment by emphasizing:

- **higher order thinking** skills through simulation, problem-solving and tools application and state of the art media centers to learn research skills;
- **a past, present, future focus** through simulation, scenario construction and historical time lines;
- **whole person focus** through video reports/presentations; computer/video interface, musical composition, desktop publishing;
- **general education** through keyboarding skill development, computer literary applications and programming;
- **multi-disciplinary education** through coursework such as the Voyage of Mimi, problem-solving software;
- **collaboration** through cooperative products such as Discourse;
- **communication and information processing** through word processing, graphics, hypermedia presentation; Backbone networks for E-Mail, information transfer, television broadcasting, voice mail, links with home; state of the art libraries with networked data bases;
- **global orientation** through Kidsnet, AppleLink, Apple's global series and teleconferencing, and distance learning;
- **human values** through debates about intellectual property and equity;
- **active learning** through use of Productivity tools and interactive learning technologies;
- **service learning** through desktop publishing, graphics and arts;
- **life-long learning/learning** to learn through creating information centers to support research and inquiry and computer literacy;
- **personalized learning** through ILSs;
- **process and inquiry approaches** through productivity tools and probe ware;
- **master apprentice approaches** through database of masters;

- **shared decision-making** through access to databases and E-mail networks ability to share information among team;
- **parental involvement** through voice mail links, computer sharing, Talkline. (Ray, 1991a,b; Schofield & Verban, 1988).

Visions to Reality. Two specific representations of the transformation that is occurring is the **Apple Classroom of Tomorrow** (ACOT) and the **Integrated Technology Classroom** (ITC).

In the **ACOT** classrooms each student and each teacher has a personal computer at school and another at home. The following description was drawn from Power on! (1988). A computer on every desk creates a different educational environment from a room with a few machines at the back of the class or a school laboratory attended only once a week. Computer use in ACOT schools averages 50 percent of the day. The technology is used by teachers in various ways. Teachers often gather the students around only one computer to demonstrate new software or to engage them in group activity. At other times two or three students work together. Students also work alone on keyboarding, writing, and mathematics. Teachers manage records easily, and even administer tests on the computer.

These ACOT classrooms are different than conventional classrooms with few computers. For example, the noise level is higher; but concentration, excitement and engagement is also higher. The ACOT teacher rarely lectures the class; more often they move from student to student dealing with individual problems. Both teachers and parents claim that students are more interested in school, more involved and more confident. The students are not magically transformed -- they still yawn, poke their neighbors, and daydream. Yet they say that school work is more fun, less boring or a lot easier.

ACOT teachers have common experiences despite many different conditions, personalities, attitudes and levels of computer expertise. Specifically, they report that they are exhausted from the increased stress of learning new skills, evaluating software, and inventing ways of incorporating the computer into the curriculum. But they have found a new source of pride in, and enthusiasm for, their profession and are renewed by the effect of efforts on students.

The **ITC** concept was developed in Bellevue School District (WA), by three teachers in grades four and five. The vision for the ITC centered on four beliefs:

- Preparing students for the future meant they needed to be life-long learners, excited about learning and self-directed.
- Students should have frequent opportunities to interact with computers and possibly other technology as part of their everyday lives and work.
- Students would be expected to work cooperatively and actively, constructing their own meaning and knowledge from the tasks they were involved in.
- A classroom-based, rather than a lab model for computer, use is preferred so the learning environment is focused on problem-solving mathematics, whole language opportunities and integrated curriculum, and the computer is used as a tool.

The impact of technology can be impressive if the key supporting elements in curriculum redesign is present. If the curriculum is narrowly defined as content coverage, than all the "fancy technology" is a waste of money. A second element is the teacher's comfort in giving up control from the front of the classroom. Thirdly, there should be multi-aged grouping of students. The advantage is the teacher has students for two years and the returning upper grade students act as peer tutors for the incoming lower grade students. This element works best if the teacher only teaches one curriculum (Held et al., 1991).

Valued Outcomes. There appears to be some agreement that efforts to restructure schools should promote six valued outcomes (Newmann, 1993):

- Authentic Student Achievement,
- Equity,
- Empowerment,
- Communities of Learning,
- Reflective Dialogue, and
- Accountability.

STRATEGY

An effective strategy for transforming education cannot rely on change in the technical tools of instruction alone. It must address schools as total systems and include organization, management, and human resources in the agenda for innovation (Perelman, 1988). Several strategies are available which can help make the connection between technology and restructuring schools.

First, recognize that when we infuse technology, we alter the power relationships between student and teacher, among school personnel, and between the school and its environment. Therefore, the strategy employed should be cognizant that teachers adopt innovations in light of their own goals, their accustomed practice, the culture of their community and school, and their own interpretations of the information they receive about new approaches (Betterman & Mclaughlin, 1977; Goodlad, 1984, cited in Wiske et al. 1988). Rather than add technology to an overflowing plate, it is appropriate to seek ways technology can support the directions schools have already identified (Ray, 1992).

Secondly, Michael Walter, Superintendent of Tupelo School District, believes you first change the way people think about teaching and learning and from there you apply technology. You cannot apply technology first and expect that to change the way people think, because they will just apply the technology in old ways (quoted in Bruder, 1992).

Thirdly, understand that while infusion of technology is not a linear process, there do seem to be some stages that precede other stages. Alfred Bork (1990) has described three stages that have several patterns. These are summarized below:

- THE BEGINNING STAGE
    - Let's get lots of hardware
    - Let's teach languages
    - Let's teach computer literacy
    - Let's train the teachers
- NEXT STAGES
    - Let's use advanced hardware
    - Let's develop small programs for use in standard courses
    - Let's use authoring systems
    - Let's catalog existing software
    - Let's evaluate the small programs
    - Let's teach students about tools
    - Let's use networks
    - Let's develop management systems
- FINAL STAGES
    - Let's develop full curriculum using computers
        - Future learning systems
        - New courses and curricula
        - Teacher training
        - Evaluation
        - Implementation

James Lengel (1986, cited in Obynbene, 1989) has persuasively described a set of alternative stages that could be used to develop strategy. The **personal stage:** when one or two enthusiastic teachers use technology effectively. The **diffusion stage**: when the District and teachers succumb to a variety of influences to ensure that their schools have the machines and experiences everyone is talking about. And the **tool stage**: when the computer is not used for drill and practice and is not an object of study itself, but rather a tool for learning -- one that is integrated into a classroom like an "encyclopedia" and the globe as a day to day instrument for teaching.

Fourthly, with the above understandings in mind, a technology strategy could be based on the following principles:

Planning: To apply technology effectively, you must organize it.

Access: The first step in integrating technology into teaching is to give teachers a chance to use it in planning their own work. Put computers into the hands of teachers.

Curriculum: To permit the maximum advantage of technology, curriculum and instruction must change in major ways. Technology must be integrated into the curriculum, rather than being a supplement to the curriculum (Vision: Test, 1991).

Instruction: Firstly, teachers use computers in different ways, if at all. **Exemplary practice** supports the restructuring model. It is based on the assumption that important academic outcomes will result from systematic and frequent use of computer software for activities that involve higher order thinking, such as interpreting data, reasoning, writing, solving concrete, complex real world problems and doing scientific investigations (Becker, 1992). **Normal Computer Practice** supports the traditional model. It uses computers in a less intensive and traditional manner focused on knowledge and skill acquisition. (Becker, 1992). **Optimal** use of computer use will occur when computers are used as exemplary teachers use it. This assumption is based on the whole literature of cognitively-oriented theories and research on human learning and its application to classroom grouping of students in school settings (Chipman et al., 1985; Resnick 1989, cited in Becker, 1992; and Idol & Jones 1990).

Teacher Support: Classroom support includes adequately arranged time to learn, plan, integrate and develop new curriculum, as well as access to technical support including maintenance, software and hardware recommendations and curriculum advice (Vision: Test, 1990).

Effectiveness: Nothing succeeds like success. Discuss the effect of technology on learning. Return to it time and time again. Ask whether a particular concept can be taught just as well without the use of technology.

Connectivity: Remove the classroom from isolation. Create interactive learning environment where integration of all learning is the essence of education and electronic systems are the primary information delivery system for the basics of all academic subjects, and where human resource and education are highly integrative.

Networks have a tremendous potential to bring the human and knowledge sharing that a change of the magnitude being projected requires. (Northshore) They facilitate sharing of data and information locally, regionally, nationally, and worldwide. The key feature of most networks is ability of users to communicate with each other (E-mail) and to access database.

Phasing: The pace of technology makes assimilation difficult. Additionally, new technological developments outstrip the school's readiness to adopt them. But there seems to be a natural progression in the use of technologies as teachers become more familiar with technology -- they use them less for drill and practice and more for word processing and as data bases (Becker, 1992; Sheingold, 1991).

CONCERNS

Technology is still personality driven. It is used by few individuals rather than a team. The number of restructuring schools is growing, but only a few think about how technology might support their change efforts. A majority of restructuring schools have some technologies in place and are expanding each year, but they are not engaged in any organized planning or understanding of their purposes.

Restructuring schools are at very different places in implementing the directions alluded to above. They use technology, but few use it to support organizational and educational changes required by their visions (Perelman 88). Becker (1991) agrees. He found in his national surveys that although having computers function as an intellectually empowering tool is an idea that is growing in support, actual practice lags from behind. In a study of 31 schools, he found that even when supplied with sophisticated computer equipment and provided with abundant resources, teachers implemented a fairly traditional program of instruction "not very different than would have been followed without the computers".

In Ray's (1991) study of 14 schools, the following observations were made: Although the many uses of technology observed in these schools where congruent with the directives of restructuring, most educators interviewed could not describe or articulate how technology relates to their restructuring efforts. Their belief, understanding and knowledge that somehow technology is important came from a deeper, intuitive level. Currently, technology is an add-on to existing instructional practices. And, the potential for technology to change practice is largely unfilled.

Finally, Larry Cuban (1986; cited in Ognibene, 1989), a noted skeptic, observes that policy makers too often forget that classroom learning is anchored in the emotional lives of thirty children and one teacher together for large chunks of time in small crowded places. Teachers gain pleasure form the emotional circuitry wired into intense bonds that develop between them and certain students, often lasting for decades. This complex relationship becomes uncertain in the face of microcomputers. And, introducing to each classroom enough computers to tutor and drill children can dry up that emotional life.

Research is Needed. There is surprisingly little research on how technology and restructuring interrelate. A recent report from a national conference on technology and teacher education called for a deeper understanding of the cognitive consequence of instructional technology at the classroom level to promote "scientifically defensible claims about the effectiveness of computer-based instruction compared to more traditional modes of instruction. We need to know not only how teachers are coming along, but whether these practices do produce better results (Becker, 1992).

MODEL SCHOOLS

Many model technology-using schools have been developed in the past five years. Several are described below:

HUNTERDON CENTRAL -- California

Networked instructional network

- Every classroom contains a monitor, at least one computer and a telephone allowing instant communication to entire campus and beyond. Linked fiber-optically to other institutions of learning throughout the state and beyond. Local businesses can take advantage of the facilities for their own training needs.
- Prototype classrooms of the 21st century. Laser Disks, CD ROM player, computer general technology, physics and fine arts.

Applications

- Computer aided drafting program
- Graphics packages
- Desk top publishing
- BioChem = hypercard programs to collect and analyze

Instruction

- New paradigm for instruction in secondary schools

SATURN MIDDLE SCHOOL -- Minnesota

Learner-centered Environment

- Curriculum is process driven
- Textbooks are resources
- Many courses are project based
- Students encouraged to work cooperatively but may work independently if they choose
- Emphasis has shifted finding, organizing and making sense of the wealth of factual information available to today's student

Technology Role

- Technology is available; but Saturn is not technology driven
- Technology is used as tools by students and teachers in five distinct areas: individualized learning; group interaction; management and coordination of student learning; student expression; and knowledge production.

Applications

- ILS = Jostens and CCC
- Discourse System
- Flexible technology -- CD ROM -- on line data base, etc.
- Student portfolio of proficencies

TESSERACT ELEMENTARY -- Miami

Instruction

- Technology infused into curriculum
- Increased attention to individual learning styles
- Group across all grade levels
- Increased parental involvement

External Focus

- Community mentor program

Applications

- ILS = CCC
- Discourse LAB

INDIANA CREEL ELEMENTARY -- Indianapolis

Instruction

- Thematic curricular approach

Support System

- No computer coordinator -- Philosophy -- every teacher knowledgeable -- comfortable -- with technology

Networked

- Networked computer labs and classroom computers
- Linkway multi media

External Link

- Buddy system -- provides students with home computers
- We have had to change our thinking about what we expect from both students and teachers when we expand the role of technology in education. (Gould, 1991)

SECTION 2
TECHNOLOGY AND INSTRUCTION

The relationship of technology and education is a viable one. It is most viable when thought of as a tool to facilitate and enhance activities.

(Honey & Moeller, 1990)

The purpose of this section is to examine the impact of technology, primarily the computer, on educational philosophies, goals, and curricula, instructional roles, materials, strategies, and decision-making. The section begins with a summary organized around the focus questions followed by the findings that support the summary.

SUMMARY

Technology can help create a rich learning environment. This potential depends upon the teacher's ability to integrate the technology into everyday classroom activities. Integration requires a great deal of effort by the teacher. However, used appropriately, it can reinforce, supplement and extend student skills.

Technology can also support either the **traditional or learner-centered instructional philosophies**. Traditional teachers use it as a medium for drill and practice and tutorials. Learner-centered teachers use it as a tool for problem-solving, taking advantage of the word processing, database, spread sheet, graphics and telecommunication applications. Technology enables teachers to reinforce their instructional philosophy or transform it.

If adopted, technology can have an impact on teaching style, instructional philosophy and goals at each grade level, resource allocation and on instructional materials. One of the most significant impacts of the computer is on **teaching style**, even though most observers feel there is no "best way" to teach or learn. While some people think both the teacher and learner-centered approaches have their places, the technology empowers the teacher to function as a facilitator of learning rather than acting in the traditional role as transmitter of ready-made information.

The general consensus is that as a result of the adoption of technology, the **teacher's role** changes from presenter to coordinator of learning resources and frees the teacher to work individually with students. They move from being the "sage on the stage" to the "guide on the side." It is generally acknowledged that teachers are **critical to integrating technology** into the learning process. They make the decision to integrate the technology, make it an internal part of their technique, or use it as an add-on, a "treat" or reward.

There seems to be a sequence from teaching without technology and becoming an **accomplished integrator**. Teachers adopt innovations in light of their own goals, accustomed practice, culture of their community and school, and their own interpretations of the information they receive about new approaches. Therefore, it is appropriate to find uses of technology that support the instructional philosophies teachers have identified.

Teachers vary the use of technology based on their curriculum goals, assessment of student need, and preferred teaching approach. Technology-using teachers use technology in different ways: drill and practice, tutorials, simulations, problem-solving and productivity tools. The types of instructional decisions they make are dependent on their knowledge of possible uses, availability and ease of use of the technology, and their instructional philosophy. As their philosophies change, as in restructured schools, the technologies and applications they use will change also. For example, teachers generally start with drill and practice and move to applications.

There are grade level differences in the use of technology. For example, **instructional use differs** by grade level. In elementary, drill and practice and tutorials are emphasized. Middle schools and high schools emphasize word processing, discovery, problem-solving and productivity tools. Its potential is to not only reinforce lessons, but as a tool to support the development of minds from pre-adolescent through adolescent phases.

Technology applications are also emphasized at different graded levels. At the elementary and middle schools one finds more use of integrated learning systems (ILSs) than at the high schools. And, at the high schools there is more use of video disc, CD ROM and database than at the elementary and middle schools.

Teachers' use, on the other hand, is similar across all three levels, except that high school teachers don't use it to create banners for room decorations as do elementary and middle school teachers.

Curricular emphases also differ by grade level. In elementary, computers are used in math and language arts. Middle school use is more in general math and sciences. Mathematics and science are the focus in high schools. One of the most difficult barriers in **curriculum reform** has been the reluctance to drop existing content. Yet, technology-using teachers are four times more likely to introduce new topics and five times more likely to de-emphasize certain topics than non-technology-using teachers.

Resources also appear to be allocated differently across grade levels. For example, elementary schools seem to prefer to distribute their computers. In 1986, only seven percent of the K-6 schools had at least eight computers linked while high schools had linked twenty-four percent of the high schools.

Finally, the impact of technology on **instructional materials** has not been fully felt as of yet. However, several incidents portend future developments. The definition of the textbook is beginning to change. For example, the technology to produce customized textbooks exists, but it is not being utilized on a large scale. Most recent trends include the following activities. In Texas the word "textbook" means any instructional material that meets curriculum requirements. In California it means textbooks and video discs. And, Florida law allows the state board of education to adopt technology in the textbook process (Mageau, 1991). The 1992 New Grolier Multimedia Encyclopedia is a CD ROM-based multimedia encyclopedia containing 33,000 articles. It has new multimedia elements such as digitized video segments of historical events, famous people, and automation sequences.

FINDINGS

EDUCATIONAL GOALS AND TECHNOLOGY

There is increasing pressure for the schools to consider the adoption of technology, while at the same time, concern is being expressed for the impact of technology on children and the society at large (Ely, 1991). For example, some believe that individualized instruction presented via computer creates "sterile" learning environments where learners interact only with the computer apart from teachers and peers (Hannafin et al., 1987). In short, for some, "individualized" is synonymous with "isolated."

At the heart of the matter are twin goals of education -- imparting knowledge and "teaching for understanding." The 80s "Nation At-Risk" agenda, driven by an accountability imperative, caused the educational system to emphasize imparting knowledge, characterized by the teaching of basic skills. The 90s economic imperative is vigorously pushing us in the direction of higher order skill development such as critical thinking and reasoning characterized by a movement to "teach for understanding."

Today, many believe that the educational goals of imparting knowledge and "teaching for understanding" should be considered inseparable. Surely, all students must learn to read and write, multiply and divide, learn that all matter is composed of atoms and molecules, when the Civil War took place and where Paris, New York or Beijing are located on a map and, at the same time, make knowledge work for themselves, their communities and the nation. They must understand how to pose problems, conduct critical inquiry and develop informed insight. They must know how to produce and criticize a reasoned written agreement, know when and how to multiply and divide, understand what compels the adoption of an atomic theory of matter, understand the events that led to and flowed from the Civil War, and be able to analyze the factors that determine where cities spring up and prosper (Educational Technology Center, 1988).

There are also hopes that various forms of **media** will accomplish a number of important educational goals, including: (1) increasing the excellence and success of the instruction provided to students, (2) reducing the cost of instruction, (3) increasing the equitable access to education among unserved and under-represented student groups, and (4) encouraging the cultivation of new curriculum elements such as higher order thinking skills and new teaching methods such as elaborate scientific and mathematical simulations (Clark & Sugrue, 1988).

THE ROLE OF TECHNOLOGY

The use of computers can be discussed in terms of two potential roles: as a **medium** or as a **tool**.

As a **medium**, learning is treated as an ultimate goal. The computer serves to instruct or inform the user through drill and practice programs, tutorials, simulations, or educational games. The computer as a medium supports the goal of imparting knowledge. The computer as a medium also supports the **traditional model** of education.

The traditional model has most often taken a didactic instructional approach. The teacher transmits knowledge to the students, who verify that they have learned by reiterating it on a test. In this model, the teacher tends to be teacher-centered. **Teacher-centered** teachers tend to use traditional instructional methods -- whole class lecture, text books and worksheets. They are more content oriented than process-oriented and see their computer role as basic skill reinforcement, motivator or "special treat." The teacher-centered teacher has been described as "the sage on the stage" (Honey & Moeller, 1990).

As a **tool**, learning is treated as an instrumental goal. The computer serves to help the user accomplish a task (Wiske et al., 1988). The rationale for this approach is that computers should be used the way they are used in society to empower their users as personal and educational productivity tools. Teachers can use them to write lesson plans, notes to students/parents, comment on student work, and keep track of student progress. As a tool, the computer supports the "teaching for understanding goal," and the contemporary **constructivest instructional model**. In this model, the teachers tend to be learner-centered, they help students construct their own meaning and demonstrate their knowledge through performance-based assessment, such as portfolios and projects.

Learner-centered teachers generally chose individualized or collaborative approaches. They play down facts for an inquiry or discovery-based mode of learning. Their goal is to instill a sense of curiosity -- to get students to want to find things out. They engage students in projects and group oriented activities. The learner-centered teacher has been described as "the guide on the side" (Butzin, 1992).

The following guiding visions support the "tool" role of technology.

1. Teachers need a work station linked via networks to student work stations in classrooms or labs; they have a similar arrangement at home linked by modem to the school.
2. Students should have the opportunity to use computers to explore ideas, analyze data, write papers and stories, to receive and carry out written assignments, research using data bases, to design, compare, publish, plan and work with a team on a project (Kelman, 1991).

THE INSTRUCTIONAL ROLE

Technology alone cannot affect the ways in which students and teacher interact. Also needed are teachers who are skilled at structuring effective learning environments and are flexible in the roles they will play -- sometimes the lecturer, sometimes the tutor, sometimes poser of thought-provoking questions, sometimes project manager, sometimes diagnostician (Bialo & Sivin, 1990a).

<u>The Impact of Technology</u>. How will technology, which is viewed synonymously with change, be integrated into an educational system that is historically resistant to change? To change the traditional model, teachers would have to change the very nature of their practices. To change the traditional model, the system would have to rethink how students learn and develop. To change the traditional model, the system would have to change the way it assesses learning (Honey & Moeller, 1990).

Three main "visions" of how technology might affect teachers' roles inform current discussion.

1. **Replacing**. At one end of the continuum, many teachers feel they will be replaced by computers. Indeed, many large computer management systems that are now marketed claim to "deliver" most of all of the content of a subject, and to keep track of student progress.
2. **Implementing**. The most common vision is that computers are just another tool for teachers to use, one that will supplement and enhance the curriculum but not change it significantly. With this approach, it would typically be used for unpleasant D&P and tutorials on various subjects.
3. **Transforming**. At the other end of the continuum, advocates insist that technology can help transform curriculum, teachers' roles and even school structure. The teacher's role is to facilitate learning rather than lecture. Students use the potential of technology to communicate, access information, learn collaboratively, think critically and take initiative in planning and implementing curricular products (Budin, 1991).

One of the most significant impacts of the computer is on teaching style. While some people think that both the teacher and the learner-centered approaches have their place, the technology empowers the teacher to function as facilitator of student learning rather than the traditional role as presenter of ready-made information (Power on!, 1988). In this way technology extends teachers, not replaces them (Marshall et al., 1989).

TRADITIONAL INSTRUCTIONAL ROLE

Historically, the teacher's instructional role has evolved into that of manager, removing from the teacher's hands participation in decision-making about what and how to teach. The main use of the computer has been to reinforce and augment this role. For example, consider the growth in the use of ILSs. They are the fastest growing segment of the educational software industry and will be a formidable force in shaping the future of education (Sherry, 1992). Currently, eleven percent (11%) of the schools use an ILS (QED, 1991). They offer comprehensive coverage in terms of lesson plans and integration of electronic media and make fewer demands on the teacher than do individual programs that treat small sections of the curriculum. However, the general consensus among teachers is that drills and tutorial application of ILSs and CAI are better suited to teaching facts rather than concepts.

Additionally, most observers feel there is no "best way" to teach or learn. For example, compute-managed instruction (CMI) ignores the teacher's knowledge of students or teaching. It individualizes by ignoring differences among students except on simple cognitive skills treated in the software. It standardizes and routinizes sequences of instruction and makes teachers and students accountable for learning in terms of narrowly defined quantifiable objectives. Its main thrust is to replace all or part of the teacher's role (Budin, 1991).

In general, teacher goals for using computers suggest a rather traditional and uninspired function for computers (Becker, 1992). Low technology teachers in particular generally had **teacher-centered** goals. They were reluctant to use technology because a) it might alter the relationship of control and authority with students, and b) mandates and requirements did not allow time for additional activities. They were content-oriented (Becker, 1992).

Computer-Assisted Instruction. When teacher-centered teachers use technology, it is generally computer-assisted instruction (CAI). The computer provides a) drill and practice exercises but not new materials, or b) tutorial instruction that includes new materials (see taxonomy in Pisapia & Perlman, 1992). Drills and tutorials are found to be suited to teaching facts. Educators have also alluded to drill strategy as power in the development of intellectual skills, acquisition of verbal information, and development of cognitive strategies. Jonassen, (cited in Wiske et al., 1988), notes that drill and practice can enhance mastery and performance and presents teacher-proof control of information.

Results from studies (see Pisapia & Perlman) concur with findings in the literature that using the computer as tutor or employing CAI as a supplement to traditional teaching is indeed effective. Specifically, using the computer as tutor can help students become more efficient and motivated and assist them in developing a positive attitude toward the technology.

Drill and practice programs also provide special attraction to learning assistance students. Although the literature reviewed suggests CAI cannot improve students' retention of material, most teachers were unaware of this limitation, or that teachers who used drill and practice and tutorial software indicated that computers had not influenced their teaching practices (Wiske et al., 1988).

CONTEMPORARY INSTRUCTIONAL ROLE

The teacher's role in the teaching and learning process is changing as new technologies are introduced into the classroom. For example, in distance education, instruction is delivered by a teacher surrogate responsible for the major information presentation systematically through videotapes, audiotapes, computer programs, programmed textbooks, and combinations of media (Ely, 1991).

The general consensus is that as a result of the adoption of technology, the teacher's role changes from presenter to coordinator of learning resources and frees teachers to work more individually with students. They become resident advisors to students, "the guide on the side" (Herman et al., 1992).

Teachers who thought the use of computers had shifted their teaching approach most, often mentioned that computers helped them vary the traditional picture of the teacher lecturing to the whole class. Computer technology facilitates an approach in which students work on problems individually or in small groups while the teacher circulates among them, serving as coach and facilitator and helping students move from memorization to inquiry (Wiske et al., 1988; Sheingold & Hadley, 1990).

Teachers who have been using technology extensively, as well as those who expect to use it in their teaching, are interested in the potential of technology to support learning that is more open ended than drill and practice. This vision -- **learner-centered** -- found energy for many but a reality for only a few (Wiske et al., 1988).

The literature portrays three types of technology-using teachers with learner-centered goals. First, there are the high technology-using teachers with learner-centered goals who used inquiry methods, collaborative learning, hands on experiences to stimulate the creative uses of the computer, and are process oriented (Honey & Moeller, 1990). For the most part they use tool-based software that enables students to undertake creative writing project, publish newspapers, create magazines, and explore math problems through spreadsheets.

Secondly, there are technology-using teachers with learner-centered goals who liked to use technology, but there were too many barriers. Either the equipment wasn't available or there were problems scheduling time in the computer laboratory.

Finally, some learning centered teachers are low technology users. They were reluctant to use technology because of personal fears and inhibitors.

Exemplary technology-using teachers represent five percent (5%) of the teaching population (Becker, 1992). In schools where they are found:

- The fraction of time going into occupational preparation subjects was two and one half times as great as at schools with low technology users. And, time going into computer education activities, math and English and most strikingly, recreational activities, was smaller than at other schools (Becker, 1992).
- Having writing as a priority seemed to be associated with the presence of exemplary computer teachers (Becker, 1992).
- Exemplary teachers use computers to demonstrate concepts.
- More experienced technology users suggest that teachers need to be shown clearly one way of using computers, either to alleviate their work outside class or enhance some part of their classroom work (Wiske et al., 1988).
- Only math teachers are likely to become exemplary users when there are few computer users in their school. Science and English teachers are particularly dependent on the presence of other computer users in order to develop high quality practices (Becker, 1992).

CURRICULUM INTEGRATION

Whether one uses a traditional instructional model or a contemporary one, most observers agree that technology needs to be better integrated in the educational process. The current focus on integrating technology into curriculum can mean different things:

1) computer science courses and computer-assisted instruction, and/or computer enhanced or enriched instruction (see the taxonomy in Pisapia & Perlman, 1992), and 2) matching software with basic skill competencies.

Integration means the use of the computer to introduce, reinforce, supplement and extend skills (Schultz, 1989). For example, if a teacher merely tells a student to read a book without any preparation for follow up activities that put the book in pedagogical context, the book is unintegrated. If the teacher uses the computer to reward children by allowing them to play a game, the computer is unintegrated (Brunner, 1990).

The teacher is critical to integrating technology into the learning process and integrating takes a great deal of effort by the teacher. Someone has to know what software is available and appropriate, how to locate it, retrieve it, and capture it for classroom use. Someone needs to know what equipment to use and how to guide and encourage students' efforts to explore the subjects in more depth, how to organize the classroom to complement traditional teaching and make the connection in students' minds between computer trained skills and non-computer trained skills.

Even though some will be exemplary, most teachers can't integrate without support. At worst, the computer will remain segregated in the back room, where students come to visit the room where the machines live -- once in a while (Brunner, 1990).

The difference between the classrooms of exemplary users of technology and technology users is the way their classes are conducted. In the exemplary classrooms, student use of computers is woven integrally into the patterns of teaching; software is a natural extension of student tools. The computer serves as a vehicle of expression, communication, or analysis as opposed to an activity isolated from the main purpose of the class where there is little carryover from non-computer dialogue to computer task or computer task to teacher led discussion (Becker, 1992).

A Practice at the Cutting Edge. For the majority of the teachers, integrating use of computers in the curriculum remains a practice at the cutting edge. To move this practice into the mainstream, teachers and schools need information and resources in the following areas: 1) examples of what is possible, 2) examples of support and training, 3) information on results, and 4) clearly identified subject area learning outcomes, and learning to learn skills.

Curriculum Coverage. The implementation challenges increase as teachers attempt to change the core curriculum (Cohen, 1987). For example, computers have the potential to alter curriculum coverage, but one of the most difficult barriers in curriculum reform has been the reluctance to drop existing content (Becker, 1992).

Yet Becker (1992) found that exemplary technology-using teachers were four times as likely to have introduced new topics in their course and five times as likely to have deemphasized or dropped certain topics in their class as a result of using computers.

Curriculum Array. There appears to be little integration of computer-based instruction with regular curricular efforts. Becker (1992) says most schools report more time devoted to computer education and basic skill areas other than any of the others. Wiske et al. (1988) found that teaching computer courses separate from the regular academic program also served to limit the impact of computer technology. And, Collis & Martinez (1989) found that computers are rarely used to enhance learning and instruction in traditional subject areas despite abundant recommendations that support curricular integration.

INSTRUCTIONAL STRATEGY

Most uses of computers in classrooms make teaching more difficult. It takes planning to incorporate computers into a lesson, to sort out the logistics of who will use the equipment, to make sure the hardware and materials are available, and to design a fallback lesson if something goes wrong (Wiske et al., 1988).

Instructional Goals. Teachers vary the use of computers based on their curricular goals, assessment of student's need, and preferred teaching approach. Computers are used in classrooms as an object of study, or as a tool for teaching and learning subject matter in the regular curriculum. No single way of using technology will fit all aims, interests and needs (Wiske et al., 1988). The Office of Technology Assessment reported that technology cannot be fully effective unless teachers are offered the choice of using computers and unless those who choose to use them receive training and support. The report additionally indicated that one of the areas most significantly affected by computer use was classroom teaching style. The report concluded that there was not one best use of technology or way of teaching with technology (Power on!, 1988).

Instructional Use. Three general factors influence teachers' decisions to use technology: 1) teacher's knowledge of appropriate uses of computers, 2) access to necessary resources and support, and 3) incentives that favor or discourage computer use in the classroom (Wiske et al., 1988). For example, the introduction of computers does not automatically help incorporate them into classrooms. Their most common use was as a personal productivity tool. Wiske found that teachers were as likely to use computers to support students in open ended problem-solving as drill and practice. This is a change from Becker's 1985 finding where he identified CAI as the major use (Becker, 1986).

Teachers who have integrated computers in the classroom and are considered heavy users in their classroom report that they use: 1) text processing tools (95%), 2) instructional software (89%), 3) analytic and information tools (87%), 4) programming and operating systems (84%), 5) games and simulation (81%), and 6) graphics and operating tools (81%) (Sheingold & Hadley, 1990).

The 1992 study by Herman et al. showed that use of technology can influence instructional practices in a variety of ways.

- Technology use may encourage teachers to assign tasks which require students to engage in higher level thinking.
- Technology projects, more than regular classroom activities, tended to involve students in more integrative tasks, requiring them to access and use a variety of sources of information across the curriculum. In light of futurist visions of societal directions, this finding appears to be significant.

Pattern of Use. The pattern of use varies by **curricular area**. More than twenty five percent (25%) of all student computer time is credited to the major academic subjects. In a study of 484 schools with forty-eight percent reporting, Main and Roberts (1990) found that twenty-five percent (25%) of the language arts curricula, twenty percent (20%) of the science and social studies curricula, and seventeen percent (17%) of the math and business curricula were delivered with educational technology of all types.

In 1990, the software programs most commonly used by teachers were 1) word processing (93%), drill and practice (92%), 3) educational games (91%), and tutorial games (81%) (Plomp & Pelgrom, 1990). English teachers use computers more as a productivity tool, primarily for word processing (Becker, 1991).

When computers are available in urban schools with large minority enrollment, the tendency is to use them for basic skills instruction delivered by D&P software. In majority enrollment schools, computers were being used for higher order, cognitive skills (Simmons, 1987).

The pattern of use varies according to **grade level** also. For example:

Elementary. For example, Sheingold & Hadley (1990) and Becker (1986) found that elementary schools used word processing less and drill and practice and tutorials more.

On the other hand, Picciano's (1991) study of two hundred and seven elementary and middle schools in New York City and Westchester County found no difference in use of D&P, tutorials and simulation. He also found greater use of logo/basic in New York City elementary and middle schools than Westchester.

Elementary coordinators see greatest growth in 1) instruction in how to use the computer for writing and 2) basic skills practice in math and language arts. (Becker, 1991).

Middle Schools. In the middle school the curriculum moved away from programming and literacy models to an integration order where computer use is linked to instructional purposes of the curriculum (Loayzato).

High Schools. Twenty percent (20%) of eleventh grade students have never used computers in English, science, or social studies class. Only two percent (2%) say they frequently use computers in any traditional subject.

In high schools, fifty percent of student time is spent on how to use computers, word processing, keyboarding, data bases, and spread sheets. Becker (1991) reports business education teachers use computers nine percent of the time, math teachers eight percent of the time, science teachers five percent of the time, and English teachers seven percent of the time.

Piccano (1991) found significant differences at the high school level. The New York City schools used more D&P and tutorial. There was greater use of tools more in Westchester high schools than in New York City high schools.

At the high school level, computer-using teachers are still in the minority among science, math and English faculties and computer users have a limited pattern of use (Becker, 1991).

High school coordinators see continued growth in the use of the computer as a productivity tool. They see less growth in use of the computer as a learning medium in English, science and social studies (Becker, 1991).

Overall. Root & Rowe (1987) studied the use of computers at different grade levels in south Georgia schools. Teacher use was fairly consistent but instructional and administrative uses varied by grade level. (See Table 3, Appendix A). She found similarities of teacher personal use of computers at the elementary level; room decoration, word processing, assignment and worksheets, and tests. The only difference at the high school level was that teachers didn't use the computer for room decoration. Instructively, elementary teachers used computers for drill and practice. At the middle and high school level, the emphasis was on word processing, discovery, and problem-solving. Curricularly, computers are used in elementary language arts, math, science and social studies lesson. Middle Schools use computers in general math, science and social studies. And, mostly, the high schools used algebra/geometry, business math and accounting. Interestingly, only twenty-one percent (21%) of the elementary principals thought computer use was very important compared to sixty-one percent (61%) of the middle and seventy-five percent (75%) of the high school principals.

Time. Exemplary teachers use computers about the same amount of time as other computer users -- one half hour or more per day. Sixty-five percent indicate some every day use. The most frequently cited use was as a tool in the classroom for specific subject matter.

CLASSROOM ENVIRONMENT

Organization of class. Exemplary technology-using teachers run their classes differently than other teachers. Surprisingly, they did not individualize assignments more. But they were less likely to have each student do the identical computer assignment as every other student. They did emphasize more small group work. And they used smaller groups and different software for different groups (Becker, 1992).

__Interaction__. Technology also has an impact upon the organization of the classroom by reorganizing classroom interaction. With some students engaged in computer work, teachers can give assistance to non-computing students, allowing computing students to work independently.

There is some evidence that the introduction of technology empowers the interaction of students and teachers in learner-centered and teacher-centered instruction. For example, Bradly & Morrison (1991) studied the interaction of technology-using teachers and students in classroom and laboratory settings. She found more interaction occurring in the laboratories than classrooms. And, Mitranz et al. (1991) found that teaching and learning in computer-based classes were dramatically more student centered and individualized than in traditional classes (cited in Bradley & Morrison, 1991). Furthermore, patterns of interaction also varied across grade level as well as by activity structure (Chernik & White, cited in Bradley, 1991). Additionally, students engaging in microcomputer-based instruction with a partner required less teacher assistance than did students working alone (Rhodes, 1986, cited in Bradley & Morrison, 1991).

__Location__. The location of the computer in the classroom is important (Bullock, 1988; Wiske et al., 1988). The classroom location frees teachers to use them as needed. Labs, on the other hand, tend to be inaccessible and require scheduling. Forty percent of teachers said they had no access for all students (Schultz et al., 1989).

Several ecological problems are worthy of further research. Can problem-solving units using computers can be taught effectively with just a few computers, perhaps on loan for short periods, rather than depending upon the now-common centralized computer laboratories? This is an important question, because it might impact on the degree of true integration of computer resources into the curriculum.

Evidence exists that supports this position. For example, Sheingold et al. (1983) asserted that centralizing computers outside the regular classrooms helps avoid integrating them with the regular classroom. If they are correct, then studies like the one suggested above could be important keys for how to solve curriculum integration problems.

Computer-using teachers, although twice as numerous as five years ago, still only rarely provide a computer centered classroom where students use computers for a large fraction of the time on any one learning activity (Becker, 1989).

Resource Allocation. The standards and felt needs of exemplary technology-using teachers are larger than those of other users. These teachers cite not having enough space to locate computers properly, computers that are too limited, out of date or incompatible with other equipment, software that is not pedagogically sound, and difficulty keeping everything in working order (Becker, 1992).

Resources also seem to be allocated differently across grade levels. For example, elementary schools seem to prefer to distribute their computers. In spring, 1989, only seven percent of K-6 schools and twenty-four percent of the high schools had at least eight computers linked (Becker, 1991).

COOPERATIVE/COLLABORATIVE LEARNING

Using small, non-competitive groups of students works well if there are interesting problems and strong guidance by the teachers. Students under these circumstances cooperate within and across groups, with teachers, with each other, and learn important skills. Generally, students like the group work, and challenge one another to think. This instructional practice is an excellent teaching strategy to use with small groups, with problem-solving and with data base applications.

Cooperative Student Groups. While the majority of computer-based instructional applications have been designed for individual use, teachers are developing strategies and techniques to allow students to work together effectively while using the software. Slavin (1991) identified two major components of cooperative learning programs: a) an inventive structure, whereby learners share consequences for the group's success or failure, and b) a learning task that encourages cooperation. When designing cooperative computer-based strategies, teachers must deal with issues such as the size of the groups, equity concerns, and software that is designed for individual use. Various cooperative implementation strategies have been suggested, such as using a word processing program to teach written language skills (Brown, 1989; Johnson & Johnson, 1986) or using simulations such as The Oregon Trail or The Market Place in a group setting (Isenberg, 1989).

Additionally, Herman et al. (1992) found that technology affects the social organization of classrooms. When using technology, students tended to work in cooperative and/or collaborative groups. While this pattern may result from the limited number of computers available to each student, the use of technology does produce a higher incidence of cooperative learning activities than when students are not using technology.

Grouping/Pairing. There is considerable evidence that cooperative grouping and pairing makes a significant difference in learning. For example, Whyte et al. (1990-91) and Levin et al. (1987) found that pairing students for computer-assisted instruction is efficient and cost-effective. They concluded that the manner in which individuals were paired by individual cognitive style made a significant difference.

Other studies show that the use of paired/cooperative teaching methods results in both more effective and more efficient computer-assisted instruction. This research concluded that a team learning approach was significantly more cost-effective in teaching COBAL programming.

Dalton et al. (1987) found that learners working in pairs significantly outperformed learners working individually during a CAI lesson. Field independents (FI) are analytical and independent, do not seem to need an externally provided structure and function with very little environmental support. Field dependents (FD), on the other hand, show a lack of initiative and have a readiness to submit to authority. They found field dependents benefit significantly when paired with a field independents. Field independent students did equally well regardless of their partner. Groups made up of either two field independent students or a mixed group of one field dependent and one field independent significantly outperformed groups made up of two field dependents.

In addition, Johnson et al. (1985) reported that learners working cooperatively on a CAI lesson produced a greater quality and quantity of daily work and demonstrated greater problem-solving skills than learners working individually or competitively. Additionally, they found that cooperative group work with computers enhanced factual recall, application of factual knowledge, and problem-solving skills when compared to competitive group or individual group work on the same material. Finally, Mevarch et al. (1991) reported that students who used CAI for drill and practice in pairs tended to perform better than those who used the same program individually. Cooperative CAI expanded individualistic strategies and equally affected self-concept and relieved math anxiety of low ability students.

Off-task Behavior. Many educators are reluctant to implement cooperative learning systems because of potential increases in off-task behavior, despite proven benefits. Teachers often believe they lack the control necessary to focus learner attention on lesson content during cooperative learning exercises.

The results of the Char et al. (1987) study of interactive video provides instructional designers with an effective way of implementing cooperative learning systems. Interactive video may provide an effective and enjoyable means of promoting cooperation, while minimizing off-task behavior.

Group size also has an effect on off-task behavior. For example, small groups in the computer laboratory setting were more attentive to the lessons and had fewer disruptions than large groups. Further studies should look at differences in achievement gains between small and large groups using interactive video. A group size of two to four can be used as a general guideline.

According to Char et al. there is another side of this issue. Off-task behavior is a definite waster of time, sometimes by students and sometimes by teachers. Teachers sometimes backtracked unnecessarily because of ineffective planning, organization or teaching in the classrooms. Students were sometimes off-task for extended periods of time and sometimes their teachers knowingly permitted that to continue.

Cooperative Software. The strength of the cooperative grouping effect places special demands on software producers. To date there have been few applications of cooperative software available.

Structure of environment. Group work on computers does not insure cooperative learning has occurred. Rysay, (1990) says that providing structure helps. They further recommend that students summarize and explain what they are learning to their partner at various intervals. Additionally, Rawitsch (1987, 1988) hypothesized that student work styles would be related to problem-solving efficiency among students using computer databases. He concluded that the students with more structured work styles were more efficient than those with more unstructured styles.

Equity concerns. Rotating roles is suggested to insure equity. Groups should also agree on what is entered into the computer. Students should ask other group members for help when needed.

SUPPORT STRUCTURES

Teachers need an array of resources ranging from technical support to knowledge of how to use software and hardware. They need information about existing applications to meaningfully integrate technology into the curriculum (Hawkins, 1990).

The system requirements for using computers effectively are: adequate hardware, appropriate software, related courseware, a knowledgeable and skilled teacher, reasonable mechanisms for assessing learning and practice, technical assistance, and a supportive environment for teachers' professional growth and development (Wiske et al, 1988).

Specifically, the conditions that help teachers integrate are technical literacy and support systems.

1. **Technical Literacy**. Knowing how to use basic applications such as a word processor, a graphics program, a spreadsheet and a hypertext program. The skills include:

   Familiarity with options. Knowing how to advise students on which medium is best suited for a particular project and how long it will take to complete the task.

   Visual Literacy. Knowing how to select images, manipulate them, analyze them and create them.

   Non-linear Thinking. Having an awareness that deciding the order in which students will encounter new information is at the heart of creating an instructional sequence, and being willing to use hypertext tools, which allow students to create their own sequences.

2. **Support Systems**

   Intimacy with Machines. Awareness that it takes time. Computers at home help teachers become more comfortable with software and hardware, and understanding other options.

   Consumer Education. Provides an overview of the world of technology.

   Technology for Poets. Courses that help them integrate.

   Administrative Support. An understanding that it is a complex process, requires changes, physical settings, presents security problems, and scheduling problems.

Design Consultation. A resource person who creates software containers which students can scan, paint, type and copy (Brunner, 1990).

Becker (1992) found a consistent relationship between exemplary teaching practice using computers and substantial investment in supporting and training personnel.

Training. Several studies provide evidence to the importance of training. For example, exemplary teachers had access to different training opportunities in using computer application programs and formal training using computers with specific subject matter they taught (Becker, 1992).

Teachers require training not only in how to use the technology, but in how specific applications can be integrated into on-going curricular activities (Hawkins, 1990; Martin, 1987; Schofield & Verban, 1988; and Watt & Watt, 1989).

Finally, Elder (1988) makes the important observation that teachers need considerable training and practice in direct and indirect teaching methods, in classroom management, and in working with student groups if computer database units are to be successful. She spent four and one-half days training the teachers in her study and asserted that this was insufficient.

Access to Computers. Access to computers by teachers and students are important determinants of technology use in the classroom. For example, exemplary teachers were more prevalent where teachers have been able to borrow school computers and take them home and where there were more computers per capita (Becker, 1992).

A majority of computer using elementary teachers had one or two computers accessible to their class (Becker, 1992).

Computer ratios should be no greater than seven to one if meaningful integration is to take place. It can give the student numerous opportunities for practice and feedback (Butzin, 1992).

Consultation Support. Exemplary technology-using teachers were more likely (40% vs 17%) to have begun using computers initially at the suggestion of their school level computer coordinator or a district coordinator rather than starting on their own initiative or because of suggestions from school administrators or teaching colleagues (Becker, 1992). Becker (1990) also found that the consultation of colleagues was another important factor. He found computer-using teachers were found in schools where there were more computer active teachers providing a social network of computer-using teachers. This factor accounted for the largest difference he found, nearly twice as many on average.

District Environment. Exemplary computer-using teachers are likely to be found in districts with the following characteristics.

- Low income, low SES districts as likely as in high income, high SES sites.
- Districts where leadership is concerned about equity of access to computers across categories of students.
- Districts with organized support in the form of staff development activities and a full-time coordinator (Becker, 1992).
- Teachers need support from administrators, department heads and technology coordinators in order to plan and schedule lessons and review materials (Hawkins & Sheingold, 1986; Loucks & Hall, 1982, and Martin, 1987, cited in Wiske et al., 1987).
- Software/hardware should support teachers administratively and academically, and support student learning styles (Vision: Test, 1990).
- Smaller class sizes, favorable student/computer ratios (Becker, 1992).

PRODUCTIVITY TOOLS

Productivity tools allow students to do something that was not possible without technology. Some have found that the most valuable learning takes place when the teacher and the students manage computer projects together.

The use of productivity tools requires skills of a different sort than most CAI programs require. Hence group products and processes should differ (Kacer et al., 1991).

Hawkins & Sheingold (1986) state that teachers frustrated with the educational possibilities of programming and traditional courseware are experimenting with computer applications programs (tools). Tool software is open-ended, promoting an education that includes the expressive forms of learning and provides greater opportunities for problem-solving. This is in contrast to traditional software that the authors believe encourages linear procedural processes.

The computer as a tool allows students not only to invent ideas and test them in the real world, but also to share them with others. Thus, one could say that computer tools are, or at least can become, applications that profoundly extend our limited cognitive capacity (Pea & Soloway, 1990).

Problem-solving Model. There are three themes running through the studies that transcend many different categories of the problem-solving model. They are considered as "overlay factors" impinging on the whole process of using computers as tools. These are small group work, prior student knowledge and time. The **small group factor** is very positive and is reported later in this paper.

In contrast, many students lacked sufficient knowledge about subjects they were investigating. This general problem detracts from the unit objectives and student success as problem solvers and plagues all teachers to some extent.

Students' inability to work in a **knowledge vacuum** is underscored by several studies. Lack of student knowledge must be anticipated by the teacher, who has to incorporate specific ways of overcoming the problem in teaching.

Time pressure is a factor felt by teachers and students alike, to finish the activity, lesson, or unit in order to get on to the next one. Adding the use of computers increases this pressure; to do a good job means extra preparation, instruction, and practice with such mechanics as database commands and printing sequences were necessary. Students complained that they needed more time to collect more evidence or to write reports; and some teachers complained they needed more time to do more debriefing or computer lab work. In short, White (1987) found that a unit on problem-solving with computer databases tends to increase the press of time in the classroom.

Sequence. There is a definite "best practice approach" to using technology in a problem-solving application. The most successful teachers draw their students into the problem area without undue emphasis on the computer aspects of the units. They also set forth clear expectations for student work and outcomes, including intermediate "milestones" in the process. Introductions were a good time for the teacher to use a simple example of a "problem" and work on it through parts of the problem-solving process, so that the "big picture" was reinforced. Best practice includes introductions, modeling, discussion, written products, and public sharing.

Introductions. Introductions are critical. They are the point at which the teacher familiarizes students with the "big picture" of the unit. It is clear that the strength of the units' introductions -- the clarity of goals, whether the overall topic was introduced in an interesting way, the clarity of expectations for students -- were very important in shaping the eventual problem-solving success of the students. These factors seem much more important than the nature and operation of the technology application.

Modeling. The teachers' use of examples, modeling of various problem-solving steps and processes, and providing for student practice, were very important to the success of units. Without them, students tend to drift and wander rather than carry on with purposeful activity.

Discussion. Discussion seems to be an important component to achievement in problems of using applications. While using interactive video and computers can be motivating, it seems that this type of instruction should not be used alone, but rather in conjunction with teacher-led discussions. Further studies should look at the effectiveness of interactive video with discussion time versus text with discussion time.

Written Products. Associated with the practice of regular debriefings is that of asking students for interim written products of their work, checking these products, and giving clear feedback and suggestions to students to assist them in the process. The students of teachers that did this were much more successful than those whose teachers did not.

Public Sharing. It is important to include some public sharing by students of the results of their problem-solving at the end of the unit. It gives students and teachers a solid target to shoot for. It also emphasizes one key value of inquiry -- its public nature, the idea that results should be scrutinized by others.

Productivity Applications. Word processing, data bases, spreadsheets, graphics and telecommunications are examples of productivity tools that, along with simulation and interactive video applications, empower teachers and students in the problem-solving activities.

Word Processing. Of all the areas of the curriculum, writing is the one in which computers seem to earn most rapid endorsement from teachers. Many claims have been made as to the advantages of writing with a computer. Many educators who incorporate word processing into their students' writing programs agree that computers make revising and editing much easier and that once children are comfortable with keyboarding, they write more than they do when using paper and pencil. Research that evaluates the anecdotal evidence is necessary to help determine the future direction of word processing in the curriculum (Hiebert et al., 1989).

A specific example of the use of word processing in a pragmatic way is the ACOT approach. The **ACOT approach** to computing focuses on using computers as tools for learning and performing particular tasks.

Hiebert et al. (1989) reported that ACOT students routinely use computers to draft, revise, proofread and print their writing assignments. Teachers report that with daily use of computers, students do more revising at the structural as well as the mechanical level. Teachers also note that their students are not only better writers, but they are more confident, motivated and willing to collaborate than ever before.

The most significant factor in learning to write is the **quality of instruction**, not merely access to computers. Evaluations of written work in both the ACOT and non-ACOT classes indicated that focused instruction and conscientious revision promoted effective writing. However, during the writing assignment session, ACOT teachers noted that **access** to computers is likely to enhance students' willingness to write and revise more. Students wrote more and better when they had high access to computers.

ACOT children also maintained a high level of **enthusiasm**, comfort and persistence seldom seen when they plan, draft and revise their writing with paper and pencil. Computers helped make their compositions much more presentable, which encouraged sharing. Writers were much more willing to share their work when they had legible, computer-produced text. ACOT students did almost twice as much writing as students in other classes during the same time period. In addition, ACOT stories had more complicated plots and included more dialogue. This trend was especially prevalent in comparing the writing of ACOT and non-ACOT low-achieving students.

It is evident that ACOT students' writing and their approaches to writing change when they write with computers regularly. However, a closer analysis of what those changes are is critical for educators to determine how best to implement technology in the teaching of writing. Also worthy of further study is the fact that some ACOT students revert to previous levels when they leave the program. Possible reasons for the ACOT students reverting to former academic and social behavior include the short duration of the innovative program, a return to a teacher-directed, rote learning environment, and the unavailability of computer tolls to support learning.

Databases. Students who actively developed database technology projects tended to spend more time on these projects and show greater ability in problem-solving, thinking and reflection on teacher and student posed questions (Watson & Strudler, 1988; White, 1987).

Teachers appear to use databases to develop higher order thinking or problem-solving skills. No study claimed a relationship between database use and lower level knowledge acquisition or recall.

Mendrinos & Morrison (1986) and Morrison and Walters (1986a, 1986b) found that teachers also believed that quality of writing improved as a result of student involvement with the computer database and other materials.

Interactive Video Discs. Claus et al. (1990) recommended the following guidelines based on their findings: 1) use the interactive video system for review only, 2) due to the reading level of the text contained in the program, use the system in a high school setting, and 3) provide students with sufficient access to the system.

There are advantages and disadvantages to using interactive video in both the classroom and computer laboratory settings. The advantages to using interactive video in the classroom include the teacher's ability to control the amount of time spent on a lesson.

The teacher controls what is viewed by the students. Less equipment is also needed for classroom presentations. Disadvantages include more student distractions which can mean less time is available to go through the lessons and less of an opportunity to learn.

The advantages of using interactive video in a computer laboratory include allowing students to proceed through the lesson at their own pace. Working in small groups of two to four students tends to work better than larger groups of ten to fifteen. Some advantages of using interactive video in a computer laboratory setting include distractions from other videodisc setups and the need for more equipment to allow students to work in small groups.

Therefore, videodisc instruction as it is currently used should be viewed as an enhancement and not necessarily a replacement for an existing curriculum. The principal benefit of interactive video is the ability to adapt to individual needs through varied instructional pacing and individualized feedback (Clement, 1983; Menis, Snyder, & BenKohav, 1980 cited in Claus, 1990).

Simulations. Computer simulation has the potential to help students develop higher order thinking skills. A computer simulation is a representation of a real-life situation, but with less detail. Simulations are designed to allow students to be actively involved in making decisions and dealing with the consequences of those decisions. This process aids in the development of higher-order thinking skills (Lunetta & Peters, 1985).

Previous research on computer simulations showed that large-group presentation of simulations may be slightly more beneficial than small-group presentations, although no major differences in students' ability to recall concepts were found (Sherwood & Hasselbring, 1985/86). A recommendation of the Sherwood-Hasselbring study was that additional research be conducted to compare the effect of computer-based instruction to more traditional class methods before drawing any definitive conclusions.

Teachers have the option of using either computer simulations or traditional activities as follow-up to instruction. The two methods were shown to be equally effective.

- Computer simulation used alone is not as effective as a traditional classroom presentation.
- Computer simulation used alone is not as effective as using traditional classroom presentation followed by the simulation.
- There is no significant difference between using computer simulation and a traditional follow-up activity.

INSTRUCTIONAL MATERIALS

The creation of technology based teaching and learning products is based largely upon instructional design and development principles that have their roots in cognitive psychology and instructional science (Ely 1991).

Redefining the textbook

- In November, 1989, the Texas State School Board formally adopted the Windows on Science Video disc based curriculum from Optical Data Corporation for use in Texas schools, thus allowing traditional textbook funds to be spent on educational technology.
- Texas believes that they have redefined the textbook and allowed Optical Data's Elementary Science video series Windows on Science to be placed on their list (Mageau, 1991).
- Textbook in Texas means any instructional material that meets curriculum requirements. In California it means textbooks and videodiscs. Florida law allows it to adopt technology in the textbook process (Mageau, 1991).
- Technology to produce customized textbooks exists but is not being utilized on a large scale (Mageau, 1991).
- According to its CEO John Kernan, one of the reasons Jostens was formed was the belief that during the 1990s states would be routinely interested in adopting technology based texts (Mageau, 1991).

- Educators' concerns are with accessibility. We are not at the point that every child can take home a video disc or other computer product (Mageau, 1991).
- Incorporating technology into the adoption process, they predict, will affect software companies, textbook publishers and education itself. Texas (1990) California (1990) and Florida have taken this step (Mageau, 1991). For example, in March, 1989, Encyclopedia Britannica and Pioneer signed an agreement to publish 100 Britannica K-12 titles on video disc with bar code access through accompanying workbooks. This created an instant market and established a low cost bar code system (Miller & Sayers, 1990).
- And, in December, 1989, Optical Data Corporation stirred controversy with its decision to subsidize videodisc player sales to Texas schools that purchase Windows on Science.

Students using text enhanced by interactive video instruction tended to do equally well as students using text without the interactive video enhancement. Although interactive video images are captivating and increased the subjects' motivation, they did not result in a significant difference in achievement scores between the two treatments.

Software. In the last several years, increased criticism of "traditional educational software" has appeared in research literature. This criticism presents three main arguments:

- It directs rather than supports education (Sloan, 1980).
- Student interaction with computers is not necessarily neutral (Bowers, 1988).
- Drill and practice, tutorials, simulations, and programming software inhibit students from engaging in true problem-solving (Streibel, 1986, and Freedman-Relan, 1990).

Generic Market Model. This produces software to supplement other instructional materials. Content is identified by the company, then they design software to teach the content. It is likely to have a set of objectives broader than one single grade level or set of materials. The vocabulary and strategies may be different than those presented in textbooks the teacher might be using. The major weakness is that the design and development decisions are greatly influenced by the potential number of sales (Sales, 1990).

Customized Market Model. The products are more integral to the instruction they are incorporated. The design is focused on the learning outcomes of the users' instruction. They can fully integrate all the materials and prepare lesson plans which can include specific direction to the teacher on when and how to use the software to attain the best results.

- The largest publishing houses traditionally published textbooks and other instructional materials. They are beginning to use the customized market model (Reinhold, 1981 cited in Dudley et al., 1987).
- While many educators bemoan the preponderance of drill and practice software which is based on a behavioral view of learning, others defend its use (Roblyer et al., 1980). Jensen (1985) argues that the problem with much available CAI software is that software developers frequently overlook important behavioral principles like transfer of stimulus control and the use of adequate reinforcers (cited in Dudley et al., 1987).
- Computer mediated materials require a computer of some sort to enable them to be displayed, studied or used. Some of the main types are: number crunching and data processing packages, substitute tutor packages, substitute laboratory packages, data base systems, computer-managed learning systems, and interactive video systems (Ellington, 1987).

SECTION 3
TECHNOLOGY AND PERFORMANCE ASSESSMENT

> **Society currently has some very specific measures for the effectiveness of its educational system: student achievement, attitudes, dropout rate, learning time.**
>
> **(Robyler et al., 1988)**

The purpose of this section is to examine the results of using technology in instruction. Do they work? Are there more cost-effective technologies? Does assessment have to change to promote an outcome focused education? The section begins with a summary centered on the focus questions followed by the supportive findings.

SUMMARY

In general, student **performance can be improved** through the use of learning technologies. Specifically, a meta analysis of 184 studies of learning technologies concluded that, on average, a student performing at the 50th percentile will perform at the 62nd percentile on the standard normal curve.

It is also clearly evident that **performance varies**. Therefore, strengthening implementation protocols and processes will produce substantially better results. For example, the fluctuation of results by type of achievement measure indicates that teachers must address alignment and assessment issues prior to assessing the results of their instruction.

Purchase decisions can also be improved when based on a clear description of the educational problem the user is trying to solve or the opportunity they are trying to provide students through learning technologies.

The following points illustrate the **impact of technology on performance:**

- CAI and ILS applications are effective for teaching mathematics and language arts. There is preliminary evidence that multimedia may produce similar results in science.
- Newer technology applications are more effective than older applications.
- The technology in mathematics, language arts, and science proved to be educationally significant in terms of results.
- The effect of technology on at-risk students is promising.
- Learning technologies raised scores 1) substantially on locally developed teacher/researcher district developed examinations; 2) moderately on state/regionally developed criteria referenced tests; and 3) moderately on standardized norm referenced tests.
- The write to read results were negligible and not educationally significant for reading, and substantial and educationally significant for writing.
- ILSs demonstrated educationally significant results on standardized tests; and with at-risk students.
- There were few studies found that examined the effectiveness of the use of technology as a tool. In fact, these applications require that new assessment strategies be developed.

Finally, if technology is to demonstrate its potential value then there needs to be a movement away from standardized test evaluations towards authentic assessments.

FINDINGS

Several major reviews of learning technologies have appeared in educational literature the past 15 years. Each review tried to aggregate the results from diverse evaluations in order to reach general conclusions about the effectiveness of Computer-Based Learning (CBL). The term CBL is used here as the most general term describing computer applications in the schools. It is preferred to computer-based instruction, which relates to the computer or teacher delivering instruction, because it encompasses the notion of the computer as a tool.

The reviews used either a box score, narrative, or quantitative methodology to integrate study findings. Box score reviews generally report the proportion of studies favorable or unfavorable to CBL. Narratives provide descriptions of each study or review and then draw intuitive conclusions. Researchers feel narrative and box score analyses may give too much weight to anecdotal reports and studies of marginal quality. Narrative reports are found in the literature in smaller numbers. But the box score approach used in early reports has been replaced by quantitative studies using the meta-analytic process identified by Glass et al., (1981, cited in Pisapia & Perlman, 1993). There are two types of quantitative studies: "horse race studies" compare traditional methods to learning technology applications, and "instructional design studies" compare student performance before and after the use of a specific learning technology.

Instructional design studies compare technology applications to each other, as opposed to a control group. The effectiveness of four types of integrated learning systems may be compared in this type of study. An example of this type of study was conducted by the New York City Board of Education in 1988. They assessed the effectiveness of thirteen types of integrated learning systems using a experimental design. They found different results based on the instructional design used by the courseware producer. The behavioral based courseware -- Wicat, CCC, and Josten's -- performed significantly better than the concept-based courseware of Wasatch. As Richard Clark has repeatedly warned, research clearly indicates that any learning gain associated with a new medium cannot be caused by the choice of the medium (Clark & Sugrue, 1988). They believe that learning is due to factors such as task differences, instructional methods and learning traits, but not choice of media for instruction. In 1988, they stated that "our reading of the past decade of media research strongly suggests that the learning that occurs from well-prepared media presentations is actually due to three factors or types of variables: a) learning task type (e.g., more procedural or more declarative tasks; b) individual learner traits (e.g., motivation, general ability, and prior knowledge); and c) instructional method (e.g., the way that the instructional presentation compensates for deficits in learner traits that are required for learning) (Clark & Sugrue, 1988). The New York City study gives some support for their position.

EFFECTIVENESS MEASURES

The seemingly simple approach of comparing student performance after being taught with or without learning technologies presents several problems. The most difficult problem is the impossibility of creating a comparable control group. Clark (1985)(cited in Pisapia & Perlman, 1993) concluded that there are many differences other than the use of computers in most comparison studies that confound the results of these types of studies. The point is worth noting and more rigorous controls by researchers are required to produce reliable results. However, most reviewers who point to this weakness also go on to use the results as evidence of effectiveness (Clark, 1985; Roblyer et al., 1988; Jurkat et. al., 1992; Power on!, 1988). Clark's argument and rejoinders, from the Kulicks and Roblyer et al., were reviewed. The continued use of the comparison studies, and Becker's and Henig's (1987) analysis indicating that even after twenty-six percent of the fifty-six research reports were discarded due to flaw, the positive results of CAI remained stable were noted. "We concluded that the comparison studies approach, if used in a meta analytic manner, can provide be valuable and reliable guidelines for policy decisions when the effect of the learning technology is isolated as much as possible, when it is supplemented by evaluations focusing on the process and learning situations, and when the results are used as interpretative trends. We agree that there are more powerful variables to study" (Pisapia & Perlman, 1993). How technology is used constitutes an important set of variables. Future research should instead be aimed at finding the most effective ways of using the computer at different grade levels with given students on given subjects, how technology can be integrated into curriculum and instruction, and how current technologies can be applied in a more effective fashion. The use of traditional achievement measures is also of concern to researchers and practitioners in other ways.

These measures do not account for actual conditions occurring during implementation of learning technologies. For example, the fact that implementation is a process that proceeds over a period of several years; computers are used in a variety of ways for a range of purposes by teachers; widespread use of learning technologies are too new to have been supported by a body of systematic research about what works and what doesn't work; and generally, schools have only loosely specified objectives for the learning technologies they adopt (Wilder & Fowles, 1992).

Furthermore, while current testing techniques are relatively advanced in assessing whether or not students have learned basic content knowledge, they are immature in assessing more complex thinking skills (Power on!, 1988). The insensitivity of standard measures to assess higher order skills is a challenging problem since teachers mention problem-solving, global awareness, motivation, writing and cooperative learning as positive benefits of using learning technologies. Without appropriate techniques to measure these skills, the effects of learning technologies can only be inferred in regard to complex thinking and problem-solving abilities.

Finally, since teachers and students continue to use CEI to emphasize the development of problem-solving and meta-cognitive skills, it seems clear that effective measures of these skills must be developed. In their national report, the International Society of Technology Education (ISTE) declared that new assessment technologies must be developed to supplement and finally replace conventional tests. These new assessments must reflect new curricular focus, new kinds of learning and new environment (Vision:Test, 1990).

Several studies using teacher or researcher generated assessments are pointing the way to this development on a small scale. However, while alternative measures are in the process of development for the most part, they either are not yet available or not yet accepted as large scale measures for accountability purposes. (An example of alternative measures being developed by the New Assessment Measures Committee of the Maryland Education Project is found in Pisapia & Perlman, 1992).

On the other hand, until the availability and accountability issues are decided, decision-makers can be guided by the assertion of the National School Boards Association in a report on the transfer of technology to education which states: "We cannot improve the productivity of education if we don't know what it is, and that requires accepted measures of performance and cost...'[N]o measure' is the worst of all possible worlds." (Perelman, 1987, p. ES-14).

STUDENT PERFORMANCE

Evidence on the effectiveness of using computer-based technologies in instruction has accumulated for over 30 years. Effect Size tends to vary from study to study. However, CBL appears to have a rather consistent positive effect on achievement. The evidence in reviews by Pisapia & Perlman (1993), and Becker (1991), Bennett (1991), McNeil & Nelson (1991), Bialo & Sivin (1990a), Fletcher (1990), Kulik & Kulik (1989), Debloois (1988), Roblyer et al., (1988), Kulik & others (1986), Samson et al., (1986), Kulik et al., (1985), Bangert-Drowns et al., (1985), Hartley (1978), Visonhaler & Bass (1972) (all cited in Pisapia & Perlman, 1993) found increases in achievements from .27 to .56 standard deviation for computer-based technologies when compared to traditional approaches.

The conclusion of the Office of Technology Assessment was that the results thus far do suggest how certain configurations of hardware and software, used with particular populations of children and under the supervision of competent teachers, contribute to the achievement of specific instructional objectives. CAI has been researched the most and has proven to be an effective supplement to traditional instruction (Power on!, 1988).

Performance Variability. The overall analysis indicates technology applications are effective. But, Pisapia & Perlman, 1993 found that 1) 32% of the studies had a negligible effect, 2) 19% had a moderate effect, and 3) 49% had a substantial effect on student learning. It also illustrates a wide range of effects (from -.07 to .61) across the 184 studies they reviewed indicating that factors other than the learning technology cause variability.

Writing to Read (WTR), a specific form of computer-assisted instruction courseware, is also reported in Figure I. CAI studies using the WTR courseware could expect negligible effects in 39% of the studies and substantial effects in 39% of the studies. Examination of the studies utilized for this review indicate that WTR is more effective than traditional methods in teaching writing in kindergarten and less so in the first grade. WTR's effect on reading is less pronounced at either level. Critics suggest that these results are to be expected since writing is not a strong component of traditional kindergarten and first grade curricula (Pisapia & Perlman, 1993).

Integrated Learning Systems (ILSs). In the fifty one (51) Integrated Learning System studies, Pisapia & Perlman (1993) found that 54% had substantial effects, 15% had moderate effects and 31% had negligible effects. Overall, the achievement effect of 69% of the ILS applications constituted a conventional measure of practical educational significance. In fact, in 54% of the cases, teachers could expect the 50th percentile student in their class to move to the 72nd percentile, a 22% gain in achievement.

Interactive Video Instruction. The findings of Barbara McNeil and Karyn Nelson in a meta-analysis of 63 Interactive Video Instruction studies conducted in the last ten years found a substantial effect size of .53 (McNeil & Nelson, 1991). While the data found in their report did not lend themselves to our analysis, they lend support to our findings on multimedia applications.

Performance by Timespan. Bangert-Drowns, Kulik & Kulik (1985) (cited in Pisapia & Perlman, 1993) projected that differences between earlier mainframe-age studies and later microcomputer-age studies may be due to improvements in instructional technology. And, Niemiec & Walberg (1987) in their review of reviews reported an average improvement of .38 standard deviations in achievement for mainframe based studies. This compared to an average improvement of 1.12 standard deviation for micro computer-based studies.

A tendency for more recent studies to produce stronger results was found in the Pisapia & Perlman (1993) study. The years 1978 and 1985 were selected as benchmark dates because they marked approximate periods when new technology applications were introduced; for example, videodiscs in 1978 (Gindele & Gindele, 1984, cited in Pisapia & Perlman, 1993). One can see in Figure II that the average effect of studies prior to 1978 was .28, .32 between 1978 and 1985 and .35 post-1985. However, much of this timespan increase was found in ILS and WTR applications.

Their research also pointed out the changes occurring in use of learning technologies. For example, 62% of the CAI results, 62% of the CMI results and 100% of the CEI results were recorded prior to 1978. Whereas, 61% of the WTR, 88% of the ILS and 100% of the MM results were recorded since 1985. This change in courseware complemented the increases found in the three time frames examined. It lends further support that the improvements in the instructional design of courseware and the move to more adaptable learning technologies produce more effective technology applications.

The practical significance of this time scale discovery is that more recent learning technology applications have demonstrated more substantial effects which supports current efforts to reframe instruction to utilize more learning technologies.

__Performance by Grade Level__. Pisapia & Perlman's (1993) results lend modest support to the claim existing in the literature that younger students seem to profit more than older ones from the highly structured materials (small steps and immediate feedback) supplied in drill and practice, tutorial, and managed instruction. In this case, CAI proved effective at all grade levels. It had similar effects at each system level: grades K - 4 (ES .49); grades 5 - 8 (ES .36); and at grades 9 - 12 (ES .41).

Overall, 55% of the learning technology applications were used in grades K-4. ILS and Writing to Read were the predominate applications used in these grades. CAI, on the other hand, was utilized at each grade set -- heavier in grades K-4, lighter in grades 9-12 -- with substantial results at each grade level.

Generally, in elementary and middle grades, CAI and ILSs produced better results. At the high school level, CAI was less effective and CMI was more effective. The data demonstrates that CEI and MM applications, with their emphasis on higher order skills, are being used primarily at the middle and high school levels, and the basic skill approaches of ILSs are primarily used at elementary and middle school levels.

Performance by Subject. The literature provides strong support for the effectiveness of CAI in mathematics, some support in language arts and negligible support in other subjects.

One hundred sixty eight studies in the Pisapia & Perlman (1993) data base could be categorized by subject area. Thirty eight percent of the 168 studies describe: mathematics results; 50% language arts results including reading and writing; and 11% science results. No studies were located in history or geography. Sixty five percent of the CAI studies were in math, 33% in language arts and 2% in science. The CMI studies were evenly dispersed across math, language arts and science. The ILS applications were evenly divided between math (53%) and language arts (47%) CEI studies were found in math (65%) and science (33%). The newer MM applications were used primarily in science. Studies of data base use in social studies were found in the literature but did not meet the criteria of inclusion for this study.

In general, the effect sizes found in mathematics, language arts and science were educationally significant. In fact, the mathematics effect sizes for CAI (ES .49) and ILS (ES .40) were substantial. The language arts effect sizes for CAI (ES .32) and CMI (ES .36) and WTR (ES .31) were substantial as were the science effect sizes for CMI (ES .36) and MM (ES .50). Although the number of multimedia studies is small, the results lend some credence to their increased use of MM in science.

Wise's (1989) recent meta-analysis of the use of computers in science found ESs ranging from -.62 to 1.21, with mean of .34, indicating that students receiving CBL exhibited superior achievement. For example, videodisc-based applications in the laboratory had an ES of .40. Microcomputer-based laboratory lessons had an ES of .76. In biological science laboratories the ES was .22.

Performance by Student Characteristics. The results of the Pisapia & Perlman (1993) study clearly indicate that ILS is a powerful application for at-risk, disadvantaged and low achieving student populations. In 34 ILS studies, the ES was substantial (ES .41) for low achieving students. And, in 41 ILS studies, the ES was substantial (ES .39) for at-risk students. The practical significance of these findings lies in the fact that a teacher of low achieving or at-risk children could expect the 50th percentile student to move to the 63rd percentile.

Supportive of this finding is Olson & Krendl's, (1990) finding that the research on the effect of technology on at-risk students is promising. These students often show significant gains in achievement levels in basic skills content areas.

Pisapia & Perlman (1993) also found that ILSs focusing on basic skills proved to be effective in teaching reading, math, and language achievement to low achieving students. The ILSs also produced similar results for regular students on basic skills. While the number of studies reviewed is small, the results for gifted students (ES .03) are consistent with reports indicating that high achieving students operate at a ceiling level which interferes with the ability of learning technologies to show powerful results on basic skill.

At-Risk Students. The effects of computer-based teaching seemed especially clear in studies of disadvantaged and low aptitude students, for example, whereas effects appeared to be much smaller in studies of talented students (Bangert-Drowns et al., 1985; Burns & Bozeman, 1981 each cited in Pisapia & Perlman, 1993, and; Niemiec & Walberg, 1988; Robyler et al., 1988; Olson & Krendl, 1990).

On first reading, the research on the effect on at-risk student learning is promising. They often show significant gains in achievement levels in basic content areas; their attitudes toward learning and toward the instructional content tend to improve according to parents and students; absenteeism and drop out rates decline (Olson & Krendl (1990).

Performance by Effectiveness Measure. Student learning in each of the 184 studies used by Pisapia & Perlman (1993) was measured by achievement documented at the end of a program of instruction. The data indicate that learning technologies raised scores 1) substantially on locally developed teacher and researcher developed examinations; 2) moderately on state-regionally developed criterion-referenced examinations; and 3) moderately on standardized norm-referenced tests. The most powerful effects were demonstrated when local teacher or researcher assessments were utilized.

In particular, ILSs demonstrated higher ESs on standardized norm-referenced tests than on state level criterion-referenced tests. This finding was not unexpected since ILS courseware is primarily developed for a curriculum supported by national standardized tests and not by local or state assessments. Of course for additional fees, ILS vendors will customize to state or local curricula.

On the other hand, WTR applications were more effective with local school division, teacher or researcher developed assessments than standardized tests of any type. In the WTR studies, the standardized tests were generally used to measure reading gains. The WTR results for reading were negligible and not educationally significant. The local and researcher developed assessments used to measure gains in writing generally produced educationally significant results.

In general, their findings lend themselves to two interpretations. First, it appears that the closer the test development is to the teacher and to the learner, the more significant the results. The implication for future studies and the development of cost-effective models is that different outcome measures and assessment techniques should be utilized when testing for basic skills and higher order skills.

Secondly, the fluctuation of results by the type of achievement measure indicates that teachers must be sure to address alignment and assessment issues prior to assessing the results of instruction. For example, as indicated by the results on norm- and criterion-referenced tests in ILSs, alignment problems may exist between instructional objectives, computer courseware, and the tests used to measure achievement. These alignment problems possibly mask significant differences in student achievement which were not measured in a particular experiment.

Basic skills acquisition. Several meta-analyses indicate that computer-assisted instruction (CAI) generally produces small but significant increases in achievement test scores (Power on!, 1988). The improvement rate varies according to the grade range studied and the application, but, at a minimum, achievement increases from the 50th to the 60th percentile on such tests (Bangert-Drowns). Other meta-analyses find improvements from 50th to the 61st percentile (Kulik & Kulik), to the 63rd percentile (Samson et al., p. 313), and to the 68th percentile (Kulik et al., cited in Pisapia & Perlman, 1993).

Higher order skills attainment. Higher-order skills can evidently be demonstrably enhanced with the aid of technology. For instance, the average achievement level of junior high school general mathematics students on a standardized test of problem-solving rose from the 33rd to the 68th percentile over four years of television instruction (Chu & Schramm, 1989). The Higher Order Thinking Skills (HOTS) program developed by Stanley Pogrow of the University of Arizona shows gains in thinking skills and social interaction that continue beyond the experimental experience. The HOTS program is used to develop the thinking skills of metacognition, interference, deconceptualizations, and synthesis in at-risk students (Pogrow, 1987).

Pogrow, 1987, cautions that "simply using thinking software, word processors or the computer as a general tool will primarily benefit high-performing students who have already internalized procedures for generalizing and linking ideas. In the case of at-risk students, special, intensive techniques need to be developed to promote internalization of key basic thinking process before they can benefit measurably from sophisticated applications integrated into content."

Achievement results, need to be understood in context: standardized tests may be insensitive to the types of changes pursued in a tool orientation to computer use in the area of higher level thinking. Future technology evaluation work may wish to consider developing a more detailed, longer range instrument that is more sensitive to the long-term, creative writing process students use with technology as a tool (Herman et. al., 1992).

Attitudes. There is ample evidence collected from the survey that students' attention span is greater when working with the computer than when working with drill cards (Robyler et al., 1988).

Only two of the field studies used scientific measures of student attitude outcomes. Both Cornelius (1986) and Rawitsch (1987, 1988) found more positive attitudes toward use of computer databases in problem-solving among students in computer-using classes, although in the Cornelius study there was a difference in only one of the two comparisons (Cornelius; 1986 is cited in Rawitsch, 1987).

Herman et al. (1992) reported that the program does appear to have had a substantial impact on the students' attitudes toward school and learning in general, on their interest and proficiency in technology use, and on their attitudes and motivation while working with technology.

Motivational effect. Arguments about the motivational effects of media, the 'strong' media theory, suggests that certain media are more 'motivating' than other media. The 'weak' media theory suggests that the independent variable in motivation studies is not media, but is our beliefs of values related to media. For example, studies which have shown increases in motivation (or learning) with decreases in attitude toward a specific medium are now predictable given self efficacy theory.

Interactive video has been effective in improving performance in a wide variety of learning contexts (see, for example, Ferrier, 1982; Floyd, 1982; Harless, 1985; Hon, 1982; Wooley, 1982), and has improved learner motivation and attitudes toward instructions (Dalton, 1986) (all cites Pisapia & Perlman, 1993 notes).

While the literature reports that teachers do not stress the use of the computer for motivating students, a substantial number of teachers interviewed for this study have called the computer "a motivator" (Clark & Salomon, 1986 cited in Pisapia & Perlman, 1993 notes).

Herman et al. (1992) report that parents indicate that their children interest and attitude towards leaning and their language skills where more positive.

Novelty effect. While it is possible that the higher attention span can be attributed to novelty effect, as one teacher has pointed out, even after the initial novelty wears off, the level of interest in the automated workbook is still greater than that in the regular workbook. The increased attention paid by students sometimes results in increased effort or persistence which yields achievement gains. If they are due to a novelty effect, these gains tend to diminish as students become more familiar with the new medium. This was the case in reviews of computer-assisted instruction at the secondary school level (grades 6 to 12) (Clark & Sugrue, 1988).

Time. Time pressure impacted on teachers and students alike. Closely related to time pressure was the extent of integration of the computer-based problem-solving into the teacher's social studies curriculum. Where the integration was high, the time pressure seemed not much of problem. But where the problem-solving was "tacked on" to the regular curriculum, the prevailing approach seemed to be one of hurrying on to the next task, and then to the end of the unit, rather than focusing on problem-solving outcomes.

There is a general consensus that students need less time to learn a given amount of material with the use of computer-based learning technologies than without. (Kulik & Kulik, 1987). But, not in all applications. For example, when using data bases, students demonstrated greater achievement, but it took them longer (Rawitsch, 1987). Few current studies measure learning time. Roblyer et. al., (1988) feel this may be due to the fact that most studies are in public schools which have a set time for grade levels and courses therefore decreasing learning time may not be important for decision-makers since the entire system would need redesign to take advantage of accelerating learning.

Retention. The effects on retention are basically positive, but not as clear as initial performance. Retention is difficult to measure. Five studies with follow-up examinations investigated retention over intervals ranging from 2 to 6 months. In 4 of the studies, retention examination scores were higher in the CBI class, but none of these 4 retention effects was large enough to be considered statistically significant. In the remaining study, retention examination scores were significantly higher in the control class (from Pisapia & Perlman, 1993 notes).

Duration. Studies that were shorter in duration produce stronger effects than do studies of long duration. Studies that were shorter in duration produced stronger effects than did studies of longer duration. Although the small effects reported in longer studies may actually show that experimental effects decrease in potency with extended use--too much of a good thing--it is also possible that shorter studies are better controlled and more likely to estimate true effects (Notes from Pisapia & Perlman, 1993 notes).

Databases. Rawitsch (1988) studied database use in 16 different classes in suburban districts a total of 339 students were involved. He found:

- students solved a greater percentage of the problem correctly when using a computer,
- students took more time to do it,
- therefore, there was no difference in efficiency (combination of accuracy & speed) between using computer and not using it,
- students liked using computer better,
- students with more structured work style were more efficient in using computer than those with an unstructured style,
- 50% performed more efficiently or as efficiently on real life exercise as on academic exercises,
- students who practice using data bases periodically during school will be significantly more efficient at solving problems, and
- strategies need to be matched to work style.

Rawitsch and Bart,(1987) found that students who used data bases increased their ability to classify and solve certain kinds of problems (White, 1985; Rawitsch, (1987); Underwood, (1985); reported in Ehnamr and Glenn, 1987).

Distance learning. Distance learning is defined as recognized learning that takes place at a site remote from the point of origination. It has the potential to address equity/opportunity and is a strategy for improving education in rural schools. Examples of such uses are interactive TV, audio conferencing, video text (Dbase access from home), electronic pens and electronic mail. There are organizational concerns such as teacher certification issues restrict use of telecommunications, and who is responsible for evaluating teachers. Students like as well as conventional programs but would prefer conventional classes if available. Programs are most effective with students who work well independently, are self-disciplined and well-motivated, and score above average range for most of their courses. Not all students benefit from telecommunication learning as much as conventional courses (Notes from Pisapia & Perlman, 1993).

COST-EFFECTIVENESS STUDIES

A few notable studies have experimented with cost data and models of cost-effectiveness in public schools. The general results are:

- Placing micro computers in classroom rather than labs reduced costs and makes them available for other projects.
- Pairing students may reduce student costs by close to a factor of 2 without reducing achievement.
- If students utilization was increased, cost-effectiveness would increase.
- If computers are spread out over more subject areas and more of school day cost/effectiveness would be lower.

The specifics of several studies follow:

One such study, conducted at the Westberry Elementary School in Saskatchewan, Canada, involved students in grades 3 and 5 who were assigned randomly to a study group and a control group and were tested before and after the teaching period to measure mathematics achievement and attitude and computer literacy. These investigators reported CAI costs, including overhead, of $250 (in 1985 dollars) per student per year. They also reported a per student cost of $14 per month of grade placement gain in arithmetic computation skills (measured by the Stanford Achievement Test) found in each of two groups--665 grade 1-6 students in California and 513 grade 1-6 students in rural Mississippi. The authors concluded that these costs compared favorably with those of **alternative compensatory techniques** achieving similar results with disadvantaged students.

Research by Levin (1986; and Fletcher et al., 1987) presents a strong case for the cost-effectiveness of **grouping students** on micro computers located in classrooms. Given the results reported here and by Levin et al. (1987), a strong case is suggested for the cost-effectiveness of grouping students on microcomputers located in classrooms. Pairing students for work on microcomputers may reduce the per student costs of CAI by something close to a factor of two without reducing achievement. Grouping more than two students at computer workstations will reduce costs even further, but it may also reduce the effectiveness of both the instruction being presented and the peer tutoring that may result from this practice.

Levin et al. (1987) performed a cost-effectiveness analysis of CAI by Of the instructional alternatives they considered, CAI in mathematics was a more favorable cost-effective alternative than either tutoring performed by adults for 20 minutes a day or increasing instructional time by 30 minutes a day. It was less cost-effective than **tutoring performed by peers** for 20 minutes a day and had about the same cost-effectiveness as reducing mathematics class size.

Levin's analysis revealed that, when sites make a determined effort to promote full **utilization of computers** an software, C/E increases by a factor of 50 percent. Most Levin's finding that there are **dramatic C/E differences for the same CBT programs** between implementation sites. That is, when the same CBT program is implemented in different schools or cities, the C/E ratio changes by as much as 400 percent! This strongly suggests the importance of management systems for implementing and directing the use of CBT systems.

Fletcher et al. (1987) found, on the other hand, that "adjunct microcomputer-assisted **mathematics instruction** was found to be more cost-effective than traditional mathematics instruction in elementary schools.

In testimony before the Senate Committee on Labor and Human Relations, Taggart states that "the cost per **reading** grade gain achieved by CCP (Comprehensive Competencies Program) learners has averaged only $350, and the cost per math grade gain only $250, roughly half the cost per grade gain in traditional programs." Finally, the Institute for Defense Analyses has reached the preliminary conclusion that **computer-assisted training** costs approximately one-third less per unit of effectiveness than does conventional instruction.

These are **favorable results,** and they could lead to the adoption of CAI by many schools. However, educational decision-makers must know not only the effects of alternative approaches to instruction, but also what must be given up to get me. In other words, they must know the costs as well as the effects of instructional alternatives, and any choice among instructional alternatives is sufficiently informed if it fails to include both sorts of information. Additionally, decision-makers may not consider all instructional outcomes equal (all above from Notes by Pisapia & Perlman, 1993).

SECTION 4
...ACCESS TO TECHNOLOGY

By 2000 students should have continuous access to a wide range of technologies that promote learning activities.

(Vision: Test, 1990)

The purpose of this section is to examine the relationship of technology and equity, access, and disparity. The equity issue is reviewed through patterns of use and resource availability. The access issue is studied from the student, and teacher aspects. The disparity issue is examined through technology applications such as telecommunications that can relieve inequalities in educational opportunity. The summary section addresses the focus questions followed by the supportive findings.

SUMMARY

Computers are pervasive in the schools. If progress is judged on the amount of hardware and number of students using it, then progress has been made. For example, in 1989, the ratio of students of computers to schools was 6/1 at the elementary level and 21/1 at high schools. However, **access** continues to be an important issue regarding equity, gender, location of the computers and disparity.

The findings on **equity** are mixed and somewhat confusing. On the one hand, the ratio of students to computers was found to be nearly twice as favorable for schools containing low SES students. Yet, others report that students with high minority enrollment have less than one-half the computer access compared to students with majority enrollments. Socioeconomic factors play a disturbing role in low SES student access to computers, particularly at the elementary school level. This trend disappears at middle school and high schools, but it may be to late by then.

Equity in school computer use must involve not only equal access but also consideration of the learning needs of poor, minority and female students. This means that equity must be a priority, a part of every policy decision and every classroom action.

Gender differences are also of concern. It has been reported that instruction based upon cooperative modes rather than competition is preferred by females. If this is the case then the move from traditional uses of technology to more contemporary use as tools has the potential to reduce gender bias and make the technology more attractive.

Some observes feel that **placement of the computers** rather than the total number is the key variable in defining access. The literature portrays some doubt as to where the computers belong in the schools. But it is clear that student utilization depends on organization of computers in labs or classrooms and the availability of appropriate software.

Other problems exist with **connectivity** beyond the school day. The futurists say it won't be a problem because in the future every student will have a lap top with a modem to access whatever information or tools they need. While not considered a serious problem by most observers, it is a concern today.

Telecommunications is linking education to the world. It is being used in education to increase information access and reduce **disparity** through television, satellites and distance education. These technologies are eliminating barriers of time, geography or local expertise. Rural students are using them for meeting graduation requirements; urban students use them for low cost field trips. Minnesota and Memphis demonstration sites use them for distance tutoring. Several states use it to deliver courses to meet graduation requirements. Others use it to enrich the classroom through programs such as CNN Newsroom and World Classroom.

Finally, what does seem to be related to exemplary uses of technology is **administrative leadership**. Administrative actions to insure equity in access to different categories of students such as sex, ability, and ethnic group are three times as likely to be found in schools where exemplary technology-using teachers are found.

FINDINGS

Part 1 ACCESS

Computers are pervasive in the schools. Virtually every school in the United States has microcomputers (Ely, 1991). If progress is judged on the amount of hardware and number of students using them, then progress has been made. Consider the following facts reported by Quality Education Data Inc., a Denver research firm in its annual reports:

- Microcomputer density (students per computer) has been reduced from 125:1 in 1983-84 to 18:1 (QED, 1991-92).
- Range is from 8,858 schools with less than a 9:1 ratio to 7,082 schools with 90:1 ratio (QED, 1990-91).
- 98% of schools have computers (QED, 1990-91).
- Apple has 65.7%; IBM 14.1%; Radio Shack has 6.2%; Commodore 5.4% market share of the computers used in schools (QED,1990-91).
- 34,662 of the 81,203 schools possessing computers have more than 21 (QED, 1990-91).

Other sources confirm this growth. For example, Becker (1991) noted that over the past six years around 300,000-400,000 computers were added each year. The steady growth is beginning to have impact on most students and schools. In 1989, the ratio of computers was 6/1 in elementary schools, and 21/1 in high schools. In 1985, the ratio was 20/1 for elementary and 45/1 for high schools. The number of computers increased from fewer than 50,000 to roughly 2,400,000 during the 1980's (Becker, 1991).

Still others add that in:

- 1985 53% schools had 1 computer (Levin, 1984).
- 1984 Fewer than 10% of the schools had 15 computers (Becker 1985).

STUDENT ACCESS

Location. The placement of computers rather than the total number is perhaps the key variable in defining access (Green & Eastman, 1991). Student utilization depends on organization of computers in laboratories/classroom; availability of appropriate software (Power on!, 1988).

There is some doubt as to where the computers belong in the schools. There appears to be no pattern of distribution or locale of use. Some classrooms have several units, but rarely enough for the entire class. Some have computer classrooms where the entire class comes to one room. Still other schools use the school library media center as the place where computers can be used or borrowed.

The Office of Technology Assessment recommends that you start in a central location. Then, as computers become more plentiful, put them into the classroom (Power on!, 1988).

Socioeconomic Factors. Most students had used computers regardless of family socioeconomic condition. The higher the father's educational background, the more likely students had access to a home computer (Collis & Martinez, 1989). On the other hand, word processing has become part of the experience base of students, regardless of father's educational level (Collis & Martinez, 1989).

GENDER ACCESS

There appears to be a significant correlation between gender and perceived computer-related skills and attitudes toward computers. Several trends are noted by Collis & Martinez (1989).

The tendency to see computer use being associated with boys, not girls, was significantly established at the beginning of Grade 1. Unfortunately, participation in a full year of daily computer activities in the WTR program did not serve to change the impression. Secondly, a tendency of girls to take word processing courses while boys elect programming courses has been noted. Thirdly, instruction based upon competition rather than cooperative modes preferred by females is an effective burden on many young women. For example, many computer-based instructional programs have competition with the computer, the clock, the random number generator or the scoring device at their motivational core. Finally, males still outnumber females in all categories of computer usage.

Gatekeeper. Often it is mathematics that stands between female students and computer opportunity. Since computers have mathematic and formal logic at core, when applied to any disciplinary or social problems, the problems must be viewed in ways amenable to quantitative or procedural analysis (Sutton, 1989). Many girls transfer mathematics anxiety and attitudes toward mathematics fairly directly to the computer (Hawkins, 1987; Collis 1987).

Facilitators. Gender differences tend to dissipate when computer use in highly structured and closely linked to curriculum (Power on!; 1988).

Secondly, gender differences may also be facilitated by differences in amount of experience. For example, in male and female students with the same exposure, **attitudes were the same** (Chen, 1986, Levin & Gordon, 1989); students are more competent in their **knowledge about computers** (Martinez & Mead, 1988) and use of computers (Kersteen et al., 1988; Martinez & Mead, 1988, Waugh, 1986) (all cites in Sutton, 1991). However, it is not enough to expose students to computers. Students, especially females, need additional support on developing skills and attitudes (Collis & Martinez, 1989).

Thirdly, gender differences are less pronounced among **occasional users** than frequent users. Females are equal to males on **initial use,** but males build more on initial access (Collis & Martinez, 1989).

Finally, differences between males and females disappear when more general **computer applications** are considered (Chen, 1986 cited in Woodrow, 1989).

Training. Females finished a computer literacy course with less enthusiasm about computers than did females who had not taken the course. Males who participated were more positive (Collins, 1985). And boys are three times as likely to attend a summer computer camp than girls (Hess & Miurr, 1985) (cites were found in Sutton, 1991).

Attitude. Many studies have found that girls have a less favorable attitude toward computers (Chen, 1986; Collis 1985; Lenn & Gordon, 1989; and Muirr, 1986; cite in Sutton, 1991). A recent study based on longitudinal data reported that over an extended period of time (three years), girls consistently displayed less interest in computers and reported negative attitudes toward the technology (Krendle & Broihier, 1991). Additionally, girls' more negative response to computers did not dissipate over time.

TEACHER ACCESS

Many references to teacher access were found. For example, a policy statement of the National Education Association declares that there should be a computer with appropriate support software on every teacher's desk for use in class preparation. Additionally, every classroom should have large screen displays and local access to CD-ROM and videodiscs. And, the International Society of Technology Education recommends a computer on every teacher's desk, a computer in every teacher's home, and a telephone and modem in every classroom (Vision: Test, 1990). These policy type statements are supported by the following evidence.

- Exemplary technology-using teachers practice in much more resource-rich situations. Class sizes averaged 20% smaller and was the largest predictive variable. Fewer students per computer and more software also characterized their classrooms (Becker, 1992).
- Exemplary technology-using teachers were more likely to choose a computer to use at home for extended periods of time and more inservice from among incentives offered by the school district (Becker, 1992).
- Teachers need time to practice, communicate, get work done
  A major concern is time on computer -- labs are tightly scheduled -- they need more access --- closer to student.

HOME ACCESS

Home access to computers is growing and with it some concerns over equity. Consider these facts:

- In 1984, 8.2% of households had computers. In 1989 15% of all households have computers (Kominski, 1991).
- In 1982, 30% of children 3-17 years of age used a computer at home or in school or both. In 1989 46% used a computer at home or in school or both (Kominski, 1991).
- In 1984, 24.6% of employed adults said they used a computer at work. In 1989, 36.8% (Kominski, 1991).
- In 1989, one-third of the U.S. population (74,884,000) used a computer in some way (Kominski, 1991).
- Families of male students are much more likely to own a computer than families of female students (Martinez & Mead 1988, Swandenes & Janett, 1986).

- In a study of 51 families with computers, the level of home academic computing was low. Sixteen percent of the families occasionally engaged in home academic computing. Parents in most of the 51 families provided little or no support for home academic computing. Schools did not emphasize it -- schools should (Giacquinta & Lane, 1990).

Home computers are particularly challenging problem structures for educators. Several issues revolving around home access exist with connectivity beyond the school day. Educators have dealt with the problem in different ways. Some have chosen to ignore it and encourage parents to provide access. Others have extended school access by buying portables and/or providing tool availability after 3 o'clock, as well as by scheduling extended hours after the school day or hooking the home into the school network for 24 hour access. Still others have encouraged the use of public libraries. However, all of the above options have the potential to increase inequity (Moursand & Ricketts, 1988).

Pilot projects include: Home Link, the Transparent School Model, Computer Call software, the Buddy System and Talkline. Several cases in point are worthy of description.

First, in **Minnesota** a school district interested in complying with the mandate that schools guarantee mastery of minimum competencies in all students, involving parents in the learning process and upgrading their computer inventory, created a computer/software loan program. Although results were favorable, the increased burden on the classroom teacher led to a recommendation that the loan program should not be added to the duty of the classroom teacher (Sales & Earle, 1989).

Secondly, several programs have used telephone technology through answering machine call-in programs. Rebecca Schubel and Joan Erickson (1992), report that in **Alabama,** a Transparent School Model, consisting of a telephone and answering machine in each classroom paired with an office computer and software package called CompuCall (developed at Vanderbilt University), allows parents to call in for daily information and teachers to call parents and leave them recorded messages. Interaction between teachers and parents quadrupled and there was an increase in the rate of homework completed during the first month of the program.

Thirdly, **Indiana's** Buddy System provides computers for use in classrooms and student homes for students in grades 4 through 12. A major goal was to view the computer as a tool to aid learning in the content areas. Several indicators of success are presented by Duffy et al. (1992). For example, level of use was daily and throughout the day. Student level of proficiency with the computer was judged as highly proficient to expert across all groupings of students. Type of use varied by installation site but the "tool for the students to develop and present information" use clearly dominates the Buddy System philosophy and practice. Teachers noted that it was only because of the ready availability of the computers, both at home and at school, that they could do the larger, more complicated tasks of reasoning, analyzing and constructing knowledge.

Fourthly, TALKline, a telephone based application, was implemented in **North Carolina.** It is as a community-based phone line for parents to call for the purpose of discussing concerns or obtaining general information regarding their children. The uniqueness of the program is that parents talk to volunteers and the program is not school-based. The programs evaluations continue to point to the difficulties of reaching fathers, low-income parents, minority parents and single mothers.

Finally, an experiment was conducted with a Head Start classroom in **Indiana.** The system used a telephone answering machine in the Head Start office. Weekly language enrichment activities for parents to use with their children were recorded for parents to access via telephone. Each week different activities were recorded. Weekend use tripled, weekday use and continued use were recommended. Since then, the program has expanded to other headstart classrooms. The service described was not complicated by family factors, such as lack of transportation, varying work shifts, need for baby sitters or the parents literacy level.

Part 2: EQUITY

Equity has become a quantitative idea. It is measured by counting and by computing averages and ratios. The ratio of computers to students, the number of minutes of computer time, the number of software packages designed for girls, the ratio of black faces to white faces on a screen display, and the number from various ethnic groups enrolled in computer courses are computed and compared in order to assess how we are doing on computer equity (Damarin, 1989).

What is related to exemplary computer-using teachers are administrative actions taken to insure equity in computer access to different categories of students, such as sex, ability, and ethnic group. These practices are three times as likely to be found in schools where exemplary technology-using teachers are located (Becker, 1992).

Equity in school computer use must involve not only equal access, but also consideration of the learning needs of poor, minority and female students. Poor children "are unlikely to have other resources apart from the school system for having their learning needs met -- there is no other option" (Malcom, 1988). This means equity must be a priority, a part of every policy decision and every classroom action (Sutton, 1989).

Equity issues have been defined as 1) access to computer literacy and computer-assisted learning, 2) tracking through differential users of computer technology, and 3) exposure to gender bias and stereotyping in educational software (Wisconsin Plan; 1990).

ACCESS

Socioeconomic factors play a disturbing role in minority student access to computer. More white than Black students have used a computer. More white students are studying with computers. More white students have computers at home. The differences are especially evident at the lower grade levels.

Statistics indicate that low income elementary schools consistently have less access to micro computers. The trend disappears by the time students enter middle schools and high schools, but providing more micro computers at this point may be too late for the at-risk student.

Schools in inner-city and poor areas are being priced out of the computer market and students already advantaged because of wealth would be further advantaged in employment because of access to computers in schools or at home.

On the other hand, Piccano, (1991) found that in typical New York City elementary school you would find the same number of computers than the typical elementary school in Westchester County, New York; in high schools more.

INEQUITIES

Inequities have been noted between rich and poor, urban and rural, and minority and non-minority students. For example, the current range of per pupil expenditure for public education is so wide (2,000 to 17,000 per year) that equitable access to technology is almost impossible (Vision: Test, 1990).

Inequities in computer use are evidenced in several instances:

- Ratio of students/computer was nearly twice as favorable for schools containing low SES students (U.S. Congress, 1987 hereafter cited as "OTA")
- Students in elementary and middle schools with black majority enrollment had approximately half the computer access compared to students in elementary and middle schools with less than 5% black enrollment (Becker & Sterling, 1987).

- Students in relatively poor districts have significantly less potential access to computers than peers in relatively rich schools (Bauman, 1988).

Pattern of Use. Becker (1984) previously found higher SES students associated computers with open-ended computer use, and, Drill and practice associated with Lower SES (cited in Collis & Martinez, 1989). Others have noted the same phenomenon.

- 56% of the use by low SES students was for drill and Practice and 13% for programming, and 39% of the use of high SES students was for drill and practice with 30% of the use for programming (OTA, 1987).
- 32% of white students owned computers, compared to 22% black students and 21% Hispanic students (Martinez & Mead, 1988).
- The computer controls low SES students, Learner controls High SES (OTA, 1987).

Software. Roblyer et al. (1988) reviewed 80 studies and concluded that software developed for the general population was not successful with minority, disadvantaged and Spanish speaking populations.

Key Board Time. In Utah, keyboard time ranges from 36-142 minutes. Interestingly, students using teacher-directed software spent more time at keyboard regardless of grade level than students using ILS (Bluhm, 1992).

Allocation. The allocation of computer in school buildings also can create potential inequities. The decision options include:

1. Set no policy, allow different initiative of teachers and students; determine who will use them,
2. Set priorities among competing subject users (math, writing),
3. Set policies giving everyone a share of a scarce resource even if it limits the amount of time, and

4. Set priorities assuring that categories of teachers or students (low ability, special education, gifted) have proportional access to the resources preventing domination by resourceful motivated or ambitious students (Becker, 1992).

STANDARDS

A standard can alleviate inequities. They can be as general as "enough stations in every school so they have a chance to put their learning to use." Or, as specific as the International Society for Technology Education's claim that by 1995, there must be student/computer ratios of 5:1 with a range of supporting technologies (CD-ROM, video disc, VCR's, camcorder, group display equipment) (Vision: Test, 1990).

Consider the standards set in The Kent School District Plan (1990). It recommends 1) key board time at 46-60 minutes per day, 2) six computers to a teaching station with appropriate software and one printer for every three computers and 3) a ratio of ten computers to one student has been recommended by several national task forces (Kent School District Plan, 1990).

MODEL SCHOOL POLICY

Equal access for students, teachers, administration, and parents is a goal for every district.

1. Include all faculty in training, female teachers are appropriate role models for female students
2. All students should be exposed to computers in at least one learning situation,
3. Select software on basis of appeal to both sexes, all economic levels, all ethnic groups,
4. Select software that appeals to all levels of students,
5. Have computers in library available for student users,
6. Provide extracurricular computer activities for students,

7. Offer parent training sessions,
8. Involve teachers of special education, and
8. Infuse computers into the curriculum (F. M. Black Model School Houston).
10. Technology should be applied in areas of greatest need for administration and instruction (Norfolk School Division Plan, 1988).

Part 3: TECHNOLOGY AND TELECOMMUNICATIONS

Telecommunications is the link that is connecting education to the world. Telecommunications describes electronic point-to-point communications between individuals and groups through telephone lines, dedicated lines, cable and satellite transmission. Messages may be **interactive**: E-mail, computer conferences, and two-way audio and video conferences. Or they may be **one way**: television through cable and satellite systems. Telecommunications involves the concepts of Connectivity, television, satellites and distance learning. It can act as a catalyst to equalize experience.

CONNECTIVITY

The International Society of Technology Education recommends that schools should be encouraged to establish internal networks to interconnect teachers, students within all locations in a district. Students' and teachers' homes should be connected to the network. State subsidies should be available to ensure equitable distribution of such capabilities (Vision: Test, 1990).

Networking. The dominant trend within telecommunications is networking. Ehrman (1990) described four conversational models for networking: 1) direct instruction; 2) real time conversation; 3) time delayed conversation; and 4) learning by doing.

Networking has the following purposes:

- Professional Collaboration,
- Student collaborative investigation,
- Access to experts,
- Information access,
- Access to resources,
- Collaborative development,
- Teacher enhancement,
- Online courses, and
- Networked community support,

Commercial utilities such as Compuserve and Prodigy are spreading. For example, several **commercial vendors** are prominent in the field such as: AT&T learning network, Kids Network (National Geographic Society), **Bulletin boards** (FREDMAIL, DIDONet). And, **state networks** such as: NY: (NYSERNET), Texas: (TENET), Virginia (VaPEN). The states seem to be the organizing units for the delivery of telecommunication technology.

The **future** for networking is bright. Consider that Congress authorized the National Research and Education Network (NREN) by passage of High-Performance Computing Act of 1991. The intent is to improve the information, computing and communication infrastructure for the country's researchers and educators (Kurston & Harrington, 1991).

TELEVISION

The literature on television transmission is more concerned with getting the signal to the school rather than its ultimate use. For example, "We can get a signal from 3,000 miles around the world, but the last 200 feet into the teacher's classroom is the hardest part."

- Sixty percent of the schools have access to cable television. But forty-five percent of the teachers said they had trouble getting equipment to use in the classroom (Mann, 1991).
- One out of eight classrooms did not have an electrical outlet (Mann, 1991).

Pattern of Use.

- Fifty-six percent listed PBS as prime source of programming; twelve percent used CNN (Mann, 1991).
- Ninety-six percent of the teachers in grades 6-12 expressed enthusiasm for television in instruction; 3 out of 4 plan to use it more next year (Mann, 1991).
- Fifty-six percent of the teachers used television in current affairs; literature 38%; performing arts 37%; and history 33% (Mann, 1991).

Program Availability. Cable in the Classroom is a national project aimed at providing all junior and senior high schools with free cable service and at least one VCR and monitor (Ely, 1992). Other cable programs entering classrooms are:

- **A&E Classroom** -- a one hour block of programming run Monday through Friday from 7 to 8 AM EST.
- **Assignment Discovery** through Discovery Channel 9-10 AM each day reports use by 438,000 teachers and viewing by over 8 million students.
- **CNN newsroom** is a daily 15 minute news program specifically designed for school use.
- The **learning channel** offers more than 20 programs for in school use by teachers.
- Monitor channel produces **World Classroom** in English and Spanish (Ely, 1992).
- **Channel One** reaches over 10,000 schools (Skill, 1990). The news program is 12 minutes daily and includes two minutes of commercials. It remains controversial because of the commercials that accompany the daily program. New York passed a law prohibiting use in schools; on the other hand, the judiciary in North Carolina ruled that local school boards do have the authority to accept the program because it's supplementary, and California failed twice to impose a statewide ban on electronic advertising in schools (Ely, 1992).

SATELLITE

Access. The states seem to be the organizing units for the delivery of telecommunication technology.

- 33% of the schools have satellite dishes. Hawaii, Kentucky, and the District of Columbia report all schools with satellite dishes (QED).
- Massachusetts Corporation for Educational Telecommunication (MCET) operates the **Mass LEARNPike**, a satellite computer-based network dedicated to improving the quality of learning in the state.

- The **Kentucky Educational Network** is linked by satellite to all its 1300 public, elementary, middle, and high schools.

Distance Learning. Distance learning (DL) provides greatly enriched educational options, while eliminating barriers of time, geography, or local expertise. Rural students can use DL for meeting graduation requirements. Urban students can use DL for low-cost alternatives to field trips (Vision: Test, 1990). Its principal attraction is that it transports information to people rather than people to information.

Studies of distance deliverers of instruction generally indicate that students enrolled in distance learning programs exhibit achievement and motivation at least as high as those shown by students in traditional settings. Research cited in the Texas long range technology plan focuses on instructional television and some other forms of telecommunications-based technologies including radio and mail, which have also proven successful.

DISPARITY

Application of newer computer- and telecommunications-based technologies to distance learning are noteworthy strategies to demonstrate the range and ability of telecommunications to assist with disparity problems. First, a pilot evaluation project by the Texas Education Agency of delivery by distance of courses for credit in 1985-86, then Minnesota's Demonstration Site program and then a peer tutoring program in Memphis, Tennessee is described.

The **Texas Education Agency** evaluated delayed videotaped Spanish courses (which were noninteractive in 1985-86), courses in German I and Psychology provided by **Instructional Television Fixed Service (ITFS)**, and Computer Science I, French I, and Psychology provided by satellite; the latter two systems were live one-way video and two-way audio. The evaluation concluded that:

- Overall mastery demonstrated by program students was equal to or better than mastery by comparable students in the traditional classes.
- Test scores suggest that these highly cost-effective services provide a good alternative source of instruction in cases where on-site teachers cannot be provided.
- Students feel that telecourses require more effort than traditional courses.
- Both telecourse and traditional teachers tended to rate their own courses positively.
- Most parents were favorable in their general opinions of televised courses.

Another example of successful uses of technology to deliver curriculum to remote districts is the **Demonstration Site (TDS)** program created by the Minnesota Education Act of 1983. A wide variety of technologies is used in TDS schools, including in-class computers and two-way television for distance learning and inservice.

Tutoring. Unfortunately, achieving student-teacher ratios of even 20:1 is impossible for most schools, given the practical constraints of limited budgets, teacher shortages, and lack of classroom space. Even when there are qualified volunteers to work with children after school, arranging mutually convenient times and places to meet can be difficult. There is no easy answer, but a clear contender would undoubtedly be one-on-one tutoring with each child working with his or her own teacher.

For example, an alternative one-on-one instructional approach, using **distance tutoring** through an electronic Bulletin Board System (BBS) accessed by modem, was developed for the Memphis Apple Classroom of Tomorrow (ACOT). The project, which paired university students with academically at-risk sixth grade ACOT students, was a collaboration between Apple Computer, Inc., the Memphis City Schools, and Memphis State University.

Tutoring assignments monitored during the study consisted primarily of activities designed to develop writing skills. For example, students would send pieces of writing to their tutor for critiquing before submitting a final version to their classroom teacher. Or the tutor would send a document containing errors, and the students would attempt to identify the mistakes. In addition to formal assignments, tutors and students were encouraged to use the BBS to share everyday experiences and to keep in regular contact with each other.

The BBS tutoring program has shown some positive student performance effects. Evaluations of student outcomes showed some advantages for ACOT students over control groups on the California Achievement Test subtests of math computation, math concepts/applications, and language mechanics. Attitudes toward school and education were more positive for ACOT students and parents.

Part 4
ETHICAL ISSUES

COPYRIGHT LAW

Copyright protects the tangible expression of an author's ideas by granting the author exclusive control over the reproduction of the material, the preparation of derivative works based upon the work, the distribution of copies of the work, and the right of public display (Copyright Act of 1976, § 102[a]).

Two areas of concern are software ownership issues and the positive or negative effect that specific government regulation or nonregulation of software may have on the software industry research and development. "The central legal, as well as policy issue, is whether or not existing American Copyright law is adequate to provide sufficient software ownership protection and to stimulate future software research and development" (Weimer, 1991). The foundation of American copyright law is based on a dualism--the public benefit derived from the creativity of authors and the economic reality that a limited copyright monopoly is essential to encourage the greatest creativity of authors.

Copyright law protects computer software in general, however, several specific provisions have been added over the years. In 1976, a provision was added that stated that the owner of copyright in a work did not receive any greater or lesser rights concerning the use of the work in relation to computer systems than those provided under federal, common, or state law. Id. Codified at 17 U.S.C. § 117 (1976) subsequently amended by Congress in 1980 to provide a specific definition for "computer program" and to refine the section dealing with computer systems and copyright. This provision permits the creation of copies that are necessary as an "essential step" in utilization of the computer program and as "back-up" copies of computer programs for the personal use of the individual software owner (Pub. L. 96-517, §§ 10(a), 10(b), Dec. 12, 1980. 94 Stat. 3028-9). Copies or adaptations of these software programs cannot be leased, sold, or transferred without all of the rights in the program being transferred, and only with the permission of the copyright owner.

In 1990, the Computer Software Rental Amendments Act of 1990 prevents the unrestricted rental, loan, or lease of computer software without the permission of the copyright owner. Exceptions were made for the transfer of phonorecords by a nonprofit library or nonprofit educational institution, and for the transfer of lawfully made copies of computer programs by nonprofit education institutions to other like institutions (Weimer, 1991).

At the current time, caselaw is in evolution and there is not absolute precision regarding the specific parameters of copyright software protection. However, several guides can be identified.

- "Shrink-wrap license" - When the cellophane packaging is broken you are automatically required to comply with certain prescribed terms such as copying, use and remedies.
- The dichotomy between the 'expression' of ideas and the 'underlying ideas' themselves. In Baker v Selden, the Supreme Court found distinctions between a work which 'describes' an art, method or process and the 'actual' art, method, or process itself. The expression of an idea is subject to copyright, and the underlying idea or concept, is not subject to copyright.

Clearly, computer programs are protected under copyright law through the 1980 software amendment. Questions have arisen concerning which portions of a computer program are subject to copyright protection and which are not (Nimmer, at § 2.04 [c](1990). For example,

- Both the operating systems and the applications programs are subject to copyright protection.

- The structure, sequence, or organization of a program is subject to copyright protection.
- Source codes, micro codes and object codes are subject to copyright protection.

CODE OF ETHICS

The computers are changing the way people teach and learn. Because of the long-term ramifications on the lives of students, vendors and parents, a code of ethics is an essential guide to technology- related decision-making.

The International Council for Computers in Education's (ICCE) Code of Ethical Conduct covers issues related to: curriculum, computer access, privacy and confidentiality, teachers, students, the community, the school and software and hardware (see Table 11 in Appendix B).

GENERAL CONCLUSIONS

While educational institutions have made increasingly large investments in educational technology (Washington: 1990). The technology has been misused or underutilized (The National Task Force on Educational Technology; 1986). Power on! (1988) concluded that:

- Access to computers had increased significantly during the past decade.
- Students in relatively poor elementary and middle schools had less access than students in richer districts.
- Black students had less access than white students.

SECTION 5
TECHNOLOGY AND TEACHER TRAINING

In the rush for a quick fix, effective teacher instruction as the critical element in the successful classroom use of computers was overlooked.

(Cohen, 1988)

The purpose of this section is to examine the strategies being utilized to enhance preservice and inservice technology skills of teachers and administrators. The section is divided into two parts: inservice and preservice training. The summary addressing the focus questions is presented first, followed by the supportive findings.

SUMMARY

Any plan to make greater use of technology must include teacher training. Yet, relatively little scholarly attention has been paid to changes in the role of the teacher due to technology intensive classrooms. However, the research is clear on two points: 1) the process by which teachers appropriate technology is more complex than that by which they adopt other changes and therefore takes time -- five to six years -- to master teaching with computers, and 2) the lack of teacher training is perceived as an issue most likely to impede the advancement of educational technology, second only to funding in importance.

It takes about five years to become an accomplished technology user. It requires the teacher's motivation and support from colleagues, schools, school districts, colleges and departments of education.

Teacher training and preservice education can both be improved by understanding the characteristics of the five percent of the teaching force who are considered exemplary technology users. For example, they had 1) more formal training in using computers and teaching with computers, 2) more specific training on how to integrate software into existing lessons, and how to organize class activities to allow computer use during class time, and word processing and other computer applications, 3) learned applications through self-instruction and spent twice as many hours personally working on computers at school, and 4) progressed from applications that directly reinforce what is being taught, such as drill and practice, to those that are more expansive, such as tools.

The **types of training** required are: 1) skills needed to work with technology, 2) education that promotes vision and understanding of the possibilities of state of the art applications of technology, and 3) skills to revise and modify courseware. A three-tier approach to training is recommended. The first tier involves the minimum expertise needed to operate the technology. The second tier involves new educational skills: classroom management and the integration of technology into the curriculum. The third tier involves annual skill updates to allow for new developments. Exemplary technology-using teachers recommend that training start with one application that is easily used and quickly adopted.

The literature identified colleges of education, school districts, regional service centers, professional organizations and private corporations, including vendors of hardware and software as potential deliverers of technology training. Regional centers are playing a growing role in training. In fact, seventy-five percent of the states sponsor training through centers, and twenty-two states use electronic networks to provide training.

With regard to **preservice education**, the perception is that prospective teachers: 1) are not being educated to integrate technology into the classroom, 2) are being taught by instructors who lack expertise with the computer, 3) are ill prepared to teach with computers, and 4) attribute less value to using computers than business school majors.

However, in 1988, ten of the fifteen largest teacher training instruction programs included a computer literacy requirement for graduation. Two years later the number had risen to twelve. There is a trend among colleges to start with separate classes before proceeding to offer more comprehensive approaches.

Several conditions must be met if colleges can produce teachers who are knowledgeable and comfortable with teaching with technology. For example, students and faculty must have access to hardware and software equivalent to what they will find in the classrooms they will enter. Expanded activity requires expanded capacity.

Prospective teachers should be immersed in an environment that requires them to use technology to improve communications, increase productivity and enhance the teaching/learning process. Several models appear in the findings that are worth investigating.

Based on the existing research, it is difficult to predict the effects of technology on the skills required for teaching. A basic premise is that teachers will need to possess all the skills currently required in addition to the new skills made necessary by technology. There are few explicit pedagogical models existing for teachers to emulate when trying to integrate technology and teaching. This condition has led school districts to establish the operational criterion for selection as "interested, experienced, and appropriately educated."

However, year 2000 educators (whether they are classroom teachers, central office, or state department personnel) will have to be engaged in a range of functions rather than perform only specialized tasks. Instead of increasing specialization, all members of an organization must possess a core set of knowledge skills and attitudes that are redundant in all organizational members such as collaborator, mentor/mentee, planner, researcher, and seeker.

FINDINGS

Part I: INSERVICE TRAINING

Inservice, not preservice is going to do it.

IMPORTANCE OF TRAINING

Teacher training and funding are seen as the issues most likely to impede the advancement of educational technology (Bruder, 1989). This conclusion is one of the most supported findings in the studies and opinions reviewed. Several of the sources are listed to present a sense of the passion for this conclusion.

Sheingold & Martin (1987) after surveying 28 urban school divisions, declared that teacher training and resources are major hindrances to the successful implementation of technology. In a later study, Sheingold and Hadley (1990) stated that the vast majority of teachers have little or no training on how to apply computers in teaching. Only about one third of all K-12 teachers have even 10 hours of computer training.

Marshall et al. (1989) also found that the use of technology requires well-trained teachers, effective planning regarding how these tools will be used, high quality software, and reliable system maintenance.

Finally, teachers and schools must be given time to learn how best to use existing equipment. Only with broad knowledge of various technologies can teachers be expected to move on to new and more powerful application. Teachers don't know how to use it, they don't know how it changes kids or how it changes how teachers teach or how the teacher learning process goes on (Bruder, 1989).

CHARACTERISTICS OF THE TEACHING FORCE

Less than 1/3 of the teaching force have as much as 10 hours of computer training -- much of it focused on learning about computers, not learning how to teach with computers (Power on!; 1988).

Attitude Toward Training. The training approach tends to reinforce the dominant teacher role of managing instruction. A more meaningful role is to emphasize teaching as much as computing and make them expert enough to make meaningful curricular decisions (Budin, 1989).

Several studies reported a positive correlation between attitude toward computing and experience with computers (Durndell, 1987, Koohang, 1987, Byrd, 1987; Van Holzen, 1990).

- Even though practicing teachers generally made positive statements about computers, they were less positive concerning their own use of computers (Smith, 1987).
- The value teachers place on computers may be an important factor in how successful computer technology is implemented in the classroom (Violatta, 1989).
- Teachers lacking a deep interest in learning may be unlikely to develop effective practices using computers (Becker, 1992).

Gender Differences. Teacher age and gender have little or no significant correlation with teachers' familiarity with educational applications of computers. In fact, Woodrow, (1989) found that computer experience was found to be the only dependable determinant of knowledge of computer application. On the other hand, Becker (1992) found that among exemplary technology-using teachers, men have more advanced degrees. And, fifty eight percent of the men but only thirty seven percent of the women were math/science/liberal arts majors.

The Accomplished Integrators. Two national studies, one by Becker (1992) and Sheingold & Hadley (1990), extracted the characteristics related to the cadre of teachers who are considered exemplary -- they are teachers who have integrated technology into their everyday practice. The results of both studies are listed below.

Becker (1992), in his national study identified 5% of the teaching force as exemplary users of technology. These teachers had the following characteristics:

- Exemplary teachers had accumulated significantly more credits and degrees than had other computer users.
- Sixty-three (63%) of the exemplary teachers majored in math, science, the social sciences, or the humanities. Only 40% of other computing teachers did so.
- Exemplary teachers had more formal training in using computers and teaching with computers.
- Exemplary teachers has larger areas of formal training in how to integrate software into existing lessons in: a) the subject they taught; b) how to organize class activities to allow for computer use during class time; c) how to write computer programs; d) how to use word processing programs; and e) how to use other computer applications. Secondary math and elementary teachers' training more than doubled other teachers' experiences.
- Math teachers who have used computers for six years or more were 20 times as likely to be classed as exemplary.
- Younger English teachers are more likely to be exemplary. They learned through self-instruction and use more time at home using computer.
- While men comprise only 1/4 of the computer-using teachers, 50% of the exemplary teachers were men -- disproportionally so in science and English; women were disproportionally represented among math teachers.

- Exemplary computer-using teachers spend more than twice as many hours personally working on computers at school. Working at home differences were small. Making equipment more readily available and giving them the time to use it may improve quality.
- Male teachers use computers for about twice as many hours per week as female teachers and 2 1/2 times as much at home as do teachers in total. Male teachers spend nearly four hours more per week than female teachers.

The results of Sheingold and Hadley's (1990) national survey present the following characteristics of teachers who are experienced and accomplished at integrating computers into their classrooms. They:

- are comfortable with computer technology, devote their own time to learning how to use computer, and receive local support for using them,
- work in schools which average more than twice the number of computers than other schools,
- use computers for many purposes including demonstrating an idea, instruction, word processing and promoting student generated projects,
- expect more from their students, are able to present more complex material to their students and foster independence in the classroom,
- use it as a multi-purpose tool,
- have a large software repertoire of instructional and tool packages,
- have six in ten students making their own products, and
- teach in classrooms are more student-centered, where teachers act as coaches and facilitators.

Barriers To Integration. Significant barriers still remain: inadequate amounts of hardware, time to plan and carry out CB lessons. The conditions to accomplish more means more -- hardware -- time -- the time, effort and support needs are sobering (Sheingold & Hadley, 1990).

Conditions that Facilitate Successful Integration. Three factors stand out as major contributors to the achievements of these teachers:

- the teachers' motivation and commitment to their students' learning and their own development as teachers;
- the support and collegiality they experience from their school; on-site help; local training of teaching peers and districts; and
- access to technology in sufficient quantities (Shienhold & Hadley, 1990).

Integration Training. Integrating technology into the school means not only training teachers to run software that supplements their curriculum, but making them expert enough about technology to make meaningful decisions about how computers can be used to their potential (Budin 1991).

Teacher Adoption of Technology. The research is clear on one point. "The process by which teachers appropriate technology is more complex than that by which teachers adopt other changes" (Power on!, 1988). Teachers must buy into technology as an important component of their students' learning environment, or nothing much happens in the classroom. A teacher who understands, supports and is comfortable with prepared changes in the classroom is central to the success of these changes.

Integration of computers into the curriculum takes time. Sheingold & Hadley (1990) note that the basis for any time frame of integration is poorly established, but for any given teacher a two- or three- year period would not be unusual. Becker (1992) adds that it takes 5-6 years for them to truly master teaching with computers. They generally develop from those applications that directly reinforce what is being taught to those that are more expansive (tools).

When teachers first hear about unfamiliar technology, they are overwhelmed by how much there is to know and how difficult it is to make decisions about hardware and software. Three years later, teachers no longer feel they are making uninformed decisions. At this stage, they are now knowledgeable consumers of technology products and sophisticated decision-makers about their own professional development. Moreover, they now have an increased appetite for sophisticated equipment. At three years, they begin to focus on promoting student's thinking skills.

Can these accomplishments be achieved in less than 5-6 years? On a wider scale Sheingold & Hadley (1990) are skeptical. They contend that to become expert at anything takes a long time to learn to master technology and teach with it.

Incentives. Incentives can increase the learning curve and should be considered in any strategy. The value teachers place on incentives seem to vary. For example,

- Release time seemed to be the most valued incentive, followed by salary credits (Savenye et al., 1985),
- Encourage and support teacher access for new teacher and training program,
- Restructure access to technology training, which has been a significant disincentive to any staff member seeking to improve skills (Kent School District, 1989),
- The key incentive for the exemplary technology-using teacher is to get their students using these tools effectively.
- Student accomplishment, in contrast to teachers' external rewards, is most motivating for high technology-using teachers (Sheingold & Hadley, 1990).

CHARACTERISTICS OF INSERVICE

Herman et al. (1992) found that successful training had the following characteristics:

- Introduce one technology at a time, and allow teachers to become proficient at using that particular technology before introducing another one.
- Provide training that is partly technical but primarily "hands-on," with immediate and relevant application to classroom activities.

- Assure that on-going help and support is available to help teachers with project implementation.
- Provide training at different levels for different levels of expertise.
- Encourage "front-runners" to share their successful projects and encourage others to adapt these ideas in their classrooms.
- Encourage new participants to join the program throughout the development of the project.
- Allow participants to select the technology they prefer to work with, based on their instructional needs and goals.
- Schedule regular meetings with project members at all levels to update participants on the current status of the project and to share ideas.

Carrier, (1988) found the following 12 practices contribute most to effective technology training:

- extensive practice with computers,
- comfortable and relaxed atmosphere,
- appropriate balance between lecture and guided practice,
- individualized attention,
- knowledgeable trainers,
- detailed curriculum guides and lesson plans,
- clear and relevant objectives,
- lesson-related materials and handouts,
- in-service lessons linked to instruction,
- peer interaction,
- voluntary participation, and
- strategies for teaching heterogeneous classes.

Others have found:

- Inservice tends to emphasize software that can be mastered quickly and overburdened teachers avoid spending the necessary time to learn more creative applications (Budin, 1991).
- Make local inservice in educational and administrative uses of technologies available to them that carrying graduate and inservice credit.

Focus of Training. Powerful use of technology does not occur unless four interrelated conditions are met: a) training in the skills needed to work with technology, b) education that provides vision and understanding of state of the art development and application, c) support for experimentation and innovation; and d) time for learning and practice (Power on!, 1988).

Relevant Topics. Topics have been identified in the literature as relevant for staff development in microcomputers. These include operation of the computer, peripherals, computer programming, selection and evaluation of courseware, modification of courseware, computer literacy, noninstructional uses of the computer, integration of computer-based instruction into the curriculum, design and authoring of courseware, match of courseware with student abilities and learning styles, selection of hardware, computer science curricula and teaching computer science, development of a user network, copyright protection issues, and instructional uses of computers (Marshall et al., 1989).

Program Formats. Common in-service approaches included after-school workshops and summer institutes. Irregular follow-up to training was determined to be a problem (Carrier, 1988).

The Urban Institute recommends a three-tier approach to training. The first tier involves the minimum expertise needed to operate the technology. The second tier involves new educational skills: classroom management and the integration of the technology into the curriculum. The third tier involves annual skill updates to allow for new developments (Urban Institute, 1986).

Providers of Training. Delivery sources of training include colleges of education, school districts, regional service centers, professional organizations and private corporations, including vendors of hardware and software. Two key problems were found -- unclear measures of training effectiveness and the absence of a central clearinghouse for information on training (Carrier, 1988).

Training Costs. It is generally thought that costs should be covered by local or state funds. Seek business alliances (Vision: Test, 1990).

STATE TRAINING EFFORTS

Almost all states have included training efforts in their state plans (see Table 4 in Appendix A). These efforts include:

- Three states require and 17 recommend professional development in the use of technology. Currently, Virginia recommends but doesn't allow teachers to count technology courses for recertification.
- Seventy five percent (75%) of the states sponsor training through centers. Regional centers are playing a growing role in providing technology training to educators along with other educational services.
- Twenty two states use electronic networks to provide inservice training in use of technology.
- Thirty four states allocate resources for training. The funding for training comes from the local district(3%), state (34%), and federal level (32%).
- Minnesota finds large one-time sessions conducted by vendors helpful. But teachers working with technology-using peers are most successful.
- Texas has 20 service centers serving 1063 districts. The center develops its own long-range plans which focus on coordinating service and assists in planning for districts and training (Bruder, 1989). The regional training

centers, run in some cases by teachers for teachers, gives them a major role in their own professional development, and provides on-going technological services to educators.

SCHOOL DISTRICT TRAINING EFFORTS

School District Model Policy. The Northshore School District's policy (1990) provides inservice that includes:

- adequate access to technology,
- emphasis on practical training,
- use and on-going instruction/support after initial training;
- instruction which emphasizes teaching with technology, rather than emphasizes how to use it,
- focus on activities which encourage staff to adopt application to fit specific needs;
- flexible and adequate time for training,
- staff utilization policy which allows for discretionary use,
- support of supervising personnel
- training which addresses variety of existing skill levels
- provide a **technology Resource Center** where personnel can use, examine, experiment with and receive advice on emerging applications.
- funding a **classroom of the future** to demonstrate different styles of using technology.
- make technology **focus of school.**
- make special **production technology available** in each building.

Other Centers. Cuyahagen Valley Vocational School District offers inservice courses in uses and integration of technologies into their classrooms. Teachers receive credits towards purchase of computers for homes and software packages, printers, etc. (Vision: Test, 1990).

School District Job Description. The school district computers-in-education plan should identify the staff competencies that will be required to implement the district-developed computer literacy integration matrix. The teacher will be able to use computer software to provide reinforcement, individualize instruction, motivate students, and involve students in simulated situations (Northshore District, 1990). Competencies may be chosen from the following list:

Qualifications of teachers

- **Education/Experience**
  - Basic understanding of hardware used at school
    Some formal training in instructional tech
    Operating knowledge of wide variety of courseware relevant to subject area
  - Basic knowledge of use of productivity tools
- **Operational Duties**
  - Enforcing copyright policies of school,
  - Following procedures for requesting and practicing technology based materials,
  - Recording effectiveness of computer use in instruction
  - Using a personal computer for administrative tasks
  - Showing responsible operation of equipment
- **Teaching duties**
  - Using computer to facilitate instruction
  - Using software designed especially for age group and interest levels
  - Evaluating materials and reporting their effectiveness to inform purchase of instructional software
- **Other duties**
  - Meeting with parents to promote schools technology endeavors,
  - Keepings abreast of trends in educational computing,
  - Attending computer conferences and training

PART 2
TEACHER PREPARATION

> **Teachers represent the crucial interface between technology curriculum and the student. In a very real sense the "software is only as good as the teacher". By extension, the teacher is only as good as the training he or she receives.**
>
> **(Urban Institute, 1986)**

The Office of Technology Assessment concluded that the lack of teacher training is the major obstacle to effective use of technology in education (Power on!, 1988). Relatively little scholarly attention has been paid to changes in the role of the teacher due to technology intensive classrooms. Yet it is generally agreed that any plan to make greater use of technology in the schools must include steps to insure adequate teacher training, particularly since the costs of training may exceed the combined costs of hardware and courseware (Levin et al., 1987).

CURRENT STATUS

AACTE, (1988) reported that:

- Ten of the fifteen largest schools of education have computer a literacy requirement for graduation.
- One third of all teachers surveyed have had ten or more hours of technology training.
- Many states are moving toward technology certification requirements,
- There are few data available suggesting that preservice graduates feel comfortable with technology (Carrier, 1988).

Perceptions.

- College preservice programs are typically taught by instructors who lack expertise with the computer (Budin, 1991).
- Students must be prepared to move into classroom with rich technological support. Yet only 29% of Education majors in a nationwide survey considered themselves prepared to teach with computers (Fulton, 1988).

Attitudes.

- Students majoring in education were found to be less positive about computers and attributed less value to computers providing beneficial results than business majors (Biola et al., 1989 cited in Carrier, 1988).
- A majority of student teachers surveyed view computers as unimportant (Jevens, 1982, cited in Carrier, 1988).

Recommendations.

- Professors and colleges must be role models of effective use of educational technologies and must have up to date equipment.
- Incentives provided for faculty to participate in integration of technologies into the curriculum (Vision: Test, 1990).
- Students/faculties must have access to hardware/software equivalent to what they will find in classrooms when they leave college (Vision: Test, 1990).

PROGRAM FORMATS

AACTE, (1988) found that most schools of education start with technology as a separate course before moving into more comprehensive approaches.

Model Projects

North Carolina State University developed a project with the National Science Foundation entitled "Preparation of Mathematics and Science Teachers for the Twenty-First Century." The project is based on the belief that preservice teachers should learn content and methods in a technology rich environment if they are to teach using technology.

The changes introduced included: a) technology for undergraduate instruction, and b) a constructivist approach to teaching undergraduates. The assumption is that if you immerse preservice teachers in an environment that requires them to use technology and active learning, they will use technology and active learning strategies when they become teachers. The results so far are that faculty lecture less and use discussion, inquiry, guided practice and cooperative learning more than their colleagues (Berenson & Stiff, 1990).

The **University of Massachusetts** sponsors a pilot program for 25 students. The foundation of the program is an internship where the student spends one-half year in school and one-half year in a corporation. The Massachusetts Science and Technology Program (MESTEP) emphasizes the use of telecommunication and bulletin boards. The assumption is that if students see how corporations use technology, they will incorporate it into their schools.

Northern Colorado University developed a degree program that emphasizes 1) instructional design/development, 2) interactive technologies, and 3) technology integration.

The **University of Illinois'** program emphasizes the following guiding principals:

- All students, faculty and administration have access to computing resources at minimal additional cost.
- One terminal for 20 students with the capability of free flow from one to another.

They have created the concept of the computer-intensive college believing that the computer presents opportunities for improved communication, increased productivity and enhancements to the teaching and learning process. Their goal is that all students and faculty have the opportunity to become computer literate. They created their **computer intensive college** by **building capacity** through training and hardware acquisition, coordinating effort and standardizing systems, expansion of opportunities for instruction and research, and developing support systems. They believe that expanded activity is based on expanded capacity, maintaining and upgrading equipment.

The **Teachers College Project** seeks to build a core of elementary teachers in three Manhattan inner-city schools who will later help teach other teachers in the same schools. It emphasizes using computers to support problem-solving and collaborative learning. The principles guiding the project are:

- Teachers must learn creative uses of technology to fit their own curricular needs. Strategies emphasized are integrated software, desk top publishing, simulations and time thinking about and discussing them in relation to their curricular themes.
- Teachers must have input in developing and implementing their own curriculum. The strategy is that as teachers become expert practitioners, they work their way into developing curriculum projects. One term to be spent with project personnel and another term spent on their own in creating curricular units that incorporate technology in ways they deem appropriate.

- Trainees' involvement with teachers should be long term and should saturate a school.

The strategy they employed was in the first 1 1/2 years, the core was trained, the next 1 1/2 years they train another group insuring that their project personnel have a 3-year relationship in working with a school and a significant portion of a faculty.

The **University of South Florida** is implementing a computer-based teaching/learning model (CTL). They believe that superior teaching shold be captured electronically. To do so increases the permanence and possible range of applications of good teaching models.

They developed an introduction to computer course which is required of all education students. The purpose is to enable prospective teachers to integrate microcomputer applications into the teaching and learning process.

Students must demonstrate their ability to evaluate software and conceptualize the use of the computer in CAI, CEI and CMI, and develop generic software applications for word perfect and databases to graduate.

Technology should be used to store, and report information related to the models operation for research, evaluation and revision.

The **University of Oregon** requires all education majors to learn the basics of computer operation, wordprocessing, data base management, spreadsheets and the uses of computers for testing. Students who plan to teach computer science at the high school, district or state levels are offered a comprehensive interdisciplinary master's degree program requiring 12 hours of computer science courses (David Moursand, 1988 cited in Carrier, 1988).

CERTIFICATION

Based on the existing research, it is difficult to predict the effects of technology on the skills required for teaching. A basic premise is that teachers will need to possess all the skills currently required in addition to the new skills made necessary by technology (Carrier, 1988).

There are few explicit pedagogical models existing for teachers to emulate when trying to integrate technology and teaching. This condition has led school districts to establish the operational criterion for selection as "interested, experienced, and appropriately educated."

At the state level Bob Kansky, (1987) noted that nearly half of the states had not developed standards specific to the certification, endorsement, and accreditation of pre-college teachers of computer science or information systems and none had any plans to do so.

Of the states with certification standards, half provide only for endorsement to an existing certificate. Several states were planning to develop standards to the endorsement level.

Twelve of the fifteen largest Colleges of Education require a course in technology to graduate; in only six of the 12 states is the course required for certification in the state. In addition,

- 18 states require, and eight recommend that teachers seeking certification take computer-related courses.
- Texas certification requirement (1984), is 3 semester hours in computing and information technology.
- 23 states require some computer courses to be certified.

SECTION 6

TECHNOLOGY AND FUNDING, FACILITIES AND EQUIPMENT

> **In the auto rental business, technology investment per counter worker is $10,000; in education the investment is $1,000 per teacher and $100 per student.**
>
> **(Perelman, 1987)**

The purpose of this section is to examine the relationship of technology and funding options. Secondly, the implications technology presents for design of new schools, renovation of existing schools, the operating, capital and maintenance costs are reviewed. Finally, the acquisition and disposal cycle for disposal of hardware and software are discussed. The section presents a summary addressing the focus questions followed by the supportive findings.

SUMMARY

Funding has been and still is the most important issue in the advancement of educational technology. At the current rate of investment, states can expect broad experimentation, continuing equity questions and slow but steady improvement in access and software.

The state has a special role in funding to provide equal access within schools and within classrooms. State funding is mixed with funding from the federal government, business and industry, software publishers, hardware vendors, and private foundations. Currently, the major sources are 30% state, 10% federal, and the majority (60%) from local funds. There is a general consensus that all potential sources need to be encouraged to participate because the size of the investment is large. More importantly, what is needed is a steady funding source that can provide a steady base funding source.

Several **funding options** have been suggested to get a more steady funding base at the legislative level such as: adjustments in the foundation program, earmarking permanent school funds, and short-term bond financing. Creative financing strategies such as grants and contributions from the private sector, using the textbook fund to purchase software, low interest loans, and special innovation funds have also been suggested.

The most widely held **justification for state funding** is to improve access and support integration of technology into the everyday life of students and teachers. State funding priorities have been distance learning, software and video preview centers, electronic bulletin boards, and development of instructional TV. School districts are using federal and local funds for technology hardware.

Telecommunication and computers are merging. This fact is putting pressure on current **facilities** and requires design changes in new schools. The most noticeable changes will be in the classrooms and laboratories. More space and flexibility costly equipment will be needed such as science and language laboratories and closed circuit television.

The **equipment** most commonly associated with the modern classroom are instructional television, the video cassette recorder, the microcomputer, and the interactive computer-based video disk machine.

FINDINGS

Part 1: FUNDING

In Electronic Learning's 9th and last survey (1989), funding was still described as the most important issue in the advancement of educational technology. While state support widens use, few have sufficient resources to deal with changing technology and increased access. For example, two thirds of the states reported that insufficient funding hampered the implementation of technology which led to equity concerns.

The Office of Technology Assessment (OTA), finds that at the current rate of resource allocation, the nation can expect a continued broad base of experimentation, steady but slow improvement in software, and spotty access to the technology by children (Power on!, 1988).

STATE FUNDING

Policy makers must provide special funds for necessary resources in under funded areas to provide equal access within schools and within classrooms.

The emphasis should be on continued funding for the emergence and expansion of all technology programs. While funding is not always more in most states, it has generally equalled the previous year (Bruder, 1989). For example,

- Forty four states allocate funds specifically for educational technology or make other state funds available, and
- Funding is not steady -- it ranges from $41 million in some states to less than $200,000 in others.

Regardless of the rate of investment, policy makers should focus their attention on four closely related areas if technology is to realize its potential. Each of these areas affects, and is affected by, the others:

- Increase student access by expanding amount and capability of technology in schools,
- Providing training and support for teachers,
- Encouraging improvements in software, and
- Supporting research, development, demonstration, and evaluation, with emphasis on ties between research and the classroom (Power on!, 1988).

Additionally, administrators can improve computer use by assuring on-site computer coordination, relevant staff development activities, resources are allocated in large enough measure to enable a community of users to develop, foster the sequential use of computers and favorable ratio of students to computers and relatively small classes (Becker, 1992).

Funding Sources. Public school funds typically come only from: local tax revenues, state appropriations, federal appropriations and outside grants.

- State funding is mixed with funding from federal government, business and industry, software publishers, hardware vendors, and private foundations.
- Major sources of school funding are 30% state and 10% federal, while 15% use neither state nor federal funds.
- Fifty states use federal funds for technology; chapter 2, chapter 1, title II, special education and vocational funding. (See Table 5 in Appendix A).

School districts commonly finance large capital outlays through bonds which offer a way to repay large sums from current revenues over many years. However, the equipment generally has a life span of only 10 years which creates problems in long-term financing. And, since computers, satellite dishes, etc. are considered moveable personal property, districts have been limited in the possible methods of financing them. One method has been tried in Texas. The Texas School Services Foundation (TSSF), an arm of the Texas Association of School Boards, administers a program enabling districts to finance personal property through bonds while pooling the issuance costs. The chief advantage of the program is that it is able to spread financing over the useful life of a piece of property, while obtaining lower interest ratios and pool bond issue costs. Each participating district is liable only for its own borrowing and pro rata share of program and bond issue expenses (Marshal et al., 1989).

State foundation programs could be altered to provide technology funding like vocational and special education, and transportation costs. Since such programs formulas are built on number of students served, a formula for a student computer ratio could be established. A grant for technology programs can also be established as an add-on to the foundation program after local share has been deducted.

State appropriations offer the most desirable sources of funding. However, Electronic Learning (1988) suggests five supplemental sources of computer funding: Apple Computer Grants, the National Science Foundation, federal grants from the Departments of Commerce and Education, parent and local community groups, and Chapter 2 funds.

Funding Justifications. Justification for expenditures was not a problem in states experiencing favorable economic circumstances. In these states, the impetus is to address broad goals of education such as equity and excellence, or "bring education into a new era", or keeping up with other states.

States with tighter economic conditions tend to justify their technology programs on a more concrete basis, such as savings in time or cost; or, in the case of distance learning, in hiring new teachers or leveraging the talents of master teachers.

In all cases, the justification for expenditures on programs was justified on an economic bias alone. The program judged to deliver the most educational benefit for the dollar was the one that received funding (Marshall et al., 1989).

Private Sector Funding and Donations. Private sector funding remains a minor source of funding. But, state agencies and districts have tapped private sources of funds for donations of hardware, software and technical assistance. Donations of money are rare. No special legal status or statutory requirements controlling the ability of public education institutions to accept donations of assets or money from private sources were identified (Marshal et al., 1989).

Herman et al. (1992), found that private sector donations significantly stimulate and enhance technology programs. However, to be effective, important opportunity costs must be considered. Donations need to be considered before they are accepted to assure they will help meet and not hinder longer-term objectives. Some problems they found were:

- In some cases there was not an optimal match between offered donations and site needs.
- Donations of inexpensive machines which required extensive maintenance.
- Offers of machines using different operating systems that would have required extensive new training for teachers and students.

The decentralized nature of private sector donations does not lend itself to massive projects. However, business partnerships can lead the way to increased state funding. A case in point is Maryland's experience with the use of business partnerships based on technology infusion. In 1985, IBM and Unisys installed networked labs in six schools. These labs required local matching funds to cover cost of implementation and software. In 1986, Apple Computer provided a pilot lab. These early contributions spurred interest from the business community and by 1987, Potomac Edison Power Company formed the first major partnership with schools in its service area of six school districts in the western portion of Maryland. Eighty-two schools benefited from the partnership. This partnership led to others such as Baltimore Gas and Electric and to state funding for computer labs. Through these partnerships, some school districts with favorable student computer ratios were those with little money traditionally available to provide these kinds of services to students (Salehi et al., 1990).

A second strategy is developing a structure which has less emphasis on the public relations goals and solicits large contributions from the business community. The philanthropic foundation established by business, civic or school leaders seems to be the most appropriate for large projects which cannot attract adequate state or district funding. A statewide foundation might be feasible if business representatives help plan the project (Marshall et al., 1989).

Funding Strategies. The state's goals and constraints will determine the most appropriate methods of finance and will affect how technology is implemented and used. Different methods of funding have different strengths and incentives built into them, besides those concerning equity. Some methods would minimize the costs of implementation; others would encourage the adoption of technology in local districts; and others would assure the development of high quality technology products or plans in the schools.

Funding mechanisms and sources utilized have been determined primarily on the basis of economic conditions. In states experiencing no economic crises, funds for technology usually come from dedicated legislative appropriations, or out of the state Department's operating budget. States with economic concerns place greater emphasis on local tax efforts, federal funds provided through existing programs and private resources. Private resources were tapped through partnerships with universities utilizing their ability to accept grants, donations and endowments. While is easy to become excited about possibilities, there is also the danger of acting too early, thereby wasting money (Marshall et al., 1989).

OTA suggests that steady funding is preferable to money that must be spent quickly (Power on!, 1988). They recommend establishing technology equipment as line item expenditure.

Finally, when funds are scarce, states revert to demonstration projects which attempt to fit into existing curriculum, and continuing earlier initiatives rather than using technology and efforts to restructure their schools.

State Funding Options. States generally have two investment options available to them. They may invest directly in the schools by supporting the capital and operating costs of a technology program and/or it may invest in the development of educational software. States must consider which option benefits students the most. Secondly, the state must decide whether it wishes to provide funds to districts on a one-time or on-going basis. One-time funds can be used to make capital purchases or to finance short-term demonstration projects. Districts then have to judge whether they will be able to continue programs. On-going funds adds to the permanent revenue needs of the state but have the advantage of providing predicable revenue to districts (Marshal et al., 1989).

The National School Board Association's On Line, Financing Strategies for Educational Technology (1989), discusses innovative financing alternatives to integrate technology and make it accessible such as:

- grants and contribution from private sector,
- short term bond financing through capital acquisition program,
- adjustments in foundation programs,
- earmark earnings of permanent school fund,
- textbook fund to purchase software,
- create special Innovation Fund, and
- low interest loans.

State department funds can be limited such as for hardware or training components, or applied at the discretion of the district. Some states use a matching formula, funds from lotteries and dedicated increases in state funding.

There appears to be a need to build state requirements, local partnership and enlist the aid of business/universities because the size of investment is large. Tables 5 and 6 in Appendix A displays funding options found in state technology plans, legislation or are in practice.

Replacement Cycles. School districts should plan their technology funding on a replacement cycle no more than 5-6 years (Vision: Test, 1990).

Volume Purchasing. States generally have regulations and procedures which govern what items may be purchased. For example, Texas has arranged for districts to purchase computers and site licenses on state contract, thus providing access to volume discounts (Marshal et al., 1989).

Cost Factors. Costs associated with technology programs include hardware, software, training curriculum, research and development, maintenance, and construction costs. Cost of security, replacement, and opportunity costs were not mentioned by the states surveyed.

Total costs vary a great deal. One source says that non equipment costs such as training, maintenance and facilities sometimes amounts to as much as three times the investments in equipment. Schools should not underestimate these costs. The price to be paid is under utilization and frustration with the equipment.

Improvements to practice call for similar infusion of funds. But many decision-makers want to be reassured that it is worth the cost to achieve in Exemplary Practice, or they may continue to invest in smaller classes, systematic on-going classes, larger salaries, fewer classes, and more planning time. Some analyses of the relative cost benefit of these factors would be helpful to inform the decision process.

Becker (1992), for example, found that his findings emphasize that successful use of computers may be costly not only because of the direct costs of hardware and software training and human support, but also smaller class sizes. The trade off investments might be:

- Lower class size or providing computer coordinator,
- Staff development or more planning time, or
- More software or more computers (Becker, 1992).

Costs may be estimated by examining the prices of high quality equipment currently available. For example, in 1992, the cost of an IBM compatible computer with monochrome monitor, 140 megabyte hard disk drive, a modem and a printer was $______ from vendors on a state contract. To provide one work station with this equipment for every 25 students would cost roughly $_______, not including software, furniture, local area network, staff training, etc. The same estimation can be conducted for Macintosh work stations. Costs should be calculated on a cost-per-student basis--not just total cost. A program costing $25,000 is more efficient if it serves more students.

On-going costs are difficult to predict since the equipment being used is new and its useful life has yet to be established. **Cost centers** include the following: **Capital Costs** for hardware and equipment; **Development costs** to put the system in operation; **Operating costs** to run the programs; **Marginal cost** of adding user sites or students; **Expansion costs** to enlarge the program; **social costs** of time and energy and staff needed to implement the program.

STATE SPENDING

The spending categories for state funding are included in Table 6 in Appendix A for your review. Some of the highlights include:

Spending Categories	# States Participating
Distance Learning	38
Software/video	33
Preview centers	33
Electronic Bulletin Boards	32
Development of Instructional TV	27

States are spending their money on telecommunications (43) and Distance Learning (42) video (37) and networking and desk top publishing (29) students at risk 34, special education 35, gifted and talented (Bruder, 1989).

Research and Development. Research and Development is generally built into the cost of software and equipment. However, the Minnesota Educational Computing Consortium and the Indiana Consortium for Computer and High Technology Education are examples of state-initiated research and development bodies. The Texas Learning Technology Group is a district funded example.

LEADING STATES

Marshall et al. (1989) reported the following information on leading states gathered through telephone interviews.

California. In 1988, the California legislature demonstrated its commitment to educational technology with a budget of $9 million in the initial year which was increased to $15 million the second year and $26 million the third year. In the fourth year the budget was cut to $13 million as a result of tax revolts. State funding for technology has been considered as "seed money" for projects with supplemental funds coming from local taxes. The state has not been able to provide any process for on-going review of software.

New York. Project initiative primarily comes from the district level driven through a program of categorical aid for hardware and software based on enrollment and wealth. This funding mechanism has been critical to equity and covers a broad range of technology.

They spent $16 million to support ninety-nine Teacher Resource and Computer Training Centers that served over 180,000 teachers statewide during the 1988-89, school year. Funding for centers is based on competitive bid. Linkage is between education and business through representation on Center boards. Teacher union support is required as a condition of every proposal. A second effort has been made with the Teacher Summer Business Training Program which reimburses teachers up to $1,000 for participation in training with applications that can be transferred back to the classroom.

North Carolina. Funds for integration of computer technology are distributed on basis of specific plans submitted by the district to the department. This is a dedicated appropriation to offset costs of hardware and software only. Funding for other costs, i.e. training, maintenance, facilities construction or modification and replacement, must be provided from other sources. Plans must contain on-going evaluation to measure project effectiveness. The definition and standards for outcomes are established at the state level, determined in part by pilot demonstration projects established by the state.

Funds for the electronic pages telecommunications project came from the operating budget of the State Department of Education.

Utah. The state has not attempted to tap private funding sources. Funding comes from the general operating budget. They are allotted to districts requesting funding on the merits of the programs proposed. State funding is provided for curriculum components only. No state funding is available for hardware purchases. Productivity grants are provided by the legislature to districts that want to start new projects to enhance the efficiency of education delivery or administration.

South Carolina. The state educational television network has been chartered such that they can accept private funds in the form of grants, donations and endowments. The only state money available to schools is from remediation, vocational education and incentive programs. More than one half of district funding on computers comes from federal sources. Local districts accounted for 20 percent of hardware and software expenditures; the rest comes from local businesses or parent-teacher organizations.

Distance learning has been pursued through the Instructional Television Fixed Service (ITFS) and Interactive Television (ITV) offered by the South Carolina Educational Television (SCETV) network primarily to address equity concerns. Funds come from SCETV's operating budget. Funds are allocated on a matching basis to support local initiatives.

Florida. In a good economic climate, technology program funding has not been a problem from general state revenues. Private funds were also tapped through the State Department of Education with universities in joint ventures. The state agency is allowed to accept donations of hardware from private sources but, to date (1988), has accepted no money. Their plan targets funds available through programs such as state and federal compensatory programs, job training and partnership act grants, vocational education and summer institutes. Also, lottery funds generated have been targeted to instructional technology in order to meet specific needs of children at risk. All education K-university, are under a Commissioner, therefore it has been easier to coordinate funding.

The level of funding was $30 million between 1982-1988. Funding has continued at the $8 million dollar per year range. The bulk of funds have been used to purchase hardware, software and application software for interfacing with sites and to establish a data base to facilitate reporting by the districts.

PART 2
FACILITIES

The computer is not in isolation; it brings all forms of communication together into one continual ribbon of information that can be assessed by the user.

(Unknown)

Technology is changing our world and is making significant impact on education and, in turn, school design, and hardware and software needs (Brubaker, 1989). The increasing capabilities and reasonable cost of new electronic technology will more fully integrate educational processes with daily life, and the school will become part of the community.

THE IMPACT OF TECHNOLOGY

A recent study sponsored by Apple Computer, Inc. predicted that by the year 2000, students will be using "electronic notebooks" with flat screens, data entry keyboards that will serve as a link to both home and school (Brubaker, 1989). The notebook may be used to:

- monitor student attendance,
- allow equal opportunity by tapping into the broad resources of the community,
- customize schedules for every student, and
- encourage independent study, the new force for education supplemented by small and large group activities.

C. William Brubaker (1989), in an article for the Educational Facility Planner, described the impact of technology on educational facilities as follows:

- Technology can help encourage the **creation of smaller schools**, with the computer and television making community resources available to these schools.

- The most noticeable changes will be in the **classrooms and laboratories**. Large, thin-wall screens used to display printed text, data, maps and art, will replace chalkboards, overhead projectors, and small, bulky television screens. Labs and shops will use computer-controlled simulation to graphic display processes. In administrative offices, computer memory will replace filing cabinets.
- In the **arts**, computers, lasers, television and robotics will be part of art studios, as will synthesizers in music rooms, while drama will benefit from new lighting and projection techniques.
- Learning technology will help forge new links between **home, school and community.** For some students, the home will be the principal place for learning. For others, the school may be more important, offering a social setting, a broad range of materials, and the opportunity for interaction with others. Regardless of where learning takes place, the home will play an important role for most students. Aided by the electronic notebook, (a link to other computers), and sharing education with parents (lifetime learners), education will be a part of life, not apart from it.
- The process of **school planning** will be facilitated by the computer. It already is a proven tool for school programming, allowing for continuous updating of total calculated areas and budgets. Computer-Aided Design (CAD) is useful for many phases of projects such as planning, design, construction documents and equipment and furnishing while a good word processor is indispensable for the preparation of specifications. The computer is also invaluable for estimating, construction management, scheduling, equipment coordination and payment tracking.
- The **technology of building**, essentially unchanged for generations, will also change. Reduction in energy costs, and new construction techniques are expected impacts of technology; more efficient air-conditioning; lighting and heating systems (Brubaker, 1989).

PLANNING KEYS

There are several **key signals to planners** of educational facilities about the characteristics required for an educational environment that will be viable both now and in the future. Considering the curriculum that is emerging, and the resulting instruction and its use of technology, several universal characteristics point to a need for the educational environment to be inviting, affirming, aesthetic, flexible, healthful, and intelligent. These terms, and the prototype classrooms and laboratories built on these principles, are described in the paper Raymond Farley delivered to the American Educational Research Association (Farley et al., 1992). The switch from facility to environment is deliberate because it is likely that education in the future will not be limited to a single facility.

Renovate or Build? Retrofits are preexisting buildings that must be assessed and refitted with appropriate cabling, conduits, outlets, etc. First determine if the current electrical power is sufficient, where they can run the cabling, where to set up wiring closets (where cables from the computer terminals meet), and then deal with unexpected problems like asbestos removal, insufficient ventilation and underground electrical cables (Electronic Learning, 1991). **The Houston School District** assumes that new and used buildings will be part of the technology facility plan. They say, "School districts cope with strict financial constraints. Therefore, the model must use existing school structures (Smith, 1987).

Cost Accounting. Levin's method (1983) for annualizing the cost of an ingredient is to compute its annual cost by considering depreciation and the interest on remaining or unappreciated value. To use the factors, one need only multiply the appropriate annualization factor by the replacement cost of the ingredient to obtain the annual cost.

> (a) **lifetime of resources** - a method to account for the expected life of each resources; and (b) **interest**-to account for the foregone income on each investment that would have been realized if the funds had been invested at a given

interest rate instead of being used to purchase the resource. For example, in Table 7 (Appendix A), a 9.25 percent interest rate was selected as the annual interest that could have been received by the school division during the project.

Classroom Layout. Changes in instructional methods can exert an important influence towards more or less radical alteration of traditional classroom layout. More space and more flexibility are needed. The layout needs to be more diversified, with new types of furniture and large amounts of costly equipment (e.g. science laboratories, language laboratories, documentation centers, computers, audio-visual equipment, closed-circuit TV), as computer-assisted learning, group learning, peer-teaching, individual instruction and experimental science cannot make do with the classical series of identical classrooms on a corridor.

Classroom Standards.

Elementary Schools

In 1988, there were 50,000 computer labs in elementary schools.

They were generally used in four ways. As:

- central computer labs with a one student/one computer ratio base on 25 computers in a classroom.
- mini-classroom centers with four to six computers, sometimes rolled in on carts.
- one or two computers in classroom at all times.
- a networked telecommunication center with administrative capability for teachers.

Secondary Schools

In secondary schools, the distribution was:

- four to six computers in a mini-labs layout for English.
- classroom teacher work stations interfaced in flat panel overhead.
- a computer, laser disc, large screen monitor for every academic department.
- writing lab established for English.

Computer Configurations. What computer configuration is best? Are large computer labs better for instructional purposes than one computer in a classroom? What is the best computer configuration for integrating the microcomputer into existing curricula?

Herman et al. (1992), found that a wide range of equipment, available in a centralized setting, combined with equipment available in all classrooms linked via networks within and across schools, as well as with the larger information networks, was the best configuration.

An Albuquerque school study found the mini-lab was used between 90% and 100% of the time. All academic departments found use for the mini-lab. Word processing was the most popular use of the mini-lab. The second most popular use was for tutorial instruction and drill and practice. Science and Math departments used the lab more than others. Telecommunications applications and instrument interfacing seem to have found an audience only among science teachers. They were also used on a school wide basis for research papers and school newspapers. The mini-lab was also effective for addressing equity issues, and, during science fair time, students used it before and after school to work on their projects. The result was that students from disadvantaged homes were able to compete effectively against more affluent peers (Barba, 1990).

Computer Labs. The advantages of computer labs are that:

- Cooperative learning is facilitated. (Two students on a computer is an efficient number and an optimum learning environment (Webb, 1984 cited in Barba, 1990).
- They are cost-effective. Many programs can be legally booted on all the machines from a single diskette.
- Central storage aids in security of hardware and software.
- They receive high usage by teacher and students. Districts report usage between 42% and 71% of the instructional day.

The disadvantages of computer labs are that:

- Classes must be scheduled into the lab.
- Labs must meet fire codes for science classes.
- There are conflicts between classroom teachers and teachers who run the lab.
- The computer lab is an inflexible classroom.

One Computer Classroom. The advantages of the one computer classroom are that:

- It's great for demonstrations.
- It assures availability when teacher requires it.
- It is flexible.

The disadvantages of the one computer classroom are that:

- It tends to be a teacher's personal tool.
- There is little time for individual student use.
- Teachers need their own software.
- More planning required to offer on line and off line activities at the same time.
- Hardware and software are not secure.

Computer Mini-Lab. The mini-lab has three or four computers mounted on a cart. Teachers sign up for the lab in the same way as other equipment. It's stored in the media center or in each department.

The advantages of the mini-lab are that:

- It is highly flexible.
- It is cost-effective.
- Students receive adequate computer time.
- Cooperative learning is facilitated.

The disadvantages of the mini-lab are that:

- Sign-up is required.
- Teachers must plan on line and off line activities.
- It requires flexible classroom situations.

Backbone Networks. How do you plan for a future where there are no quarantees about your budget, students' needs, and the kind of technology that will be available? Many schools create a "backbone network" that will support whatever technology you buy in the future. So as needs and budgets allow, they can place technology in every room of the building. However, when you commit to such a scheme, in a sense you are committing to a whole new approach to instruction (Peter Reilly, assistant director of technology for the Regional Information Center of Southern Westchester BOCES, Tarrytown, NY, quoted in Electronic Learning, 1991). Typical network plans were estimated in 1991 at $65 to $748 per classroom.

PART 3
HARDWARE/SOFTWARE ACQUISITION

STATE ROLE

- Thirty three states have procedures to purchase at reduced prices.
- Twenty four states have negotiated agreements to purchase administrative or applications software at reduced prices.
- Twenty eight states support evaluation activities.
- Twenty four states assist in electronic distribution of software.
- Thirty states involved in curriculum development projects using commercial software.
- Seventeen states offer technical assistance for development of educational software (Electronic Learning, 1987).

CAPITAL OUTLAY

Schools must develop more capacity to use emerging systems as they develop and understand most technology will become obsolete before it wears out. Herman et al. (1992) found that the wear and tear of school use requires professional grade equipment.

Business expects to change every 18 months. Educational standards differ to some degree. For example, the Wayzata School District strategy for capital outlay for instructional computing hardware is to replace rather than to add needed instructional computing equipment if funds are tight (Wayzata School District, 1990). Some suggested guidelines are:

- To create a funding cycle,
- To set life expectancy at 5-6 years then write off,
- To assume that state of art or first generation behind hardware will be bought,
- To keep old hardware and software in service beyond if still reliable,

- To use opportunity of new building or remodeling to upgrade facilities that will accommodate future uses of technology you envision,
- To open new facility with new hardware -- shift old to other,
- To ensure that software does not wear out though it might become dated. Analyze if software still meets need.

SCHOOL DISTRICT HARDWARE/SOFTWARE PLANNING

The **Northshore School District** of 1990 plan for Hardware/Software includes the following guidelines:

- Establish hardware selection committee to review, acquire and develop an updating process,
- Thoughtful and equitable selection and distribution of hardware and software,
- One station per certificated employee,
- One station per secretary,
- Two computer stations per elementary classrooms,
- One computer station per department in secondary,
- Provide labs,
- Provide LAN for each building including lab,
- Develop formal software selection, review,
- Acquisition and updating process,
- Process needs to allow for balance between cost-effectiveness, standardization and flexibility.
- Establish district policy in following areas:
- Copyright protection,
- Software adoption, and
- Procurement of segment materials and systems.

GENERAL RECOMMENDATIONS

Information Exchange. There is a need for a information exchange strategy. One tactic is to develop a clearing house activity for exchanging experience on new methods of educational building management and planning.

A second tactic could be to encourage the production of case studies on the development of computer-assisted management of school buildings with detailed cost and technical data, and descriptions of the main difficulties encountered as well as an evaluation of results.

Such case studies are deemed very useful by specialists of other countries. For example, these case studies could help solve the need for standardization:

- of concepts used in school building planning and design
- of codification of data.

Thirdly, a priority should be the codification and agreement of local, national and international standards to permit the extension of networking and inter-connectivity of hardware from different manufacturers. Lack of hardware standardization introduces the problem of software transportability.

Compatibility. Compatibility seems to be the main problem when equipment has not been planned as a whole but has been done piecemeal and, often, individual users. This may be a hindrance to networking.

For example, software written for implementation on one type of computer will not necessarily run on a machine produced by another manufacturer. Furthermore, machines produced by the same manufacturer are not always compatible.

Finally, it might be extremely useful to have at one's disposal a reference file of available software and applications. This could take the form of an annotated bibliography to which would be added a series of evaluations made by the members of the school divisions (Bousquet et al., 1990).

Herman et al. (1992), found that technology projects would greatly benefit from an easily accessed source(s) which could provide sound advice on acquiring, installing and maintaining hardware and software.

Evaluation. Constantly changing technology may be one of the factors which leads decision-makers to a "wait and see" attitude. The point of evaluation studies is not to persuade decision-makers, but to present them with all the elements of a decision. One knows more or less what is being done elsewhere, but seldom how it compares with previous manual management and what were the difficulties encountered and the costs.

Evaluation is a function that is useful but difficult to maintain in the press of organizational affairs. Evaluation would be helpful in the evaluation of plans, prototypes, space planing analysis and optimization of construction costs. These evaluations would be helpful in setting norms for facility use: area per student, daylight sound and temperature insulation, ventilation and specifications of building materials.

The evaluation of software is also essential. The variety of software offered on the market makes choice very time-consuming. There are said to be 10,000 pieces of educational software on the market. Generally, assessment from the available documentation is never completely sure. There is no substitute for a trial use made with reference to the task to be performed.

Finally, the simulation of implementation of computer-assisted planning and management would help to visualize problems and alternative solutions.

SECTION 7

PLANNING, IMPLEMENTING, and EVALUATING TECHNOLOGY

> **Like beauty, innovations exist only in the eye of the beholder and it is the beholder's perceptions which influence the beholder's behavior.**
>
> **(Rogers & Shoemaker; 1991)**

The purpose of this section is to identify planning models that could be used, determine the models currently being used; their components and the implementation practices to diffuse those plans. This section is divided into two parts. Part 1 presents the findings for planning. Implementation is the focus of Part 2. A summary addressing the focus questions is presented first, followed by the supportive findings.

SUMMARY

Planning for the use of technology should be focused on four key concepts that characterize the direction of educational technology. First, educational technology will be **interactive, controlled by the learner.** It will engage the student and enhance decision-making and problem-solving. This fact alone will revolutionize the classroom and the place we call school.

Secondly, educational technology will make **resources more accessible**, changing the place of schooling, the role of the teacher and relationship between teacher and learner. With massive data bases, with visual images immediately available, the teacher will no longer be the holder and dispenser of information and the trainer of skills. Teachers will be more like coaches, mediating technology, diagnosing learning styles and proficiencies, and facilitating a variety of strategies.

Thirdly, educational technology will be **more affordable**. It will be in reach of all learners in and outside the school.

Finally, educational technology will be **integrated**, bringing together many tools in exiting and creative fashion. The merging of computers and video technologies with telecommunications is already in the current system (Farley, 1992).

Planning for technology is an **important state role**. The justification for state involvement revolves around equity of access to resources, coordination of resources, and developing infrastructures that allow information sharing and alleviate disparities. The planning model chosen by a state is generally dependent on tradition and the manner in which they handle major reform efforts.

States use a variety of mechanisms to develop state technology plans. They can be conceived through a task force structure composed of key constituents who develop a consensus around the components of a master plan. These constituents would be external to the department of education and would include businesses, the legislature, professional associations and members of the general public. The task force is responsible for presentation of the plan to the appropriate decision-making bodies. In this model, the department of education acts as staff to the task force, providing information and being responsible for the mechanics of putting the plan together. Secondly, once the decision bodies (such as the State Board of Education) review the plan, they are responsible to amend the plan in accordance with the decision body's recommendations. Finally, under this model, the Department reverts to its managerial role of implementing the plan through budget requests, and if successful, through implementing decisions and tactical plans to implement the components that survive the decision-making process.

A second model used is to develop the Master Plan in house. While this committee is generally composed of department members it also includes members of the professional associations and the professional community. This model generally has some public input and review process such as public comment periods in the drafts that are forthcoming from this process. At the conclusion of the work the plan is submitted to the executive level of the organization, who recommend changes then to the public decision-makers for review and prioritization of components of the plan. After producing the first draft of the plan, the department's role is similar to the task force model.

No matter which overall planning structure is utilized, the process will generally use an adoption, political market place, a concern based strategy, or some combination of the three, such as strategic planning process. Each strategy has its strengths and weaknesses and they are detailed in the findings.

The **state master plans** have focused on hardware acquisition, software acquisition, evaluation, distribution, staff training and development, electronic linking of agencies and sources, integrating technology into instruction, encouraging local school divisions to plan for the use of technology prior to the purchase of equipment, and providing financial incentives and cooperative purchasing agreements.

Distance learning has become a staple of state efforts and is evident in nearly all state plans. Some leading states have created centers for research, development, dissemination, demonstration and evaluation of technology and software. Others have created demonstration schools. The emphasis there is to marshall all the resources for integrating technology into the daily life of a school. Others have focused on creating electronics networks to connect the schools to the world. Others have moved to establishing a statewide administrative management information resource.

State plans generally require or encourage school district planning. If there are state funds available for technology, they require it prior to the release of funds. Some may even help school districts write informal, appropriate plans on the use of technology and help determine needed software.

It has been demonstrated that **technology can do the things it promised.** A majority of states have developed plans. Many school districts have developed plans. However, judging from the incomplete diffusion of technology in the schools it is apparent that the best uses of technology have not been reached or there has been insufficient funding for its installation.

The lack of **systematic implementation models** to follow, incentives for individual teachers, limited amounts of equipment and the unsystematic use of software, primarily at the lower grades, have been identified as barriers. The facilitators of technology implementation are seen as the attitudes of teachers and administrators toward the innovative uses of technology, a good understanding of user perceptions, communication of possibilities and successes, and allowing sufficient time for a consensus to be established. Most essential is the existence of a core of enthusiastic technology-using teachers and a dynamic supportive administration that together provide the leadership to design and implement the plan.

The **role of evaluation** is nothing less than to provide: 1) policy makers with the information they require to contribute to their decisions to enhance or expand technology, and 2) designers' and users' information which will contribute to improvement, continuance or expansion of their programs. As important as evaluation is the state role that has been limited.

Most progress has been made by learning by doing. A few states require that the components of their master plans be evaluated periodically. Some require an evaluation component for every technology project they fund. California has been a leader in this area. They require formative evaluations of each of their demonstration schools. Cost-effectiveness has been much proposed and advocated, but there is little evidence that rigorous studies have been conducted or utilized.

Planning for the use of technology should be focused on four key concepts that characterize the direction educational technology is moving towards. First, educational technology will be interactive, controlled by the learner It will engage the student and enhance decision-making and problem-solving. That fact alone will revolutionize the classroom and the place we call school. Secondly, educational technology will make resources more accessible, changing the place of schooling, the role of the teacher and relationship between teacher and learner. With massive data bases, with visual images immediately available, the teacher will no longer be the holder and dispenser of information and the trainer of skills. Teachers will be more like coaches, mediating technology, diagnosing learning styles and proficiencies, and facilitating a variety of strategies. Thirdly, educational technology will be affordable. It will be in reach of all learners in and outside the school. Finally, educational technology will be integrated, bringing together may tools in exiting and creative fashion. The merging of computers and video technologies with telecommunications is already in the current system (Farley, 1992).

FINDINGS

Part 1: PLANNING

According to experts in the field, allocation of equipment is no longer the major issue confronting educators. The challenge today is improved adoption, diffusion and utilization of computers.

THE FOCUS OF PLANNING

Herman et al. (1992), found that technology projects require strong and sustained leadership, and require individuals who encompass a variety of expertise needed for successful reform. Clear strategic plans, incorporating teachers' voices, are a critical ingredient in project implementation. Schedules must permit adequate time for such planning. Technology innovation needs to be incorporated within school-wide plans for learning and instruction.

Planning for the use of technology should be focused on four key concepts that characterize the direction educational technology is moving towards. First, educational technology will be interactive, controlled by the learner It will engage the student and enhance decision-making and problem-solving. That fact alone will revolutionize the classroom and the place we call school. Secondly, educational technology will make resources more accessible, changing the place of schooling, the role of the teacher and relationship between teacher and learner. With massive data bases, with visual images immediately available, the teacher will no longer be the holder and dispenser of information and the trainer of skills. Teachers will be more like coaches, mediating technology, diagnosing learning styles and proficiences, and facilitating a variety of strategies. Thirdly, educational technology will be affordable. It will be in reach of all learners in and outside the school. Finally, educational technology will be integrated, bringing together may tools in exiting and creative fashion. The merging of computers and video technologies with telecommunications is already in the current system (Farley, 1992).

Reasons to Plan. Several reasons to plan are found in the literature.

- A wide disparity of student, staff and faculty access to technology and technology resources exists.
- There is an urgent need for access to technology resources in every teaching and learning environment.
- The ability of those involved in the teaching learning process and its management and support to access technology resources is not universal.
- Coordination of public and private resources is limited.
- Many private and public networks are not linked electronically.
- K-12 schools must be encouraged to incorporate technology into existing school district, and institutional plans and initiatives.

PLANNING MODELS

The literature presents three planning models used by states and school divisions: the Adoption Model, the Concerns Based Model and the Political Market Driven Model. It also suggests that there are problems associated with each of the three models.

The Adoption Model. The model presumes that if faculty members are given access to the technologies, knowledge of how to use them, and the power to choose and develop their own tools to meet instructional objectives, the result will be school wide integration of technology in the curriculum. This integration, in turn, will enhance student's learning experience and improve learning outcomes across grades and subjects (Stearn, 1991).

Efforts to install computers have fallen victim to the same adoption model illusion that dominated previous attempts to initiate change. Such procedures are designed to elicit a "buy in" by teachers, which presumably encourages teachers to try the technology and upon trial, invest in its success. Unfortunately, the adoption diffusion strategies do not automatically ensure the best interests of the system.

Installation efforts are often little more than attempts to promote painless infusion, to install without really changing, and to accommodate but not improve. Failure has often been assured by the methods used to "sell" computers to schools. Teachers with limited knowledge, and often conflicting priorities, influence how, when, or even if needed innovations are to be implemented. Instead of promoting change it is often stonewalled due to territorial, personal and political threats posed to the innovation. Certainly teacher input is important to the installation of computers in the schools, but such import cannot control the fundamental need to install innovations. The individual autonomy that has involved evolved affords teacher extraordinary control over both content and method. Many teachers and administrators persist in belief computer is simply another educational fad that will run its course in due time.

By intent and default the system has established unfavorable ground rules. We sometimes promote territoriality. In elementary schools, libraries and media centers have garnered considerable control of computer resources. At junior high schools, mathematics, computer science and business departments have assumed control (Hannafin et al., 1987).

The Political-Market Model. This political-market model of innovation stresses the role of the state in spurring innovation and movement along the learning curve by setting standards, providing infrastructure, funding vital activities, and mobilizing support for change. Pilot projects that show clear winners and losers and drive competition, as well as training to build constituencies can help drive the political agenda.

Political entrepreneurs, working for change and hoping to mobilize support, have defined programs broadly to win support (e.g., 'every school should have at least one computer.') While this allowed programs to be established, the programs have remained without a strong constituency: for business this is still a small market, for teachers it threatens to change working conditions and to take funds that could be used for textbooks and pay, for administrators it is a costly initiative with unclear payoffs that may require major reorganizations of schooling to be used effectively.

As a result, the issue keeps threatening to slip to the back of the political agenda. The result is that inadequate funding spread so thinly that it has no big impact anywhere and makes it hard to demonstrate performance. Funding for research, dissemination and support is unpopular, slight and vulnerable to budget cuts. This encourages marginalization of this technology to reinforce current practice. Resulting in lackluster performance, in turn, undermines public, professional, and political support for the program. This cycle creates "ghost technologies," as the interesting technological and instructional options fade before the institutional and political realities.

Government could be a catalyst for change, but costs, complexities and the need for a broad coalition to sustain change overwhelmed efforts at revolution from above. There is a vicious cycle at work here.

Governments have proved to be catalysts for change as political entrepreneurs introduced and defined programs to win support, but costs, complexities, and the need for a strong, broad-based coalition to sustain change overwhelmed the technology revolution. The result has been a cycle of inadequate funding, lack of dissemination and program support, marginalization of the technology, and attenuation of public, professional, and political interest in the programs. The impact of education technologies has been more positive in the work place, and it is possible that a substantial technological impact on educational achievement will result from policy and practice in the political-market model of innovation (Marshall et al., 1989).

Concerns Based Planning Model. The model assumes that technology should be found in area where it provides a direct benefit based on a defined need. Just because it can be used doesn't mean it should be or that it provides the best solution.

Plan the Plan -- Benchmark Current Status -- Envision future trends Identify stakeholder needs and wants. Develop model and recommendations. Identify resource requirements for each alternative (training, on-going support, connectivity, information networks, applications systems, media resources, technology equipment (Sydow and Kirkpatrick, 1992).

Education's use of technology should be needs driven, not "bell and whistle driven," and look beyond current needs to the future, function oriented and planned. The Plan should be closely aligned with the state's strategic plan -- tactical plans can be developed annually that fit strategic direction of the organization.

- Finding technological solution to meet Division needs is more important than asking if they are state of art. The state-of-the-art for any period of time will not remain state of the art -- (up-grade-able) (Kent School District, 1990). Decisions concerning the implementation should be needs driven.

Planning Assumptions. Good decentralization requires good centralization. Education systems are neither completely centralized or completely decentralized. New technologies will lead to greater decentralization and to the empowerment of teacher and students by putting more and better information in their hands. However, effective implementation of the new technologies requires effective planning and action on part of state authorities (Marshall et al., 1989).

Planning should involve teachers, administrators, higher educators, parents, legislators, SEA officials, and the information technology industry. Teachers and administrators who volunteer for the schools should be educated to use technology. The schools should develop and use differentiated staffing to work toward more cost-effect, productive, and efficient learning environments. Parents and students should be encouraged to volunteer for enrollment. The schools should develop a systematic program to provide assistance to other schools. State and local authorities, the designated federal agency, and the technology industry should cooperated in dissemination of information (National Task Force on Educational Technology, (1986).

STATE ROLE

Planning for technology is an important part of state role. Plans demonstrate each state's approach to technology, educational policy and governance, and the relationship with local school districts. A state's approach to technology generally reflects its approach to educational reform. It can be rigid mandate oriented or facilitive oriented, or a mixed approach. No matter which approach is used, a main justification for state involvement is to further equity of access through acquisition, evolution and distribution of hardware and software.

State Policy Focus. After analyzing state plans for technology, The Office of Technology Assessment concluded that the state role focused on hardware acquisition; software acquisition, evaluation, and distribution; staff training and development; and integrating technology into on-going instruction (Power on!, 1988).

Programs can be grouped in two broad categories: 1) programs whose scope and application were limited either by geographical, economic, institutional or governance considerations, and 2) programs whose scope or application could be applied on a statewide basis. All states encouraged program initiatives originating at the district levels. The degree of district autonomy varies from state to state but was consistent regarding the type of program delegated to the districts for development. For example, computer technology programs were generally delegated. State program initiatives were concerned with those programs that spanned boundaries. For example, distance learning programs. State responsibility for these programs has grown out of the need to coordinate program usage and access as well as the larger imperative to pursue equity and economic development goals.

Funding requests were granted primarily on the basis of plans submitted by districts according to criteria set forth at the state level. Criteria include standards, curriculum, equity, economic conditions, evaluation and accountability requirements.

Evaluation of distance learning and communication networks were evaluated at the state level on a system wide basis. Programs conducted at the local level were evaluated by the districts on a program by program basis. Source of funding is the most significant factor determining where the responsibility and control over evaluation processes. In fact, authority and control is clearly in proportion to funding input. States generally define the output from a technology program according to the goals of the project rather than just on student productivity. For example, New York evaluates on state priorities. Evaluations of distance learning have focused on the number of courses offered, program hours and end users (Marshal et al., 1989).

State Planning Guidelines. The National Governor's Association Center for Policy Research and Analysis made the following recommendations for States in their report, Time for Results: The Governors' 1991 Report on Education:

- Encourage all school districts to develop written plans regarding the use of various technologies, prior to the purchase of any equipment.
- Encourage all prospective teachers to learn about effective and emerging uses of technology in their respective curriculum areas.
- Encourage every college of education to develop relationships with as many schools that use technology as possible.
- Help school districts and schools write informed, appropriate plans on the use of technology.
- Help school districts, schools and universities establish continuous training programs on the appropriate uses of technology and ways to incorporate them into their curriculum.
- Help all states share data cost and achievement from experiments being conducted within their respective states.

- Aggregate purchases and establish wider markets.
- Provide financial incentives and assistance for district planning for the use of technology by providing support for purchase of equipment.
- Provide for establishing and improving training program for educators about cost-effective ways to use educational technology.
- Assist school districts that are willing to experiment with ways to restructure school environments to increase educational productivity by using various forms of technology.
- Encourage greater cooperation among states through creation of consortiums and other technical assistance.
- Establish independent institutes for research and demonstration of technology to education, modeled on the National Science Foundation (NSF).
- Recognize each state's most creative technology-using educators.
- Make technology more available for students from low-income families.

A second set of recommendations was developed by The National Task Force on Educational Technology (1986) for state action.

- Ensure equity of access to educational technology.
- Encourage and support local planning and implementation efforts.
- State legislatures should provide incentives to businesses to help schools adopt new technology.
- Urge all teachers to become effective users of technology.
- Cooperate with higher education and publishers to ensure that textbooks are an integral part of the instructional package that includes technology.
- Work with districts to define the needed software.
- Define for the software industry where software is needed and what it should be like.
- Provide financial support for research on the effective use of technology.
- Each state should ensure that demonstration schools eventually cover K-12.

State Capacity. Fewer State Departments have full-time directors of Technology thirty two in 1988 and 26 in 1989. Part-timers are up from seven in 1988 and twelve in 1990 (Bruder, 1989).

STATE PLAN COMPONENTS

Twenty one states have long range plans for educational technology. Thirteen states are developing them. Texas, Minnesota and California are regarded as leading states in educational technology use among educators.

The state plans generally include the following components:

- Legislative Authority for Master Plan
- Previous and Existing Programs
- Planning/Leadership
- Funding
- Community
- Clearinghouse
- Training In service valuation
- Research
- Training

Several policy options have been identified in the state plans. (A listing of state plan components by states is described in Table 8 found in Appendix A). For example, the plans address personnel, centers and demonstration school.

Personnel. Mentors, technicians, credentialed library media professionals and others are needed to provide the support necessary for successful implementation of technology.

Centers. Create "full-service" centers where faculty, staff members and institutions receive assistance to facilitate operations related to acquisition and purchase of educational technology tool kits (California Plan, 1992). Some state purposes of such centers are research, development, dissemination, demonstration, and evaluation of technology. Texas, California, Florida, Oregon, and Missouri have developed central technology support centers.

Technology Demonstration Schools. Demonstration schools require the leadership of the state education agency. They should be financed under existing mechanisms, with the exception of start up costs. All resources (equipment, curriculum, teachers, administrators, community and parental support) for integrating technology into the daily life of the school should be planned for. And, connect schools to research centers (Power on!, 1988).

Distance Learning. Distance learning has become a major instructional force. Twenty five to fifty percent of the nation's students are reached by distance learning technology.

Distance education is evident at almost every educational level in almost every sector (Ely, 1991). The **NGA** supports this claim. It reported that Distance Learning is used in some capacity in all states. This literature review above found thirteen states with state supported programs (see Table 6 in Appendix B).

- Distance learning provides systematic instruction to individual learners who are physically separated from their teachers. State programs in Kentucky, Oklahoma, Michigan, Minnesota, Texas and Virginia were cited.
- Many distance learning programs are course-based; (they offer complete courses with teacher in remote location). Some uses are supplementary classroom instruction to enrich learning (satellite teleconferences, CNN newsroom, AT&T Learning network).

STATE PLAN RECOMMENDATIONS

Technology in Every Learning Environment. Provide access to an array of information and instructional technology devices and instructional resources for every learner, faculty, and staff member in every teaching/learning environment.

Professional Development and Support. Provide equity of access to sustained and on-going professional development and technical support for every information technology user in the teaching learning process.

Education Network. Establish and coordinate a statewide integrated linking ...network.

Instructional and Information Resource. Improve existing and establish new statewide instructional and informational resources.

Student Data Resource. Establish a statewide student data resource for educators and administrators.

Management Information System. Establish a statewide administrative management information resource.

Educational Technology Coordination. Establish a state-level intersegmental education council and industry council to cooperatively implement the Master Plan and to develop future plans.

Evaluating the Implementation of the Master Plan. Provide for on-going evaluation of the extent and impact of the implementation of each recommendation of the Master Plan.

Resources to Accomplish the Master Plan. Develop substantial, sustained public and private funding mechanisms for the recommendations of the Master Plan (California Plan, 1992). Private sector support of the implementation of the Master Plan shall be provided through in-kind and cash donations and through direct investments in education (California Plan, 1992).

LEADING STATES

The following information was collected by the state of Texas and is provided for your review (Marshall et al., 1989).

California. The main program thrust has been on integrating the new technology into the education process with the objective of making teachers comfortable with technology rather than to affect student achievement. The current state plan is based on "wants" assessment rather than "needs" assessment. Projects have come in a variety of shapes and sizes. Provisions for equity are required by the state Department of Education. However, local districts have focused on efficacy or excellence. Program emphasis has been on curriculum reform with technology used as an enhancement or supplement. In addition, technology programs have been pursued to alleviate teacher shortages, which have been experienced in specific curriculum areas and in certain geographic regions. The "Model Schools" structure has been used to facilitate the development and transfer of program design for both technology and curriculum.

The 1992 California Plan, specifies a number of objectives technology can contribute to their success. These objectives are

- Equity of access to technology resources;
- Equity of resources anywhere learning and teaching occur;
- Coordination of resources from public and private providers;
- Electronic linking of educational agencies; and
- Coordination of educational technology among the four segments of California public education, k-12 education, California Community Colleges, the University of California and the California State University.

New York. Educational priorities have been driven by three priorities: 1) excellence, equity, and efficiency as determined by productivity, 2) accountability, and 3) the contribution to economic revitalization.

The bulk of technology research is conducted by key institutions of higher education identified by the state Department of Education. Individual programs are evaluated according to requirements of the funding source. The actual evaluation is conducted by the Legislative Program Evaluation Office. This structure separates the parties responsible for program operation from the evaluators in order to ensure objectivity.

The integration of technology into the curriculum is required and emphasized in all new programs. The state also requires a close correlation be established between current curricular objectives and hardware applications in any proposed technology program. In requesting funding, districts are required to make application for specific instruction and content areas (Marshall et al., 1989).

North Carolina. North Carolina's technology efforts have focused on three major programs: 1) purchase of computers and software to achieve a computer/student ratio of 1/23 (1988), 2) establishment of a telecommunications and Electric Pages network linking the six regions across the state, and 3) establishment and expansion of distance learning technologies, including satellite network, Ti-IN, to provide curriculum to all districts in the state (Marshall et al., 1989).

Utah. A master plan has been implemented at the state and local levels. In the past, programs for the most part have developed at the district level to address local needs with little direction from the agency. They have primarily taken the shape of distance learning because of the geographic and economic needs of the state and a desire to address equity and hold down costs of hiring new teachers.

Impetus for future developments is coming more from the state. This impetus will develop as districts respond to the newly defined core curriculum required for graduation from high school. Technology has been identified as one of the Core Curriculum elements students are required to master in order to graduate. Districts have the choice of offering technology curriculum as either a discrete course or as an integral part of other curricula.

The state has developed communications standards for districts to follow, especially for reporting requirements. The state maintains a Technology Center, which acts as an information repository and provides technical advice, provides or coordinates in service training programs offered to teachers across the state. Software reviews are maintained on a statewide data base; but this date base is neither comprehensive nor up to date due to the magnitude of task and lack of funding commitment. Program evaluations are made by third parties. Programs are evaluated on specific need it addresses. For example, distance learning is evaluated on availability of new courses. As long as students are passing or doing no worse than students in conventionally delivered courses, equity will remain the criterion for success.

The state owns and operates a "Microwave Backbone," an interactive video system developed with funding from the Department of Commerce. The system is operated by higher education and state transportation agencies; public education accesses it mainly for educational administration and teacher in-service training through a lease arrangement (Marshall et al., 1989).

South Carolina. The statewide technology efforts have centered around two major areas; distance learning and the reduction of teacher's paperwork through the use of computer technology. Specific computer technology initiatives are driven by the districts with the state agency acting only in the capacity of a technical advisor or coordinator. Local district efforts have centered around those programs that primarily utilize computer technology.

The state participates in the Software Evaluation and Exchange Dissemination (SEED) that involves several southern states.

Florida. There have been several areas of emphasis in their plan. These include a need to promoting excellence, assuring a supply of high quality teachers, providing diverse programs to meet needs of at risk students, strengthening partnerships, preparing students for a competitive world marketplace and accommodating growth.

The primary project in progress is the statewide Data Communications Network. It's a joint project linking the university system, community colleges, and local districts. No attempt was made to justify on an economic basis, cost/time savings. The Network was seen as a way to keep up with student mobility by facilitating student records through the state; the side benefit was increased ability to gather and interpret data on program make up in requests for funding from the districts and legislature.

The department has also created joint efforts with post secondary institutions in funding centers to evaluate software. These evaluations primarily emphasize a comparison and correlation with existing state education needs and capabilities. Additional they established a bulk discounts and purchasing incentives for technology purchasing in the state. All program evaluations are conducted at district level (Marshall et al., 1989).

SCHOOL DISTRICT PLANS

The overall use of technology is growing in our schools nationwide. Distance learning is a dominant existing new technology. Interactive video disc is a promising new technology. If we don't require some planning from districts, and if we don't do research on when and if technology is effective, it could fade away (Geoffrey Fletcher, cited in Bruder, 1989).

Reasons School Districts Plan. School districts **adopt** technology for various reasons:

- **Covet thy neighbor**-- Solely because a neighboring school division used that technology resulting in pockets of use independent of other parts of organization. No one determines the division's needs to ensure that the technology solution meets a need.

- **Division Experts** -- Planning by a few experts, consultants, vendors, in house experts -- assumes the wants and needs of staff who will use technology.
- **Availability of capital** -- needs may not met -- implementation costs not included (readability).
- **Decentralization** -- request continual support -- not connected.
- **Identifying needs** and wants and meet them with today's solutions results in obsolescence since implementation takes place over period of years.
- **Eye to future** -- meeting tomorrow's needs by tomorrow's technology based solution.

District Planning Guidelines. The National Task Force on Educational Technology (1986) recommends that school districts should do the following:

- Plan to include as line items in the regular school budget all the costs of employing technology.
- Develop strategic plans for educational improvement that recognize the needs of a changing society and that provide for continuing planning that anticipates future changes.
- Include technology as a regular budget item.
- Work with the information industry to secure favorable prices.
- Use all sources of available information to select the most useful and best technology.
- Work with parents, industry representatives, and economic development offices to secure support for adequate funding.
- Collaborate with higher education to develop programs for in-service training on application of technology.
- Use technology in development of programs for in-service education of teachers.
- Provide leadership and support for developing the new curricula,
- Provide opportunities for parents to learn about educational technology.

School District Plan Components.

Appelton School District Plan Components

- Mission
- Applicable Law/regulations
- Goals
- Coordinator of Inst. Computing
- Curriculum Integration
- Staff development
- Computer equipment (the specify 10 computers for every student)
- Program/Courseware/Software
- Facilities development
- Elementary and Secondary Standards for Hardware and Software
- Mobile Carts
- Lab
- Fixed Location
- Reader 15-20 units
- Secondary lab
- Implementation sequence

Alameda Plan Components

- Demonstrate practical knowledge of current tools of technology
- Select technology relevant to task and use it to carry out task

Teachers

- Technology at hand in classroom
- Incorporate easily into lesson plans
- Explore relevance it brings to working with students

District Future

- Daily accustomed use by making computers available in classroom and centers
- Providing new technology of research and reporting

Community

- Make available during extended hours.

Implementation Issues (11 months to implement)

- Formalizing project goals
- Determine best technology teachers
- Renovating facilities
- Waiting for more powerful computers with more attractive power/price ratio
- Back ordering
- Installation problems
- Network creation

Equipment

- Determine # of computers
- Formula suggested (# students/5 + # of teachers = total # of computers)
- Determine specifications for computer
- Determine configuration
- Provide for maintenance
- Order computer hardware
- Design/schedule wiring
- Determine security needs
- Install computer

Northshore School District Plan

Components

- Curriculum

  Integrate into curriculum as instructional/communication tool. Recognize long term nature of endeavor. Technology implementation cycle (aligned in some manner with current curriculum review and adoption process)

Support Systems

- Appropriate support system to maximize use of technology
- Focus implementation of plan

- CRTs at buddy level
- security/insurance
- take home policy
- Design/renovate to accept networking/telecommunications
  Power supplies/ space, security (Northshore, 1990).

Elements for Success of Plan

- Include entire community in process
- Complete clear, concise philosophy statement, well-planned and funded staff in service
- Integrate technology into curriculum
- Develop curriculum based policies for hardware/software
- Adequately fund technical and maintenance support; ensure administrative support
- Establish policies that allow for plan modification, secure, adequate and stable funding for plan implementation (Northshore, 1990).

Pilot project

- Networking complete
- Permanent labs at Elementary to review and evaluate software
- Permanent labs at Middle School for multi departmental use

Implementation

- Select one school to receive suggested baseline of hardware.
- Select one curriculum to proceed with comprehensive review
- Select one buddy to pilot production technology

Part 2: IMPLEMENTATION

Implementation consists of the process of putting into practice an idea, program, or set of activities new to the people attempting or expected to change.

(Fullan, 1982)

Technology has lived up to its promises. It can do all the things it has promised, and it can do them very well. The problem is that technologies have out-paced our ability to use them, especially in education (Becker, 1987). However, judging from their incomplete diffusion through the schools and, despite their potential benefits, it is apparent that agreement on the best uses of technology has not been reached.

IMPLEMENTATION STRATEGY

The National Governors Association (1987) reported that there were two general strategies used by the states.

- One approach used is **to spread technology thinly**. For example, providing an allocation formula of 50 computers per student, or one computer for every elementary school, or setting up one computer lab in each school. Under this approach, wealthier districts continue to have more resources for use for hardware.
- The **pragmatic approach** focuses resources on a few areas, i.e. training teachers, distributing hardware, supporting administrative uses of technology, evaluating software, and distance learning or a portion of the student population, for example, using technology to further basic skills achievement in low achieving students or providing courses to the under-served through distance education.
- A third approach is the **build the infrastructure** approach to create an infrastructure of information highways to speed and sustain innovation and diffusion of information, and equalize access to information resources.

- The **Natural Experiment approach** focuses on broad diffusion, and decentralized acquisitions to create and exploratory atmosphere.

Others have noted that flexibility is needed to change plans as technology changes. Emphasizing a single use could stifle much needed innovation. Initiating and experimenting with the varied capabilities of technologies are key to power (Power on!, 1988).

Implementation Barriers. A significant barrier to the implementation of technology is institutional in nature. That barrier is the **absence of systematic models** for school systems to follow in determining their educational needs, in evaluating the effectiveness of the technologies in meeting those needs, in incorporating the technologies into the curriculum, and in training teachers to use the technologies effectively.

Also absent are **incentives** for individual teachers to assume the additional burden of incorporating technology into the curriculum (Marshall et al., 1989).

There is also the apparent need for quick fixes. School administrators, faced with a barrage of advertising promising improved skills acquisition and higher test scores, lean towards this kind of software (Budin, 1991).

Becker (1987) added from his second National Survey of Instructional Uses of School Computers that "In terms of statistical patterns, computers so far had limited impact due to the **limited amount of computer equipment** in the schools, the relatively **brief experience provided** to individual students, and the genuinely **unsystematic use of software** at the lower grades.

SUCCESSFUL IMPLEMENTATION

Successful Implementation is related to:

- Orientation/awareness, especially of administration,
- Attitudes of teachers/administrators toward computer innovation is the key to varying rates adoption and diffusion (Washington, 1990).
- Importance of research, especially that which is conducted in other school districts and focuses on potential uses of technology. One of the ways that future science will progress is by a combination of precise observations of actual systems followed by computer modeling of those systems.
- Communication is important, especially that which is conducted between administrators and is involved in planning existence of product evaluation. It helps to predict proper effectiveness, improvements for teachers, administration, students -- especially teachers. Adoption requires more understanding of user perception.
- Allow sufficient time for consensus. Support for project decisions appears to be an important aspect of the planning process.
- Strong support from principals and site coordinators is essential (Herman et al., 1992).
- Site coordinators are vital to implementation success.
- Teachers, site coordinators, and project directors must be willing to invest time in becoming increasingly sophisticated technology users (Herman et al., 1992).

Pre-Requisites for Success. The pre-requisite is a pre-existing core of enthusiastic computer expert teachers and a dynamic supportive administration that together provide the leadership necessary to design and implement a computer-based program (Woodrow, 1989). In addition, it is thought that the technology implementation process is assisted when administrators use technology to some degree.

The National School Boards Association's Institute for the Transfer of Technology to Education (ITTE) in 1985, specified ten requirements for successful implementation of technology in the classroom.

- A top down commitment to bring technology into the classroom,
- A tangible financial commitment to provide a technological program in the annual capital and operating budget-building decision-making process by the school board,
- The establishment of a training program for teachers and administrators, with appropriate financial incentives included,
- The development of a knowledgeable computer technology teacher or facilitator within a school prior to the allocation of computers to that school,
- The establishment and operation of an adequate computer maintenance and repair capability,
- The appointment of an administrator by the superintendent to lead the district-wide technology instructional initiative who is truly expert in computer technology.
- The district must participate in state, regional and national networks and coalitions to press for the development of high quality software,
- The district must devise a comprehensive strategy on technology in the instructional program, with sound articulation between and among all grade levels and active participation by teachers and administrators,
- There must be bottom-to-top sensitivity to the twin issues of equity and access in the technology instructional program, and
- A pervasive evaluation component, working at all levels, must be established on a district wide and individual school basis. Thomas A. Shannon, "Requirements for Successful Implementation of Technology into the Classroom. NSBA Board News-Oct 14m ,1985.

PART 3: EVALUATION

Evaluation cannot prove anything: it can only support or not support conclusions and decisions made by human beings. It is essential to remember that evaluations do not make decisions, but people do.

(House, 1980)

Evaluation has taken on greater importance as the concept of performance technology has been further developed. Performance technology means technology that works. It is based on assumptions that training does not solve all performance in organizations (Ely, 1991).

ROLE OF EVALUATION

The role of evaluation of technology is nothing less than to provide practitioners with the information they require to maximize their expertise and creativity in the design, production, use, and improvement of technology. A secondary use of evaluation information is to provide the designers and users of technology with timely, accurate information which will contribute to decisions about the improvement, continuance, and/or expansion of their programs (Anderson & Ball, 1978 cited in Cooley & Bickel, 1986).

An important point to remember is that evaluation almost always occurs within a political context, and because the findings of evaluation must often compete with other sources of influence to affect decision-making (Cooley & Bickel, 1986).

STATE EVALUATION ROLE

The current state role in evaluation, research and development is limited, yet:

- State research projects are important because they can focus on question in implementing technology in schools and investigate technology users to serve deferred needs. States can work with vendors in pilot projects and award grants for innovative projects.
- 16 states fund a technology project with research and/or evaluation component (DE, IN, KY, MD, MN, NH, NJ, NY, TX, UT, VA, WV, FL).
- CA has created 5 model sites to study long-term effects of using technology in educational instruction. The fund is a percentage of total state funding for technology.

EVALUATION STRATEGIES

Decision-makers and evaluators can opt for 1) a strategy of rigorous experimental approaches using familiar indicators such as test scores to determine optional technologies, or, 2) learning by doing where hardware and software are installed and experience dictates the direction of change and improvement.

Problems with Technology Evaluation

Experimental Designs. What could be simpler than trying to compare instructional treatments using the types of experimental research designs derived from the "harder" sciences of physics, chemistry, and biology? However, the preponderance of evidence is that these methodologies have produced few results of statistical, much less education, significance (see Pisapia & Perlman, 1993).

Assessment of the worth of project objectives. More often than not, these projects are initiated on the basis of political, bureaucratic, or competitive agendas. There is ample evidence that the planned and actual uses of instruction innovations vary considerably (Cooley & Lohnes, 1976 cited in Cooley & Bickel, 1986) and designers and evaluators are advised to make few assumptions about program implementation without careful assessment.

Type of Evaluation Needed. There is general consensus that, "We don't need another simple control-group comparison of "learning gains." The types of evaluation systems that are needed measure complex, higher order skills rather than recall of facts. Or, research which answers such questions as, what works best? How? With what? In which way? (Clark & Sugrue, 1988).

The effective integration of learning technologies into the everyday life of a classroom and school will require an atmosphere of openness to trial, error, and correction. At a minimum, the evaluation design should include a comprehensive needs assessment and contextual analysis, and the impact of the installation.

The evaluation results must provide recommendations for activities implementors should emphasize or avoid to have utility for decision-makers. For example, how can school division adoptions emulate those with consistently significant effects on students and schools; how can the human element be eliminated?; how can the teacher replaced?; how is technology best used as a servant to the teacher, and the technology is used to provide more one on one?; how is technology to become the drive shaft rather than the hood ornament? or, how is technology an end instead of a means?

Moreover, the results should have been replicated beyond the initial vision before decision-makers recommend or consider the application for adoption.

LEVELS OF EVALUATION

There are several types of evaluation schemes that can provide the types of information needed by decision-makers such as protocol analysis, aggregate analysis, individual project effects, formative evaluation, net benefit analysis, and cost-effectiveness assessments. They are described briefly below.

Protocol Analysis. Protocol analysis assumes that no compelling model is likely to be developed without observing students and teachers. Therefore, any evaluation design using protocol analysis should include spending a lot of time with teachers and students. Protocol analysis seeks to improve systems by trial and error. A version of a system is generated and tested, modification of the system occurs on the basis of the test results, and then the system is tested again. The current literature called this type of evaluation Bench marking. It has gained popularity as a part of Total Quality Management programs.

Protocol analysis is gaining currency as a way to improve systems. It addresses the growing concern that the uses of technology systems are not grounded in a substantiated model of learning. Protocol analysis, both quantitative and qualitative, should precede model building. The models generated should then be validated by the teachers and students who use the system.

Most people jump into implementations rather than doing notable groundwork in data gathering and analysis and in model building. Users of protocol analysis have sought improvement by trial and error. They generate a version of the system, test it, and modify the system on the basis of test results and test it again.

Aggregate analysis. Aggregate analysis uses multiple case studies, whereas protocol analysis studies an existing system and makes comparisons against your own system.

When multiple case studies provide good information about the context and process of implementation, aggregate analysis can help clarify essential conditions for success. Such findings can have strong implications for the design and use of technology and sound policy.

Donald Ely (1990) has noted that the number of educational technology case studies is growing and provides general guidance for users. They were evenly split between computer use in teaching and learning and use of telecommunications.

Individual project effects. The effects of individual projects should be part of the planning and resource acquisition process. Teachers are asked to specify projects, objective methods of assessing effectiveness, implement their assessment plans and report their findings. This type of evaluation is intended to assess the instructional effectiveness and efficiency of technology being used within the immediate contexts of its implementation.

Assessment of a project 's immediate effectiveness is most often considered to be a matter of subjecting users to pre-tests and post-tests of the knowledge, skills, and attitudes engendered in the program's goals and objectives. However, though such tests may have value as diagnostic and motivational instruments, they are often inadequate indicators of the instructional effectiveness of the uses of technology.

Formative evaluation. Formative evaluation involves collecting the opinions, suggestions, and criticisms of project participants for purposes of revising and improving aspects of the interactive video. Formative evaluation is the essence of good instructional design, and it should be carried out with respect to all aspects of the project, i.e., the processes as well as the products.

Net benefit analysis. The results of a net benefit analysis is extremely important to decision-makers. If the primary user (in most cases the teacher) does not see or receive some benefit attributed to the use of technology, the implementation will be hindered.

Shannon and Weaver (1949) assert that a basic tenet of information theory is that information derived because it reduces uncertainty about something of interest to the users. Therefore, if the teacher has a) no uncertainty regarding the performance of their students or b) if the reports don't alleviate that uncertainty, the system will have little value to them (cited in Pisapia & Perlman, 1993).

Secondly, there must be transaction benefits. Transaction processing benefits accrue when there is a time reduction to accurately process each transaction, and eliminate the need to reprocess at some future point in the system (Keyes, 1989).

The combined benefits of transaction processing and information derived must exceed their production cost for the system to be seen as successful to the primary user.

The Net benefit can be expressed as the total benefit (TB) - cost of operation (CO). (CO = time, money, intellectual effort and TB = information value + transaction processing value)

Therefore, the total benefit to the primary user can be increased by a) reducing input replication, and b) focusing on system enhancements which reduce the time and effort required to perform some of the classroom management functions. These steps can cause a positive net benefit even if the value of the information from system remains constant.

COST-EFFECTIVENESS ANALYSIS

Two key questions often faced by school boards are: How much do new instructional technologies cost? And, are they worth the money? Inevitably, the cost question compels a series of even more difficult questions: Will the new learning tools be more effective than books? Could reductions in class size bring about similar achievement gains at lower cost? What type of computer-assisted instructional tool is most appropriate to a given school system's needs?

That costs as well as educational results should be taken into account in making choices seems obvious. After all, measurement of cost benefits is a routine business function. However, differences exist between business and education. Most school districts do not have the resources to devote to the collection of complete cost data, or to control measurement of educational effect (Power on!, 1988). Secondly, business decisions can be assessed on profit - a quantifible indicator of performance. However, the definition and measurement of educational effects is extremely complex. Schools have multiple goals that cannot conveniently be lumped into a single quantifible indicator necessitating a cautious approach to cost estimation of educational technology.

Risks of Using Cost-Effectiveness Analyses. Several risks are inherent in using cost-effective analysis. For example, progress towards new purposes may be delayed, comparing costs of traditional and technology based programs is futile because goals of program differ substantially, and, it's inherent bias toward short-term results. Finally, one glaring deficiency of cost-effectiveness analysis is that the conventional approach does not account explicitly for **multiple objectives**. For example, if computer-assisted instruction produces gains in one area, other areas of learning might suffer simply because the amount of time in the instructional day is limited. Time spent on the computer mastering certain mathematics skills could mean less time for other subjects.

A Decision Not to Use Cost-Effectiveness Analyses. Cost-benefit analysis, while passionately discussed and conscientiously researched during the planning process, is not included in the Texas Long-Range Plan. After explaining methods of cost

-effectiveness analysis and reviewing experimental studies, the Texas Plan discusses the factors that need to be considered in conducting such studies as well as in using them as bases for decision-making. These factors are:

1. The utility of current outcome measures, given the changes in the process and purposes that computers are likely to cause in education.
2. The difficulty of isolating the effects of computers on education.
3. The complexity of analyzing effectiveness when multiple outcomes occur.
4. The political decisions that enter when weighing the relative importance of various outcomes ("cost utility").
5. The fact that increases in computer power and decreases in computer cost precede the publication of research results on cost-effectiveness.
6. The question for whether computers are an add-on or a replacement.
7. The problem of software production and distribution.

An additional reason that a review of the research and a position on the cost-effectiveness (considered interchangeably here with cost-benefit) of technology are not included in their plan is that, although publications on the topic are plentiful, many either focus on the importance of conducting an analysis or provide guidelines for doing so rather than actually applying data.

The most extensive and cogent issues analysis was prepared by David Stern and Guy Cox for the Office of Technology Assessment. Pogrow, Linn, and the Texas Education Agency notwithstanding, Stern and Cox (1988) argue for the utility of cost-effectiveness studies of computers on the grounds that "the exciting future potential of computer-based programs in education does not diminish our concern for careful use of resources to achieve current purposes.

State Efforts. Cost-effectiveness is, in part, a function of the level of utilization of a given computer-based instructional system. Government can encourage use of C-E decision tool by:

- preparing guidelines for data collections,
- setting standards for measurement of cost, effects,
- providing access to computer programs for cost-effectiveness analysis,
- helping divisions conduct studies (IMPAC, 1985).

REFERENCE LIST

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Abramson, G. W. (1990, October). Using a computer tool to build a life skill. The Computing Teacher, 8-11.

Agency for Instructional Technology. (1987). A survey of the use of technology with students at risk of school failure. Bloomington, IN: Agency for Instructional Technology, Canadian Education Association, National School Boards Association, Institute for the Transfer of Technology to Education.

Aiello, N. C., & Wolfle, L. M. (1990, April). A meta-analysis of individualized instruction in science. Paper presented at the annual meeting of the American Educational Research Association, Boston, MA. (ERIC Document Reproduction Service No. ED 190 404)

Alamedia Unified School District. (1992). From Visions to Reality. Alemedia, CA: Alemedia Board of Education.

Alberta Department of Education. A strategic plan for microcomputers in schools. Edmonton. (ERIC Document Reproduction Service No. ED 291 353)

Alifrangis, C. M. (1989). A critical analysis of the components of an integrated learning system and a measure of the system's effect on mathematics and reading achievement of fourth through sixth grade students. Doctoral dissertation, George Mason University.

Al-Juhani, S. O. (1991). The "effectiveness" of computer-assisted instruction in teaching English as a foreign language in Saudi "secondary" "schools" (Saudi Arabia). Dissertation Abstracts International, 52(07), 2383. (University Microfilms No. ADG92-01049)

Ambrose, D. W. (1991, December). The effects of hypermedia on learning: A literature review. Educational Technology, 51-55.

Ameen, D. A. (1990, September). Evaluating alternative computer acquisition strategies. Journal of Systems Management, 41, 15-20.

American Association of Colleges for Teacher Education (AACTE). (1986). Teacher education in the states: A 50-state survey of legislative and administrative actions. Washington, DC.

Anderson, M. E. (1987). A guide to curriculum planning in computer education. Madison, WI: Wisconsin Department of Public Instruction.

Anderson, R. D. (1990). Policy decisions on improving science education: A cost -effectiveness analysis. Journal of Research in Science Teaching, 27(6), 553-574.

Anzalone, S. (1987). The effect of PLATO instruction on basic skills in Jamaica. McLean, VA: Institute for International Research - Learning Technologies Project.

Anzalone, S. (1988, March). Using instructional hardware for primary education in developing countries: A review of the literature. Cambridge, MA: Harvard University, Institute for International Development. (ERIC Document Reproduction Service No. ED 323 658)

Apple Computer, Inc. (1989). ACOT: Apple classroom of tomorrow. Cupertino, CA: Author.

Arenz, B. W., & Lee, M. J. (1990). Gender differences in the attitude, interest, and participation of secondary students in computer use. Paper presented at the annual meeting of the American Educational Research Association, Boston, MA. (ERIC Document Reproduction Service No. ED 237 389)

Arizona Department of Education. (1990). TIEDS: Technology integrated educational delivery system. Phoenix, AZ: Author.

Arkansas Department of Education. (1990, February). Arkansas microcomputer survey and IMPAC program update. AR: Little Rock.

Armstrong, A-M. (1989). The development of self-regulation skills through the modeling and structuring of computer programming. Educational Technology Research & Development, 37(2), 69-76.

Arunyakanon, P. (1991). The effects of hand-held electronic learning aids and cognitive style on mathematics achievement of primary "school" students in Belize. Dissertation Abstracts International, 52(05), 1717. (University Microfilms No. AD691-29181)

Austin, G. R. (1988). Computer-assisted instruction, Calvert County, Maryland public schools 1983-1987. Baltimore, MD: University of Maryland Baltimore County Center for Educational Research and Development.

Austin, G. R., & Howie, T. (1990). Instructional leadership, computer-aided instruction and sustained effects. Baltimore, MD: University of Maryland Baltimore County.

Azarmsa, R. (1987, December). Teleconferencing: An instructional tool. Educational Technology, 28-32.

Baer, V. E. (1988). Computers as composition tools: A case study. Journal of Computer Based Instruction, 15(4), 144-148.

Bagley, C., & Hunter, B. (1992, July). Restructuring, constructivism, and technology: Forging a new relationship. Educational Technology, 22-27.

Bahr, C. M., & Rieth, H. J. (1989). The effects of instructional computer games and drill and practice software on learning disabled students' mathematics achievement. Computers in the Schools, 6(3/4), 87-101.

Bailey, J. S. (1991, Fall). Marketing behavior analysis requires different talk. Journal of Applied Behavior Analysis, 24(3), 445-448.

Bailey, P. (1990). Mercer County Schools Macintosh Writing Centers. Evaluation plan developed by Mercer County Schools, Princeton, WV.

Baker, E., & Herman, J. (1989). The ACOT report card: Effects of complex performance and attitude. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Barba, R. H. (1990, May). Examining computer configurations: Mini-labs. The Computing Teacher, 8-10.

Barlow, S. L. (1990). Interactive videodisc-TIPDART provides alternatives for youth. Instruction Delivery Systems, 4(1), 15-17.

Barron, A., & Baumbach, D. (1990, June). A CD-ROM tutorial: Training for a new technology. Educational Technology, 20-23.

Barron, D., & Bergen, T. J., Jr. (1992, March). Information power: The restructured school library for the nineties. Phi Delta Kappan, 73(7), 521-525.

Beach, R. (1990, June). The effects of using a computer authoring system on the quality of literature assignments (Project No. 90-5). Research Bulletin #3: Technology As An Instructional Tool: What We Are Learning. St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Beach, R. (1989). Devising guided literature activities. [Hypercard program developed for the MinneMac Apple Project]. Minneapolis: University of Minnesota.

Bear, G. G. (1990). Knowledge of computer ethics: Its relationship to computer attitude and sociomoral reasoning. Journal of Educational Computing Research, 6(1), 77-87.

Becker, A. D. (1987, October). Instructional television and the talking head. Educational Technology, 35-40.

Becker, H. J. (1986). Our national report card: Preliminary results from the new Johns Hopkins survey. Classroom Computer Learning, 30-33.

Becker, H. J. (1987). What we know about computer use and its effectiveness in schools: Existing knowledge and new research directions. Cupertino, CA: Apple Computer, Inc.

Becker, H. J. (1988). The impact of computer use on children's learning: What research has shown and what it has not. Baltimore: Johns Hopkins University, Center for Research on Elementary and Middle Schools.

Becker, H. J. (1990, October). Computer-based integrated learning systems in the elementary and middle grades: A critical review and synthesis of evaluation reports. Baltimore, MD: Johns Hopkins University, Center for Social Organization of Schools.

Becker, H. J. (1990a). Computer use in United States schools, 1989: An initial report of U.S. participation in the I.E.A. computers in education survey. Paper presented at the annual meeting of the American Educational Research Association, Boston.

Becker, H. J. (1990b). Effects of computer use on mathematics achievement: Findings from a nationwide field experiment in grades five to eight classes. Paper presented at the annual meeting of the American Educational Research Association, Boston.

Becker, H. J. (1991a). How computers are used in United States schools: Basic data from the 1989 I.E.A. computers in education survey. Journal of Educational Computing Research, 7(4), 385-406.

Becker, H. J. (1991b). Mathematics and science uses of computers in American schools, 1989. Journal of Computers in Mathematics and Science Teaching, 10(4).

Becker, H. J. (1991, May). When powerful tools meet conventional beliefs and institutional constraints. In L. Polin (Ed.), Research windows. The Computing Teacher, 6-9.

Becker, H. J. (1992, August). How our best computer-using teachers differ from other teachers: Implications for realizing the potential of computers in schools. University of California Department of Education, Irvine.

Becker, H. J., & Sterling, C. W. (1987). Equity in school computer use: National data and neglected considerations. Journal of Educational Computing Research, 3(3), 289-311.

Becnel, S. (1991, September). Evaluation in the classroom. Paper presented at the annual meeting of the Association of Louisiana Evaluators, New Orleans. (ERIC Document Reproduction Service No. ED 347 204)

Beede, N. L. (1991). A comparative case study of students' cognitive strategies when using a computerized database for social studies and science (CAI). Dissertation Abstracts International, 52(06), 2115. (University Microfilms No. ADG91-32946)

Benjamin, S., Bryant, S., & Mack, R. (1990, September). A research-based approach to elementary computer instruction. Educational Technology, 49-53.

Bennett, J. P. (1991, August). Effectiveness of the computer in the teaching of secondary school mathematics: Fifteen years of reviews of research. Educational Technology, 44-48.

Berenson, S. B., & Stiff, L. V. (1990/1991, Winter). Uses of instructional technologies: First year report on change at a university. Journal of Computers in Math and Science Teaching, 10(2), 11-19.

Bialo, E., & Sivin, J. (1990a). Report on the effectiveness of microcomputers in schools. Washington, DC: Software Publishers Association. (ERIC Document Reproduction Service No. 327 177)

Bialo, E., & Sivin, J. (1990b). Computers and at-risk youth: A partial solution to a complex problem. Classroom Computer Learning, 10(4), 34-39.

Biraimah, K. (1989, February). Inequalities in Classroom Computer Software. Savannah, GA: Eastern Educational Research Association. (ERIC Document Reproduction Service No. ED 306 951)

Bitter, G. G. (1988). Trends in hardware/software CD-ROM technology and the classroom of the future. Computers in the Schools, 5(1/2), 23-34.

Black, B. R. (1991, May). Instructional microcomputer report. Polk County Public Schools, Bartow, FL. (ERIC Document Reproduction Service No. ED 336 089)

Blanchard, J. (1989). Hypermedia: Hypertext - implications for reading education. Computers in the Schools, 6(3/4), 23-30.

Blinn, C. R., Flack, J. A., & Bates, P. C. (1989, January). Developing telecommunication linkages for microcomputer-aided instruction (TDC Research Report No. 1). (ERIC Document Reproduction Service No. ED 314 028)

Bliss, S., Gorence, M. J., & Haight, D. (1989/1990). CD-ROM applications in education. Journal of Educational Technology Systems, 18(1), 37-41.

Bluhm, H. P., Drew, C., & Blankenship, C. (1992, September). Educational partnerships: The Utah education technology initiative. T.H.E. Journal, 85-89.

Bork, A. (1990). A historical survey of computer technology in education. Educational Media and Technology Yearbook, 16, 91-105.

Borsook, T., & Higginbotham-Wheat, N. (1991, October). Interactivity: What is it and what can it do for computer-based instruction? Educational Technology, 11-17.

Borton, W. B. (1988). The effects of computer managed mastery learning on mathematics test scores in elementary school. Journal of Computers in Schools, 5(1-2), 99-110.

Boss, M. W., & Taylor, M. C. (1989, October). The relationship between locus of control and academic level and sex of secondary school students. Contemporary Educational Psychology, 14(4), 315-322.

Bosworth, K., Gustafson, D. H., & Hawkins, R. P. (1988). BARN The body awareness resource network. Madison, WI: University of Wisconsin. Final Report of a project for the Center for Health Systems Research and Analysis, funded by a grant from W. K. Kellogg Foundation.

Bosworth, K., Gustafson, D. H., Hawkins, R. P., & Chewning, B. (1992, July). Use and impact of adolescent health education via computer: The BARN system. Madison, WI: University of Wisconsin. Paper prepared for the Center for Health Systems Research and Analysis.

Bosworth, K., & Welsh, T. (1992). Teaching with groups: An interactive multimedia program for teacher education. Technology and Teacher Education Annual, 261-265.

Bosworth, K., & Yoast, R. (1991). Diads: Computer-based system for development of school drug prevention programs. J. Drug Education, 21(3), 231-245.

Botterbusch, H. R. (1991). Tune-in and turn on! Videos in the classroom. Tech Trends, 36(4), 22-24.

Bowers, D., & Tsai, C. (1990, February). Hypercard in educational research: An introduction and case study. Educational Technology, 19-24.

Boyer, A. W. (1990). Improving the expository paragraph writing of learning disabled elementary school students using small group strategies instruction and word processing. Unpublished doctoral dissertation, University of Kentucky, Lexington.

Boylan, R. F. (1989). Belridge School: The future communication program. Association for Communication Administration Bulletin, 25-28.

Bracey, G. (1988, October). Computers and learning: The research jury is still out. Electronic Learning, 8(2), 18.

Bradley, M. J., & Morrison, G. R. (1991). Student-teacher interaction in computer settings: A naturalistic inquiry. Memphis State University. (ERIC Document Reproduction Service No. ED 343 565)

Bradshaw, D. H. (1991, March). Upgrading distance learning in Box Elder School District. Brigham, City, UT: Study on Instructional Effectiveness conducted for Box Elder School District.

Branch, C. E., Ledford, B. R., Robertson, B. T., & Robertson, L. (1987). The validation of interactive videodisc as an alternative to traditional teaching techniques: Auscultation of the heart. Educational Technology, 27, 16-21.

Brandon, P. R. (1988, October). Recent developments in instructional hardware and software. Educational Technology, 7-12.

Branscum, D. (1992, September). Educators need support to make computing meaningful. MAC World. 83-88.

Branson, R. K. (1990, April). Issues in the design of schooling: Changing the paradigm. Educational Technology, 7-10.

Brant, K., Perron, J., Melton, J., Mader, W., Peters, M., Sunne, J., Orava, J., Jbara, J., Dinsmoore, M., & Wattles, J. (1992). Harlan auto engineering and design project. Birmingham, MI: Mini-grant award at Harlan Elementary School.

Branyan-Broadbent, B. (1989). New guidelines for school library media programs. Educational Media and Technology Yearbook, 15, 34-38.

Braun, L. (1990, October). Vision: Test (Technologically enriched schools of tomorrow) Final report - Recommendation for American educational decision makers. Eugene, OR: International Society for Technology in Education.

Brenden, C. R. (1990, July). Leadership for the 90s Final report of the state superintendent's task force on school library media issues. River Falls, WI: Wisconsin Department of Public Instruction.

Brennan, M. A. (1992, March). Trends in educational technology 1991. ERIC digest. Washington, DC: Office of Educational Research and Improvement. (ERIC Document Reproduction Service No. ED 343 617)

Brooks, L. (1990, January). Using technology to reform education. Government Technology, 3(1), 33-35.

Brown, A, & Camplone, J. (in press). Fostering a community of learners. Human Development.

Brownell, G., & Brownell, N. (1991). Designing tomorrow: Preparing teachers as change agents for the classroom of the future. Computers in the Schools, 8(1/2/3), 147-149.

Brubaker, C. W. (1989, November/December). The impact of technology on educational facilities. CEFPI's Educational Facility Planner, 27(6), 4-6.

Bruder, I. (1988, October). Eighth annual survey of the states. Electronic Learning, 8(2), 38-45.

Bruder, I. (1989, October). Ninth annual survey of the states. Electronic Learning, 9(2), 22-28.

Bruder, I. (1991, March). Schools of education: Four exemplary programs. Electronic Learning, 21-45.

Bruder, I. (1991, November/December). Distance learning: Bridging education gaps with technology. Electronic Learning, 22-27.

Bruder, I. (1992, February). Underwriting Change. Electronic Learning, 26-27.

Bruder, I. (1992, March). Restructuring: The best of both worlds. Electronic Learning, 11(6), 30-31.

Bruder, I. (1992, October). All things being equal: The Indiana Buddy Project has a grand vision--computers in all students' homes. Electronic Learning, 16-18.

Bruder, I. (1993, January). Alternative assessment: Putting technology to the test. Electronic Learning, 12(4), 22-28.

Brunner, C. (1990, November/December). What it really means to "integrate" technology. Technology & Learning, 12-14.

Brunner, C., & Henriquez, A. (1991). Evaluation of Stevens Institute of Technology's "Integration of computers into mathematics education" project." New York, NY: Bank Street College of Education, Center for Children and Technology.

Brunner, R. B. (1988, October). Legal, societal, and ethical issues concerning intellectual rights in computer education. Paper presented at the annual meeting of the Society of Scholars and Educators. (ERIC Document Reproduction Service No. ED 299 678)

Budin, H. R. (1991). Technology and the teacher's role. Computers in the Schools, 8(1/2/3), 15-26.

Bullock, L. (1988, September). Professional development for teachers. Teaching and Learning, 29-34.

Bunderson, C. V. & others. (1990, December). Computers in educational assessment: An opportunity to restructure educational practice. Pennington, NJ: Institute for Computer Uses in Education. (ERIC Document Reproduction Service No. ED 340 771)

Bunderson, C. V., Inouye, D. K., & Olsen, J. B. (1989). The four generations of computerized educational measurement. In R. L. Linn (Ed.), Educational measurement. New York: Macmillan.

Bunescu, M. (1990, October). Adaptive technology Hardware and software that allow physically disabled students to use computers. Electronic Learning, 10(2), 20-21.

Burwell, L. B. (1991, March). The interaction of learning styles with learner control treatments in an interactive videodisc lesson. Educational Technology, 37-43.

Butzin, S. M. (December 1992). Integrating technology into the classroom: Lessons from The Project CHILD experience. Phi Delta Kappan, 330-333.

Butzin, S. M. (1992, September). Project CHILD: A new twist on integrated learning systems. T.H.E. Journal, 90.

Butzin, S. M. (1990, March). Project CHILD: Not boring school, but work that's fun and neat. The Computing Teacher, 20-23.

Butzin, S. M. (1992, September). Project CHILD: A new twist on integrated learning systems. T.H.E. Journal, 90-95.

California Planning Commission for Educational Technology. (1992, April). The California master plan for educational technology submitted to the California Legislature April 22, 1992. (ERIC Document Reproduction Service No. ED 348 953)

California State Postsecondary Education Commission. (1991, April). State policy on technology for distance learning: Recommendations to the legislature and the Governor in response to Senate Bill 1202. Sacramento, CA. (ERIC Document Reproduction Service No. ED 340 358)

Calvert County Public Schools. (1989). Choosing for the future. Maryland: Calvert County.

Campoy, R. (1992, August). The role of technology in the school reform movement. Educational Technology, 17-21.

Cannell, J. J. (1988). How public educators cheat on standardized achievement tests. Friends for Education, 43-49, 107-109.

Carlson, R. D., & Grabowski, B. L. (1992, Winter). The effects of computer self-efficacy on direction-following behavior in Computer Assisted Instruction. Journal of Computer-Based Instruction, 19(1), 6-11.

Carney, C., & Mathis, J. (Eds.). (1990, October). Where in time is Carmen Sandiego? Inspiration: The thought processor Hop to it! The Computing Teacher, 44-52.

Carpenter, B. (1990). MIDI (Musical instrument digital interface) Technology in music education. Computers in the Schools, 7(4), 75-82.

Carpenter, T., Fennema, E., Peterson, P., Chiang, C-P, & Loef, M. (1989, Winter). Using knowledge of children's mathematics thinking in classroom teaching: An experimental study. American Educational Research Journal, 26(4), 499-531.

Carr, C. (1988, August). Hypertext: A new training tool? Educational Technology, 7-11.

Carrier, C. (1988, February). One page summary of American Association of Colleges for Teacher Education (AACTE) survey results. Paper presented at AACTE conference, New Orleans, LA.

Carrier, C. A., & Sales, G. C. (1987). Pair versus individual work on the acquisition of concepts in a computer-based instructional lesson. Journal of Computer-Based Instruction, (1), 11-17.

Carrier, C., Williams, M, Relan, A., & Earle, J. (1988). Pairing and task persistence level in a learner-controlled computer-based concept lesson. St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology, Research Bulletin, 1(1), 4-6.

Center for Children and Technology, & Center for Technology in Education. (1991, October). News from the Center for Children and Technology and the Center for Technology in Education. New York, NY: Bank Street College of Education.

Center for Educational Research and Development. (1989). Computer-assisted instruction Calvert County, Maryland Public Schools 1983-1987. Catonsville, MD: University of Maryland, Baltimore County.

Center for Technology in Education. (1990, September). The classrooms that teachers, students, and technology can create. Technology & Learning, 14-15.

Center for Technology in Education. (1991, March). Design experiments: A new kind of research. Technology & Learning, 28-29.

Center for the Study of Educational Technology. (1989, November). Research Bulletin #2 Evaluating the use of technology in schools: What are we learning. St. Paul: MN: MECC/University of Minnesota.

Center for the Study of Educational Technology. (1990, June). Research Bulletin #2 Technology as an instructional tool: What are we learning. St. Paul, MN: MECC/University of Minnesota.

Chan, C. (1989). Computer use in the elementary classroom-I. An assessment of CAI software. Computers Education, 13,(2), 109-115. Great Britain.

Char, C., Newman, D., & Tally, W. (1987). Interactive videodiscs for children's learning. In R. D. Pea, & K. Sheingold (Eds.), Mirrors of minds: Patterns of experience in educational computing (pp. 223-241). Norwood, NJ: Ablex Publishing Corporation.

Chartier, D., Mullet, E., & Grandjean, J. C. (1991). Effectiveness of a physics computer program on fifteen-year-old "technology" students. Journal of Educational Computing Research, 7(2), 219-232.

Chen, I. M. C. (1991). The comparative effectiveness of satellite and face-to-face delivery for a short-term substance abuse education program. Unpublished doctoral dissertation, University of Missouri-Kansas City, Missouri.

Cheney, C. O. (1990). Computers and students with behavior disorders: A review. Computers in the Schools, 7(3), 47-60.

Childers, R. D. (1990, October). Implementation of the writing to read program in 13 rural elementary schools in Southern West Virginia: A two-year evaluation. Final report. Charleston, WV: Appalachia Educational Lab. (ERIC Document Reproduction Service No 334 032)

Chirwa, A. S. (1991/1992). Computer based mathematics instruction at Danville high school. Journal of Educational Technology Systems, 20(2), 107-113.

Chissus, D. R., Hill, L. G., & Vivio, F. M. (1990, July). Government-sponsored programs to increase the effectiveness of science and mathematics teachers (with an example). Educational Technology, 54-56.

Christensen, P., Doll, C., & Tedrow, L. (1990). 1990 survey of Washington school libraries. Information Power for Washington State, 53-63.

Christner, C. A. (1987). Schoolwide projects: The almost revolution (?) six years later (Publication Number 86.38). Austin, TX: Austin Independent School District Office of Research and Evaluation.

Christner, C. A., Rodgers, N. D., Fairchild, M. E., & Gutierrez, L. (1987). ECIA Chapter 1/Chapter 1 Migrant: 1986-87 final technical report (Publication Number 86.03). Austin, TX: Austin Independent School District Office of Research and Evaluation.

Christoper, M. W. (1991). The writing approach to literacy: A comparison of writing influences on reading in six "elementary" "schools" (writing to read). Dissertation Abstracts International, 52(08), 2871. (University Microfilms No. ADG92-01043)

Chung, J. (1991, January). Televised teaching effectiveness: Two case studies. Educational Technology, 41-47.

Chute, A. G., & Balthazar, L. B. (1988, September). An overview of research and development projects at the AT&T national teletraining center. Cincinnati, OH: AT&T National Teletraining Center. (ERIC Document Reproduction Service No. ED 313 018)

Clark, R. E. (Ed.). (1990). Instructional media and technology research. International Journal Educational Research, 14, 485-579. Great Britain: Pergamon Press.

Clark, R. E., & Sugrue, B. M. (1988). Research on instructional media 1978-88. In D. Ely (Ed.), Educational Media and Technology Yearbook. Englewood, CO: Libraries Unlimited, Inc.

Clark, R. E., & Sugrue, B. M. (1990). North American disputes about research on learning from media. In R. E. Clark (Ed.), International Journal Educational Research, 14, 507-520. Great Britain: Pergamon Press.

Claus, R. N., McComb, G., & Quimper, B. E. (1990, December). Laser learning project (LLP), 1989-90. Saginaw, MI: An approved report of the Division of Administration and Personnel, Department of Evaluation, Testing, and Research.

Clouse, R. W. (1991/1992). Teaching and learning with computers: A classroom analysis. Journal of Educational Technology Systems, 20(4), 281-302.

Clovis Unified School District. (1992, February). Wicat Evaluation I for the 1990-91 School Year 1991-1992 Management Plan, Objective I.A.2. Clovis, CA.

Cocker, J. E. (Ed.). (1992, February). K-12 marketing news, 1(1). Norfolk, VA: The Center for SmartSchool Development.

Cohen, D. K. (1988). Educational technology and school organization. In R. S. Nickerson and P. Zodhiates, (Eds.). Technology and Education: Looking Toward 2020. Hillsdale, NJ: Erlbaum.

Colbourn, C. J., & Light, P. H. (1987). Social interaction and learning using micro -PROLOG. Journal of Computer-Assisted Learning, 3, 130-140.

Collins, A. (1991, September). The role of computer technology in restructuring schools. Phi Delta Kappan, 28-36.

Collins, A., Hawkins, J., & Frederiksen, J. R. (1991, April). Three different views of students: The role of technology in assessing student performance. Center for Technology in Education (Technical Report No. 12).

Collis, B. A. (1989, March). Problems and perspectives on the evaluation of regional and national computer-related educational activity. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Collis, B., & Martinez, M. E. (1989, October). Computers in U.S. and Canadian schools: Have we made progress? NASSP Bulletin, 73(519), 5-9.

Collis, B., Oberg, A., & Shera, W. (1988/1989). An evaluation of computer-based instruction in statistical techniques for education and social work students. Journal of Educational Technology Systems, 17(1), 59-71.

Collis, B. A., Ollila, L. O., & Ollila, K. (1990). Writing to read: An evaluation of a Canadian installation of a computer-supported initial language environment. Journal of Educational Computing Research, 6(4), 411-427.

Collis, B. A., & Ollila, L. O. (in press). The effect of computer use on grade 1 children's gender-stereotypes about reading, writing, and computer use. Journal of Research and Development in Education.

Copeland, P. (1988, June). Interactive video: What the research says. Media in Education and Development, 60-63.

Copeland, P. (1991, May). The multimedia mix. Education and Training Technology, 28(2), 154-163.

Cortines, R. C. (1991, November/December). Superintendents: Don't dread technology. Electronic Learning, 6-7.

Cory, S. (1992, Spring). Update on the instructional technology program Chapel Hill Carrboro City Schools. Chapel Hill, NC: Report prepared for Chapel Hill-Carrboro City Schools.

Council of Chief State School Officers. (1991, November). Improving student performance through learning technologies. Washington, DC: Policy Statement of CCSSO.

Daley, A. (1991). Bringing the information age into schools: Broadband networks. Tech Trends, 36(2), 13-17.

Dalton, D. W. (1990, Winter). The effects of cooperative learning strategies on achievement and attitudes during interactive video. Journal of Computer-Based Instruction, 17(1), 8-16.

Dalton, D. W., Hannafin, M. J., & Hooper, S. (1987). Effects of individual and cooperative computer-assisted instruction on student performance and attitudes. ETR&D, 37(2), 15-24.

Damarin, S. K. (1988, Fall). Recontextualizing computers in education: A response to Streibel. Educational Communication and Technology Journal, 36(3), 147-152.

Damarin, S. K. (1989, April). Rethinking equity: An imperative for educational computing. The Computing Teacher, 16(7), 16-18, 55.

Damyanovich, M. (1989, August). Computer and technology investigations in local school districts. Maple Grove, MN: Report prepared for Osseo Area Schools,

Danely, W., & Baker, C. (1988). Comparing a pre-service mainstreaming class taught by traditional methods with a similar class taught by computer-assisted instruction. Computers in the Schools, 5(1/2), 251-255.

Davidson, N., & Kroll, D. L. (1991, November). An overview of research on cooperative learning related to mathematics. Journal for Research in Mathematics Education, 22(5).

David, G. A. (1989). Testing for creative potential. Contemporary Educational Psychology, 14, 257-174.

Davis, S. (1990, June). The Iowa educational telecommunications network. Educational Technology, 48.

DeBloois, M. C. (1988). Use and effectiveness of videodisc training: A status report. Falls Church, VA: Future Systems.

Dede, C. J. (1990, July). Imaging technology's role in restructuring for learning. Houston, TX: University of Houston, Advanced Knowledge Transfer Project. Co-sponsored by the National Center on Education and the Economy and the Center for Technology in Education, Bank Street College of Education.

Dede, C. J. (1991, March). Emerging technologies: Impacts on distance learning. ANNALS, AAPSS, 514, 146-158.

Dede, C. J. (1992a, January). The future of multimedia: Bridging to virtual worlds. Manuscript submitted for publication.

Dede, C. J. (1992b, January). Potential uses of telecommunications to empower implementation of the NCTM mathematics standards. Paper prepared for the Conference, "Telecommunications as a Tool for Educational Reform," conducted by the Aspen Institute's Program on Communications and Society and funded by the National Science Foundation.

Dede, C. J., & Palumbo, D. B. (1991). Implications of hypermedia for cognition and communication. Impact Assessment Bulletin, 9(1-2), 15-27.

DeRemer, M. (1989). The computer gender gap in elementary school. Computers in the Schools, 6(3/4), 39-49.

Dickey, E., & Kherlopian, R. (1987, June). A survey of teachers of mathematics, science, and computers on the uses of computers in grades 5-9 classrooms. Educational Technology, 10-14.

Discis books. (1990). Tech Trends, 35(5), 35-38.

Doughty, P., LeBlanc, G., Spuches, C., & Yonai, B. (1992). ISD goes to school: Lessons in applying an ID approach in public school or ISD goes to school: Lessons in university-based ID consultanting. Paper accepted for presentation at the 1992 AECT Conference and submitted for publication.

Driskill, A. (1992, November). Evaluating an ILS: One schools' approach. School Executive, 4-5.

Duby, A. (1988, April). Teletext: A distance education medium. Educational Technology, 54-57.

Dudley-Marling, C., & Owston, R. (1987, March). The state of educational software: A criterion-based evaluation. Educational Technology, 25-29.

Dudley-Marling, C., Owston, R., & Searle, D. (1988). A field-testing approach to software evaluation. Computers in the Schools, 5(1/2), 241-249.

Duffy, T. M., & Jonassen, D. H. (Eds.). (1991, September). Continuing the dialogue on the implications of constructivism for educational technology. Educational Technology, 31(9). Theme Issue.

Duren, P. (1990/1991, December/January). Enhancing inquiry skills using graphics software. In J. Johnson & K. Heid (Eds.), Mathematics Computers in the Classroom. The Computing Teacher, 23-25.

Earle, J., & Sales, G. (1989). A case study of a school district's investigation of computer-managed instruction (Project No. 89-2). St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Education Turnkey Systems, Inc. (1988). Federal R & D support for educational technology: A report to the Office of Technology Assessment Power on Study Group. Fall Church, VA: Author.

Educational Technology Center. (1988, January). Making sense of the future: A position paper on the role of technology in Science, Mathematics and Computing Education. Cambridge, MA: Educational Technology Center, Harvard Graduate School of Education.

Educational Technology Center. (1988, January). Making sure of the future. Cambridge, MA: Educational Technology Center, Harvard Graduate School of Education, 15-16.

Educational Technology Consortium Newsletter. (1991, January).

Edwards, L. R. (1992, June). An annotated bibliography on microcomputers in secondary business education: The school-business partnership. Research project, Indiana University at South Bend. (ERIC Document Reproduction Service No. ED 335 459)

Ehman, L. H., Glenn, A. D., Johnson, V., & White, C. S. (1990, November). Using computer databases in student problem solving: A study of eight social studies teachers' classes. Paper presented at the annual meeting of the National Council for the Social Studies, College and University Faculty Assembly, Anaheim, CA.

Ehrmann, S. (1990). Reaching students, reaching resources: using technologies to open the college. Washington DC: Annenberg/CPB Project. (ERIC Document Reproduction Service No. ED 327 171)

El Andaloussi, J. (1988, August/September). Artificial intelligence and videotex: Marriage by attraction or marriage of convenience? Le Francais dans le Monde, [Special Edition]. Abstracted by R. W. Lemp, ETR&D, 37(1), 96-97.

El Paso Independent School District. (1992, October). Evaluation of the program discovering instructional strategies for computers (DISC), 1-22.

El Paso Independent School District. (1992, October). Evaluation of the reading improvement program (Grade 6) 1991-1992, 1-14.

El Paso Independent School District. (1992, September). Evaluation of the writing to write program 1991-1992, 1-23.

Elder, C. L. (1988). Development of a social studies database with accompanying curriculum materials to enhance information-processing skills and geographic knowledge. (Doctoral dissertation, George Mason University, 1988).

Electronic Learning. (1993, January). Chula Vista Elementary School District: Connecting Curriculum, Instruction, and Assessment, 12(4), 29.

Electronic Learning. (1987, October). Educational technology 1987: A report on EL's seventh annual survey of the states, 7(2), 39-57.

Electronic Learning. (1991, November/December). Quick tips: Promoting technology use in your district, 11(3), 12.

Ellington, H. (1987). A review of the different types of instructional materials available to teachers and lecturers, teaching and learning in higher education. Scottish Central Institutions Committee for Educational Development. (ERIC Document Reproduction Service No. ED 289 493)

Ely, D. P. (1988). The promises of educational technology: A reassessment. Educational Media and Technology Yearbook, 14. 5-17.

Ely, D. P. (Ed.). (1990). Research abstracts. Educational Technology Research & Development, 38(3), 97-102.

Ely, D. P. (1990, Winter). Conditions that facilitate the implementation of educational technology innovations. Journal of Research on Computing in Education, 23(2), 298-305.

Ely, D. P. (1990). Trends and issues in educational technology, 1989. Educational Media and Technology Yearbook, 16, 5-30.

Ely, D. P. (1991). Computers in Schools and universities in the United States. Educational Media and Technology, 17, 18-25.

Ely, D. P. (1992). Trends in educational technology (Report No. ISBN-0-937597-35-1). Syracuse, NY: ERIC Clearinghouse on Information Resources. (ERIC Document Reproduction Service No. 346 850)

Ely, D. P., Januazewski, A., & LeBlanc, G. (1989). Trends and issues in educational technology, 1988. Educational Media and Technology Yearbook, 15, 5-33.

Engelhard, G. (1990). Gender differences in performance on mathematics items: Evidence from the United States and Thailand. Contemporary Educational Psychology, 15, 13-26.

EPIE Institute. (1990). The integrated instructional systems report. New York: Water Mill.

Eugene School District 4J. (1992, July). Parent, staff and student assessment of Channel One. Eugene, OR: Author.

Fairchild, M. E., Christner, C., & Wilkinson, D. (1988, April). What price achievement: A cost-effectiveness study of Chapter 1 and schoolwide projects. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Fairfax County Public Schools. (1988, July). Writing to read program evaluation report. Fairfax, VA: Author.

Falk, D. R., & Carlson, H. L. (1992, September). Learning to teach with multimedia. T.H.E. Journal, 96-101.

Farley, R., & others. (1992, February). The wave of the future: Prototype Classrooms/Laboratories. Paper presented at the annual meeting of the American Association of School Administrators. Flemington, NJ: Hunterdon Central Regional High School District. (ERIC Document Reproduction Service No. ED 345 323)

Feldmann, S. C., & Fish, M. C. (1988). Reading comprehension of elementary, junior high and high school students on print vs. microcomputer-generated text. Journal of Educational Computing Research, 4, 159-166.

Ferrell, B. G. (1989). Edison Middle School basic skills remediation project 1989 evaluation. Houston, TX: Final report prepared for Houston Independent School District.

Feuer, M. J. (1989, March). Investing in school technology? Weigh today's expense against tomorrow's gain. The American School Board Journal, 37-39.

Fischetti, E., & Gisolfi, A. (1990, August). From computer-aided instruction to intelligent tutoring systems. Educational Technology, 7-17.

Fisher, C. (1989). The influence of high computer access on student empowerment (ACOT Report #1). Cupertino, CA: Apple Computer, Inc.

Fisher, C. W. ( ). Student empowerment in a high computer-access environment - An exploratory study (ACOT Report No. 1). Cupertino, CA: Apple Computer, Inc. (ERIC Document Reproduction Service No. ED 304 100)

Flagg, B. N. (1990). Formative evaluation for educational technologies. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Flanders, B. L. (1988, July/August). Barbarians at the gate. American Libraries, 22(7), 668-669.

Fletcher, J. D. (1989). The potential of interactive videodisc technology for defense training and education. Alexandria, VA: Institute for Defense Analyses.

Fletcher, J. D. (1990). Effectiveness and cost of interactive videodisc instruction in defense training and education. Alexandria, VA: Institute for Defense Analyses.

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

Foley, L. D. (1990, January). TV 101: Could it really work? Educational Technology, 57-59.

Forbeck, J. C. (1990). Kenton County School District Computer applications relative to educating students (C.A.R.E.S.). Independence, KY: Kenton County School District.

Forsyth, A. S., Jr., & Lancy, D. F. (1989). Girls and microcomputers: A hopeful finding regarding software. Computers in the Schools, 6(3/4), 51-59.

Forte, P. (1992, April). Technology survey of New Hampshire Schools Final report utilization needs. NH: Survey conducted for New Hampshire Public Schools by Educational Services, New Hampshire Public Television.

Foster, D. (1988, April). Technology: Implications for long-rang planning. Educational Technology, 28(4), 7-14.

Fowles, M., & Wilder, G. (1991, Spring). Maryland education project: Assessment measures task force report and Levels of progress in using computers in the classroom. Princeton, NJ: Maryland Education Assessment Measures Task Force and Educational Testing Service.

Freedman, K., & Relan, A. (1990, June). The use of applications software in schools: Paint system image development processes as a model for situated learning (Project No. 90-3). Research Bulletin #3: Technology As An Instructional Tool: What We Are Learning. St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Freeman, W., Kelly, D., & Doughty, P. (1992, March). IBM/SED joint study evaluation at Cicero Elementary School. Manuscript draft.

French, M. P. (1989). Using microcomputer simulation to promote writing in social studies. Computers in the Schools, 6(1/2), 123-134.

Friedler, Y., & Shabo, A. (1991). An approach to cost-effective courseware development. British Journal of Educational Technology, 22(2), 129-138.

Friedman, E. A. (1991, June 21). Technology's trojan horse: The classroom computer. Keynote address presented at the Conference of National Academy of Sciences.

Friedman, E. A., Jurkat, M. P., & Pinkham, R. S. (1991, September). Enhancing mathematics education through computer integration. The Journal, 19(2), 72-75.

Fulton, K. (1988). Preservice and inservice: What must be done in both. Electronic Learning, 8(7), 32-36.

Gabriel, M. R. (1988, March). Videotex and teletex: Waiting for the 21st century? Educational Technology, 27-31.

Garcia, R. (1990, March). 'Study edge': A new kind of open-ended computer-based, self-instructional system. Educational Technology, 63-65.

Garvin, D. A. (1991, November/December). How the Baldrige Award really works. Harvard Business Review, 80-95.

Gayeski, D. M. (1991). Accelerating the learning curve: Software tools for interactive media developers. Tech Trends, 36(2), 18-21.

Giacquinta, J. B. & Lane, P. A. (1990). Fifty-one families with computers: A study of children's academic uses of microcomputers at home. Educational Technology Research & Development, 38(2), 27-37.

Gevirtz, G., & Kelman, P. (1990). The scholastic guide to educational computer networks. New York, NY.

Gillman, T. V. (1989, January). Change in public education: A technological perspective. Trends and issues, series number 1 (Report No. ISBN-0-86552-0976). Eugene, OR: ERIC Clearinghouse on Educational Management. (ERIC Document Reproduction Service, No. ED 302 940)

Gilman, D. A., & Brantley, T. (1988, August). The effects of computer-assisted instruction on achievement, problem-solving skills, computer skills, and attitude. A study of an experimental program at Marrs elementary school. Mount Vernon, IN: Professional School Services, Indiana State University. (ERIC Document Reproduction Service No. ED 302 232)

Goldstein, J., & Kamil, B. (1988, September). Teaching telecourses Opportunities and options: A faculty handbook. Annenberg/CPB Project in cooperation with the PBS Adult Learning Service.

Gould, K. (1991, November). Indiana's high-tech elementary school. Principal, 71(2), 11-13.

Grady, M., & Adcock, E. (1990). Classroom-based computer assisted instruction in the elementary grades: A research report on program implementation and academic effect. Upper Marlboro, MD: Prince George's County Public Schools.

Graves, M. F., Earle, J., Thompson, M., Prenn, M, & Johnson, V. (1990, June). Effects of three sorts of revisions on students' comprehension of history text (Project No. 90-7). Research Bulletin #3: Technology As An Instructional Tool: What We Are Learning? St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Gray, C. A. (1991). Video as a tool of inquiry and communication: Application in an urban high "school" (Urban "schools"). Dissertation Abstracts International, 52(06), 2004. (University Microfilms No. ADG91-32341)

Gray, R. A. (1988, May). Educational technology use in distance education: Historical review and future trends. Educational Technology, 38-42.

Green, E. E., & Flinders, N. J. (1990, October). The computer as a production tool for teachers. The Computing Teacher, 16-19.

Green, J. (1991, May). CD-ROM: A tool for coping with the knowledge explosion. T.H.E. Journal, 54-56.

Greenman, M. D. (1990, October). A computer based problem solving geography unit. In C. White (Ed.), Computers in the Curriculum: Social Studies. The Computing Teacher, 22-24.

Greenstein, L. (1992, November). Administrative technology: Making operations run smoothly. School Executive, 8.

Gregory, J. H. (1992, September). Ten years after: Drexel's microcomputing program. T.H.E. Journal, 96-101.

Guercio, R. (1987, December). Summer TEAMS preparation program, final report 1986-87. Houston, TX: Final report for Houston Independent School District.

Gwynne, P. (1992, February/March). Stalking Asian Software Pirates. Technology Review, 95, 15-16.

Hajovy, H., & Christensen, D. (1987, May). Intelligent computer-assisted instruction: The next generation. Educational Technology, 9-14.

Hale, R. G. (1988). Educational technology in educational innovation: A state education department perspective. Educational Media and Technology Yearbook, 14, 48-55.

Hannafin, M. J., Dalton, D. W., & Hooper, S. R. (1987). Computers in education: Barriers and solutions. Educational Media and Technology: Some Challenges and Case Studies, 5-20.

Hardiman, B., & Williams, R. (1990, April). Teaching developmental mathematics: The interactive videodisc approach. T.H.E. Journal, 63-65.

Harris, J., & Bergey, N. (1990, October). To BEE is to dance. In J. Harris, M. Watt, & S. Yoder (Eds.), The Logo Center. The Computing Teacher, 25-28.

Harvard Business Review. (1992, January/February). Does the Baldrige award really work? Debate: Readers and authors face off over HBR's last issue, 70(1), 126-147.

Hasselbring, T. S. (1987). Effective computer use in special education: What does the research tell us? In Effectiveness of microcomputers in education (Funder Forum, pp. 23-41). Cupertino, CA: Apple Computer, Inc.

Hativa, N. (1988, Fall). Computer-based drill and practice in arithmetic: Widening the gap between high- and low-achieving students. American Educational Research Journal, 25(3), 366-397.

Hattiesburg Public School District. (1992, September 10). Project report/evaluation technology for the 21st century: A model for teaching and learning. Hattiesburg, MS: Office of Public Information, Hattiesburg Public Schools.

Hawkins, J. (1987). Computers and girls: Rethinking the issues. In R. Rea and K. Sheingold's (Eds.) Mirrors of Minds. Norwood, NJ: Albex Publishing Co.

Hawkins, J. (1990). Design experiments: Integrating interactive technology into classrooms. Paper presented at the meeting of the American Association of Educational Research, Boston, MA.

Hawkins, J., & Sheingold, K. (1986). The beginning of a story: Computers and the organization of learning in classrooms. In J. A. Culbertson and L. L. Cunningham's (Eds.) Microcomputers and Education. Chicago: The University of Chicago Press.

Hawkridge, D. (1990). Who needs computers in schools, and why? Computers in Education, 15(1-3), 1-6.

Hawley, D. E. et. al. ( ). Costs, effects and utility of microcomputers - assisted instruction (Tech Report No. 1). (ERIC Document Reproduction Service No. ED 284 531)

Hayek, L. M., & Stephens, L. (1989, Summer). Factors affecting computer anxiety in high school computer science students. Journal of Computers in Mathematics and Science Teaching, 73-76.

Heck, R. H. (1990). Secondary science teachers' attitudes about microcomputer -based laboratory techniques: Instructional uses and needed improvements. Computers in the Schools, 7(3), 71-85.

Heinich, R. (1988, Fall). The use of computers in education: A response to Streibel. Educational Communication and Technology Journal, 36(3), 143-145.

Held, C., Newsom, J., & Peiffer, M. (1991, March). The integrated technology classroom: An experiment in restructuring elementary school instruction. The Computing Teacher, 18(6), 21-23.

Helgeson, S. L., Howe, R. W., & Blosser, P. E. (1990, December). Science: Promising and exemplary programs and materials in elementary and secondary schools. Science education information report. Washington, DC: Office of Educational Research and Improvement. (ERIC Document Reproduction Service No. ED 335 234)

Henderson, R. W., & Landesman, E. M. (1988/1989). Interactive videodisc instruction in pre-calculus. Journal of Educational Technology Systems, 17(2), 91-101.

Henderson, R. W., Landesman, E. M., & Kachuck, I. (1988, April). The interactive videodisc system in the zone of proximal development: Academic motivation and learning outcomes in precalculus. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Henderson, R. W., Landesman, E. M., & Kachuck, I. (1988, April). Student goal orientation and self-selection of academic support during videodisc instruction. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Herman, J. L. (1992). Finding the reality of the promise: Assessing the effects of technology in school reform. Los Angeles, CA: UCLA Center for the Study of Evaluation. Unpublished manuscript.

Herman, J., Valdes, R., & Osmundson, E. (1992, June). Model Technology Schools Project-Bell Complex 1992-1992 Research and Evaluation Report: Final Report and Recommendations. Los Angeles Unified School District Information Technology Division: Center for the Study of Evaluation, UCLA Graduate School of Education.

Hicks, S. J. (1991, June). A review of selected findings of the project. In G. Salomon (Ed.), From theory to practice: The international science classroom - a technology-intensive, exploratory, team-based and interdisciplinary high school project. [Introduction to special section]. Learning: New conceptions, new opportunities. Educational Technology, 54-57.

Hiebert, E., Quellmalz, E., & Vogel, P. (1989). A research-based writing program for students who have high access to computers (ACOT Report #2). Cupertino, CA: Apple Computer, Inc.

Hillsborough County Schools. (1988) . Computer-assisted instruction: A review of the literature. Tampa, FL. (ERIC Document Reproduction Service No. ED 332 673)

Hinchliffe, K. (1989). Focus on federal-state relations in educational finance Federal financing of education: Issues and evidence. Comparative Education Review, 33(4), 437-449.

Hoctor, M. (Ed.) (1991, January). Teaching with technology. California Association for the Gifted. (ERIC Document Reproduction Service No. ED 332 438)

Hoffman, G. M., & Marcou, G. T. (1989). Curbing international piracy of intellectual property. Policy options for a major exporting country. Washington DC: Northwestern University. (ERIC Document Reproduction Service No. ED 320 593)

Hoko, J. A. (1989). SIS: A futuristic look at how computerized classrooms can enhance rather than diminish teachers' pedagogical power. Computers in the Schools, 6(1/2), 135-143.

Honea, G. E. (1992). America 2000, technology, and student outcomes. Unpublished manuscript.

Honey, M., & Moeller, B. (1990, August). Teachers' beliefs and technology integration: Different values, different understandings. New York, NY: Center for Technology in Education. (ERIC Document Reproduction Service No. ED 326 203)

Hooper, S., & Hannafin, M. J. (1988, March). The effects of heterogeneous versus homogeneous cooperative CBI methods on learning mathematics concepts. Paper presented at the annual meeting of the Association for Educational Communication and Technology, New Orleans, LA.

Hopkins, M. (1991, November). The Saturn School: Technology's cutting edge. Principal, 71(2), 16-19.

Hueneme School District. (1990). Model technology schools project year end report 1989-1990. Port Hueneme, CA.

Hueneme School District. (1990, July). Model technology schools project, year end report, 1989-1990. Port Hueneme, CA.

Hueneme School District. (1991, June). Advancing student learning using computer managed multi-media technology. Port Hueneme, CA: An Educational Technology Research Proposal.

Hughes, B. (1988). Edmonds School District No. 15: Strategic Planning 1990-1991 Workbook for staff: A learning document. Sample Technology & Strategic Plans, (Chapter 9).

Hughes, B. (1988). Kent School District: Shaping excellence for tomorrow, educational recommendations through the year 2000. Sample Technology & Strategic Plans, (Chapter 8).

Hughes, B. (1988). Lake Washington Schools: Technology 1988-94: Helping students to learn and teachers to think. Sample Technology & Strategic Plans, (Chapter 3).

Hughes, B. (1988). Northshore School District Technology Task Force: A plan for the continuing implementation of technology preliminary report. Sample Technology & Strategic Plans, (Chapter 7).

Hughes, B. (1988). Tumwater School District No. 33: Strategic Plan 1990-1995. Sample Technology & Strategic Plans (Chapter 10).

Hughes, B. (1988). Wayzata Independent School District: Technology, a blueprint for the future. Sample Technology & Strategic Plans, (Chapter 6).

Hughes, B., & Schlumpf, J. (1992). Technology & schools: A briefing for decision -makers. Kirkland, WA: NSBA/ITTE Technology Leadership Network.

Hunt, N. P., & Papalewis, R. (1989, November). Educational computing: Ethical issues for school administrators and policy makers. Paper presented at the annual meeting of the California Educational Research Association, San Francisco, CA. (ERIC Document Reproduction Service No. ED 324 821)

Hunter, B. (1987). Computer-based tools in learning and teaching a research agenda. Cupertino, CA: Apple Computer, Inc.

Hunter, B. (1988, June). Research and evaluation trends in the uses of computer-based tools for learning and teaching. Proceedings of the National Educational Computing Conference, 82-94.

Indiana State Department of Education. (1987, November). Consortium for computer and high technology education. Plan for 1987-1989 biennium. (ERIC Document Reproduction Service No. ED 297 715)

Institute for International Research. (1992, April 16). Technology and schools: A briefing for decision-makers. Pittsburgh, PA: Conference.

International Council for Computers in Education. (1988, Spring/Summer). ICCE publications. Eugene, OR: University of Oregon.

Jacobson, M. J., & Spiro, R. J. (1991, April). A framework for the contextual analysis of computer-based learning environments (Technical Report No. 527). Champaign, IL: University of Illinois at Urbana-Champaign. (ERIC Document Reproduction Service No. ED 329 938)

Jefferson, F. E., & Moore, O. K. (1990, September). Distance education: A review of progress and prospects. Educational Technology, 7-12.

Johnson, D. W., & Johnson, R. T. (1986, January). Computer-assisted cooperative learning. Educational Technology, 26(1), 12-18.

Johnson, S. (1992, June). Evaluation of writing to write program. Evaluation study conducted at J. B. Passmore Elementary School, San Antonio, TX.

Johnston, J. M. (1991, Fall). We need a new model of technology. Journal of Applied Behavior Analysis, 24(3), 425-427.

Jonassen, D. H. (1986). Hypertext principles for text and courseware design. Educational Psychologist, 21, 269-292.

Jones, J. Q. (1988, October). Access, quality and economy: The unfinished agenda for America's schools. Denver, CO: Education Commission of the States and Washington, DC: National Conference of State Legislatures. (ERIC Document Reproduction Service No ED 326 187)

Juell, P., & Wasson, J. (1988, March). A comparison of input and output for a knowledge based system for educational diagnosis. Educational Technology, 19-23.

Jurkat, M. P., Skov, R. B., Friedman, E. A., Pinkham, R. S., & McGinley, J. J. (1992, May). A field study of student performance in the Ciese High School Project: Evaluating a model for introducing computer use in high school mathematics. Stevens Institute of Technology.

Justen, J. E., Adams, T. M., & Waldrop, P. B. (1988, February). Effects of small group versus individual computer-assisted instruction on student achievement. Educational Technology, 50-52.

Justen, J. E., Waldrop, P. B., & Adams, T. M. (1990, July). Effects of paired versus individual user computer-assisted instruction and type of feedback on student achievement. Educational Technology, 51-53.

Kacer, B., Rocklin, T., & Weinholtz, D. (1991). The impact of small group instruction upon attitude and achievement of students learning computer applications. Computers in the Schools, 8(1-3), 357-360.

Kahn, J., & Freyd, P. (1990, February). Touch typing for young children: Help or hindrance? Educational Technology, 41-45.

Kamper, R. J. (1991, November). Computer-mediated communication: Conquest of time and space or just another technological seduction? Educational Technology, 20-25.

Kansky, B. (1987, February). Technology policy survey: A study of state policies supporting the use of calculators and computers in the study of precollege mathematics. (ERIC Document Reproduction Service No. 289 728)

Katkanant, C. (1990, December). The effects of using interactive videodisc laboratory simulation on problem solving and learning performance of high school chemistry students. Unpublished doctoral dissertation, University of Nebraska, Lincoln.

Kay, R. H. (1992, April). An examination of gender differences in computer attitudes, aptitude and use. Paper presented at the annual conference of the American Educational Research Association, San Francisco, CA. (ERIC Document Reproduction Service No. ED 346 848)

Kelman, P. (1991, January). Alternatives to integrated learning systems. The Journal of the California Association for the Gifted, 21(1).

Kennedy, W. P., & Wright, G. (1990, April). Making movies with your Apple II: Part 1 Desktop video. inCider, 44-49.

Kenton County School District. (1990). Solutions (for: C.A.R.E.S.). Independence, KY: Author.

Keyworth, G., II., & Abell, B. (1990). Competitiveness & telecommunications. Indianapolis, IN: Hudson Institute.

Kezer, L. P. (1991). Effects of computer "technology" and traditional methods of instruction upon the critical thinking skills of teachers and students. Dissertation Abstracts International, 52(08), 2818. (University Microfilms No. ADG92-04447)

Kimpston, R., Haugen, J., Sales, G., Wagner, M. K., Rysavy, S. D. M., & McLeod, R. (1989). A report of an evaluation study of the Computer Applications Now (CAN) project (Project No. 89-4), 19-23. St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Kimpston, R., Haugen, J., Sales, G., Wagner, M. K., Rysavy, S. D. M., & McLeod, R. (1989, November). Evaluating the use of technology in schools: What we are learning? (Project No. 89-4). Research Bulletin #2. St. Paul, MN: MECC/Center for the Study of Educational Technology. (ERIC Document Reproduction Service ED 318 453)

King, D. T. (1992, April). The saturn school of tomorrow: A reality today. T.H.E. Journal, 66-68.

Kinzie, M. B., & Sullivan, H. J. (1989). Continuing motivation, learner control, and CAI. Educational Technology Research & Development, 37(2), 5-14.

Kinzie, M.B., Sullivan, H. J., & Berdel, R.L. (1992). Motivational and Achievement Effects of Learner Control Over Content Review Within CAI. Journal of Educational Computing Research, 8(1), 101-114.

Kiser, L. (1987, November). Spatial-visual ability: Can computer visualization facilitate achievement? Educational Technology, 36-40.

Kitabchi, G. (1988). Final report for the evaluation of the Apple Classroom of Tomorrow project phase III. Memphis City Schools.

Kleene, M. (1990, June). Computers and classroom change: The teachers' challenge (Project No. 90-4). Research Bulletin #3: Technology As An Instructional Tool: What We Are Learning?, 11-15. St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Klein, J., Philip, C., Price, J., Rudzinski, R., & Snavely, J. (1988, March) Computers in instruction: A plan for the Appleton area school district, 1988-1993. Madison, WI.

Kloosterman, P., Harty, H., & Matkin, J. (1988, October). Computer utilization in elementary school mathematics classrooms. Educational Technology, 42-47.

Knapczyk, D. R. (1990, June). Use of audiographic technology in distance training of practicing teachers. Educational Technology, 24-27.

Knox, S. C. (1992, August). Evaluating the use of technology in Chapter I programs. New Hope, MN: Independent School District No. 281, Robbinsdale Area Schools.

Knupfer, N. N. (1987, April). A survey of teachers' perceptions, opinions and attitudes about instructional computing: Implications regarding student equity. Paper presented at the annual meeting of the American Educational Research Association in Washington DC. (ERIC Document Reproduction Service No. ED 287 448)

Knupfer, N. N. (1988). Teachers' beliefs about instructional computing: Implications for instructional designers. Journal of Instructional Development, 29-38.

Knussen, C., Tanner, G., & Kibby, M. (1991). An approach to the evaluation of hypermedia. Computers Educ, 17(1), 13-24. Great Britain.

Kominski, R. (1991). Computer use in the United States: 1989. Current population reports, special studies (Series P-23, No 171). Washington, DC: US Department of Commerce. (ERIC Document Reproduction Service No. ED 338 210)

Krendl, K., & Broihier, M. (1991, May). Student responses to computers: A longitudinal study. Paper presented at the annual meeting of the International Communication Association, 41st, Chicago, IL. (ERIC Reproduction Service No. ED 332 250)

Krendl, K., & Lieberman, D. (1988). Computers and learning: A review of recent research. Journal of Educational Computing Research, 4(4).

Krendl, K., & Williams, R. (1990). The importance of being rigorous: Research on writing to read. Journal of Computer-Based Instruction, 17(3) 81-86.

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

Kulik, J. A., & Kulik, C. C. (1989a). Computer-based instruction: What 200 evaluations say. Paper presented at the Convention of the Association for Educational Communication and Technology, Atlanta, GA. (ERIC Document Reproduction Service No. ED 285 518)

Kulik, J. A., & Kulik, C. C. (1989b). Effectiveness of computer-based instruction. School Library Media Quarterly, 17(3), 156-159.

Kulikowich, J. M., & Alexander, P. A. (1990). The effects of gender, ability, and grade on analogy performance. Contemporary Educational Psychology, 15, 364-377.

Kumar, D. D. (1991, February). Curriculum concerns of science-technology-society education in the United States of America. Science, Technology & Society: Curriculum Newsletter of the Lehigh University STS Program, 82, 7-14.

Kunert, D., Kunert, U., & Studer, A. (1988, August/September). Telematics: A new tool for your classroom? Le Francais dans le Monde [Special Edition], 192-202. Abstracted by R. W. Lemp, ETR&D, 37(1), 95-96.

Lake, D. (1989, January). Two projects that worked: Using telecommunications as a resources in the classroom. Telecommunications in the classroom, 21-23.

Lai, K-W. (1991). Integrating database activities into a primary school curriculum: Instructional procedures and outcomes. Computers in the Schools, 8(4), 55-63.

Langholz, J., & Smaldino, S. E. (1989, February). The effectiveness of a CBI program for teaching problem solving skills to middle level students. Proceedings of selected research papers. Paper presented at the annual meeting of the Association for Educational Communications and Technology, Dallas, TX. (ERIC Document Reproduction Service No. ED 308 825)

Lawrenz, F., & Thornton, E. (1989). The current availability and use of computers in science education Grades 7-12 in Minnesota (Project No. 89-1). St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Lawson, V. L. (1987). Students' preference for bibliographic instruction: Library tour vs. a computer-assisted instruction program. MO: Central Missouri State University. (ERIC Document Reproduction Service No 335 055)

Lawson, V. L. (1990, Spring). A cost comparison between general library tours and computer-assisted instruction programs. Research Strategies, 8(2), 66-73.

Lemons, C. D. (1988, December). Technology education: A Kansas curriculum development project. Paper presented at the American Vocational Association Convention, St. Louis 1988. (ERIC Document Reproduction Service No. ED 304 529)

Leonard, W. H. (1992). A comparison of student performance following instruction by interactive videodisc versus conventional laboratory. Journal of Research in Science Teaching, 29(1), 93-102.

Levenick, J. R. (1990, October). Teaching recursion before iteration. The Computing Teacher, 12-15.

Lever, S., Sherrod, K., & Bransford, J. (1989). The effects of logo instruction on elementary students' attitudes toward computers and school. Computers in the Schools, 6(1/2), 45-65.

Levin, H. M. (1988, Spring). Cost-effectiveness and educational policy. Educational Evaluation and Policy Analysis, 10(1), 51-69.

Levin, H. M., Glass, G. V., & Meister, G. R. (1987, February). A cost-effectiveness of analysis of computer-assisted instruction. Evaluation Review, 11, 50-72.

Levin, H. M., Leitner, D., & Meister, G. R. (1988). Cost-effectiveness of alternative approaches to computer-assisted instruction (87-CERAS-1). Stanford, CA: Stanford Educational Policy Institute.

Levin, H. M., & Rumberger, R. W. ( ). Educational requirements for new technologies: Visions, possibilities, and current realities. Educational Policy, 333-354.

Levin, S. R. (1991, Autumn). The effects of interactive video enhanced earthquake lessons on achievement of seventh grade earth science students. Journal of Computer-based Instruction, 18(4), 125-129.

Levinson, C. Y. (1989, March). Research in planning and practice for technology in Texas. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA. (ERIC Document Reproduction Service No. ED 307 858)

Levinson, J. L. (1990, September). Math/science corridor study: Year 3. Evanston/Skokie, IL: Community Consolidated School District 65.

Levinson, J. L., & Lalor, I. (1989, March). Computer-assisted writing/reading instruction of young children: A 2-year evaluation of "writing to read". Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Lewis, P. H. (1991, November). The technology of tomorrow. Principal, 71(2), 6-7.

Libler, R. W. (1991). A study of the "effectiveness" of interactive television as the primary mode of instruction in selected high "school" physics classes (distance education, physics instruction). Dissertation Abstracts International, 52(06), 2116. (University Microfilms No. ADG91-33265)

Light, P., Foot, T., Colbourn, C. & McClelland, I. (1987). Collaborative interactions at the microcomputer keyboard. Educational Psychology, 7(1), 13-21.

Lillie, D., Hannum, W., & Stuck, G. (1989). Computers and effective instruction. Chapel Hill, NC: University of North Carolina.

Lin, X. (1988, November). A selected hypertext bibliography. Educational Technology, 41-42.

Litchfield, B. C. (1990, October). Guidelines for writing (or rewriting) manuals for instructional software. The Computing Teacher, 37.

Little, J., & Pietras, P. (Eds.). (1989). DACOTT21/20: District and community of tomorrow today. McKittrick, CA: Belridge School District.

Locatis, C., Charuhas, J., & Banvard, R. (1990). Hypervideo. Educational Technology Research & Development, 38(2), 41-49.

Locatis, C., Letourneau, G., & Banvard, R. (1989). Hypermedia and instruction. Educational Technology Research & Development, 37(4), 65-77.

Lohr, N. J. (1990, Summer). Computer integration/staff development. Study conducted in Wisconsin.

Lomerson, W. L., & Knezek, G. A. (1991, August). Teacher benefit: The critical design criterion for computer managed instruction. Educational Technology, 17-23.

Louks, S., & Hall, G. (1987). Assessing and facilitating the implementation of innovation: A new approach. Educational Technology, 18-23.

Lynch, J., Fischer, P., & Green, S. (1989, December). Teaching in a computer-intensive algebra curriculum. Mathematics Teacher, 688-694.

Lyons-Smith, C. L. (1990/1991). Impact of graphic CBI on English mechanics for written communication. Journal Educational Technology Systems, 19(3), 215-221.

MacGregor, S., Shapiro, J., & Niemiec, R. (1988). Effects of a computer augmented learning environment on math achievement for students with differing cognitive style. Journal of Educational Computing Research, 4(4), 453-465.

Maddux, C. D. (1990). Educational computing: Liabilities, assets, potential. Computers in the Schools, 7(4), 99-103.

Maddux, C. D. (1991). Technology and teacher education: Stimulating the knowledge base. Computers in the Schools, 8(4), 49-53.

Madigan, E. M. (1991). An expert system as a study guide in an "elementary" statistics class and its effect on learning style. Dissertation Abstracts International, 52(07), 2427. (University Microfilms No. ADG91-37077)

Mageau, T. (1990, March). Laser-disc technology. Electronic Learning, 23-28.

Mageau, T. (1990, November/December). Teaching and learning online. Electronic Learning, 10(3), 26-30.

Mageau, T. (1991, February). Redefining the textbook. Electronic Learning, 10(5), 14-18.

Mageau, T. (1991, October). Backbone networks: The heart of the technology plan. Electronic Learning.

Magliaro, S., & Burton, J. K. (1987/1988, Fall-Winter). Adolescents' chunking of computer programs. Computers in the schools, 4(3&4), 129-138.

Main, R., & Roberts, L. (1990, December). Educational technology in the California Public Schools: A statewide Survey. Educational Technology, 20(12), 7-19.

Mandinach, E. B. (1989). Model-building and the use of computer simulation of dynamic systems. Journal Educational Computing Research, 5(2), 221-243.

Mann, D. (1991). How teachers and media specialists grade cable TV. New York: Teacher's College, Columbia University.

Marchionini, G. (1988, November). Hypermedia and learning: Freedom and chaos. Educational Technology, 8-12.

Marsh, H. W. (1989, Summer). Sex differences in the development of verbal and mathematics constructs: The high school and beyond study. American Educational Research Journal, 26(2), 191-225.

Marshall, R., Gronouski, J., & Glover, R. W. (1989). Education, technology and the Texas economy Volume 2: Can technology help Texas? Austin, TX: Texas University. (ERIC Document Reproduction Service No. ED 311 577)

Martin, L. (1987). Teachers' adoption of multimedia technologies for science and mathematics instruction. In R. Rea and K. Sheingold's (Eds.) Mirrors of Minds. Norwood, NJ: Ablex Publishing Co.

Martinez, M. E., & Mead, N. A. (1988). Computer competence: The first national assessment (Tech Rep. No 17-CCO). Princeton, NJ: National Assessment of Educational Progress and Educational Testing Service.

Massachusetts Corporation for Educational Telecommunications. (1991). The Mass LearnPike. Preliminary Schedule 1992-1993.

Massey, C., & Gelormino, J. (1987, April). The influence of a math software program on preschoolers' acquisition of mathematics: Ruton in the classroom. Paper presented at the annual meeting of the American Educational Research Association, Washington, DC.

Mathur, R., & Prakash, B. (1988, February). Individually guided system of instruction: A cooperative learning strategy. Educational Technology, 45-48.

McCormick, T. E., & McCoy, S. B. (1990). Computer-assisted instruction and multicultural nonsexist education: A caveat for those who select and design software. Computers in the Schools, 7(4), 105-124.

McDermott, C. W. (1985, December). Affecting basic skills achievement through technology. Research report on IMPAC. Arkansas Commission on Microcomputer Instruction, State Department of Education: Little Rock.

McIntyre, N. (1990, January/February). Satellite technology provides link for math and science in Pennsylvania. Tech Trends, 35(1), 6-9.

McKinsey, B. (1991). An assessment of the microcomputer in Northeast Kansas English/language arts "classrooms" (CAI). Dissertation Abstracts International, 52(08), 2808. (University Microfilms No. ADG92-01015)

McLean, L., & Tessman, R. (1991, August). Women in science: Creating a DC-ROM multimedia database. Excerpt from paper presented at Seventh Annual Conference of Interactive Multimedia '91 CD-ROM Applications in Education and Training, Arlington, VA.

McMullen, D. W. (1987). Drills vs. games--any differences? A pilot study. Peoria, IL: Department of Teacher Education, Bradley University. (ERIC Document Reproduction Service No. ED 335 355)

McNeil, B. J., & Nelson, K. R. (1991, Winter). Meta-analysis of interactive video instruction: A 10 year review of achievement effects. Journal of Computer-Based Instruction, 18(1), 1-6.

McPherson, S. J. (1991). The effects of metacognitive strategy training with computer-assisted instruction for vocabulary acquisition by students with learning disabilities. Dissertation Abstracts International, 52(06), 2010. (University Microfilms No. ADG91-32696)

McWhirter, M. E. (1991). The effect of level one videodisc "technology" on sixth-grade student achievement in science. Dissertation Abstracts International, 52(05), 1719. (University Microfilms No. ADG91-29725).

Means, B. (1992, June). Technology: A level for school change? Paper presented at the Conference on Technology and Education Reform, Dallas, TX.

Melnyk, C. ( ). Planning the k-12 technology program. Lubbock, TX: 1-2.

Meloy, J., May, I., Koontz, P., & McGrew, M. (1990, September/October). Buying Cam: Helpful tips for teachers on how to buy a micro-based 3D CAM package. Technology, Innovation & Entrepreneurship for Students, 24-28.

Mentor Exempted Village Schools. (1992, March). Educational technology (Draft).

Mergendoller, J., Stoddart, T., Bradshaw, D., & Niederhauser, D. (1992, January). A portfolio-based evaluation of Utah's technology initiative: 1990-1991 school year. Novato, CA: Beryl Buck Institute for Education.

Mergendoller, J. R., & Pardo, E. B. (1991, December). An evaluation of the MacMagic Program at Davidson Middle School. Novato, CA: Beryl Buck Institute for Education.

Merrill, M., Li, Z., & Jones, M. (1990, February). Second generation instructional design (ID_2). Educational Technology, 7-14.

Mevarech, Z.R., Silber, O., & Fine, D. (1991). Learning with computers in small groups: Cognitive and affective outcomes. Journal of Educational Computing Research, 7(2), 233-243.

Mevarech, Z. R., Stern, D., & Levita, I. (1987). To cooperate or not to cooperate in CAI. That is the question. Journal of Educational Research, 80(3), 164-167.

Meyer, B. (1989, November). The joys of networking. Principal, 20-21.

Meyer, D., & Ruiz, D. (1991, June). The impact of recommending files for novice searchers. Database, 62-64.

Mihich, O. (1990, October). Logo-style science in the junior high school. In R. Adams & Heidi Imhof (Eds.), Computers in the curriculum: Science. The Computing Teacher, 29-31.

Miller, D. C. (1987, March). CD-ROM joins the new media homesteaders. Educational Technology, 33-35.

Miller, E. (1987). Educational media and technology yearbook. Englewood, CO: Libraries Unlimited, Inc.

Miller, M. D. (1992, August). Investigation of a home/school computer project and reading, language, and mathematics achievement. Lafayette, IN: Study conducted at Tippecanoe School Corporation.

Miller. R.L., & Sayers, J. (1989). The Year in Review: The top stories of 1988. Educational Media and Technology Yearbook, 15, 110-118.

Miller. R. L., & Sayers, J. (1990). The Year in review: The top ten stories of 1989. Educational Media and Technology Yearbook, 16, 190-201.

Milheim, W. D. (1989, Winter). Computers and satellites: Effective new technologies for distance education. Journal of Research on Computing in Education, 151-159.

Milheim, W. D. (1991, April). Implementing distance education programs: Suggestions for potential developers. Educational Technology, 51-53.

Milheim, W. D., & Evans, A. D. (1987, June). Using interactive video for group instruction. Educational Technology, 35-37.

Mitchell, J. C. (1990). A comparative study of implementation strategies for microcomputer use in public elementary schools. Doctoral dissertation, University of Massachusetts.

Mitrani, M., & Swan, K. (1990, March). Placing computer learning in context. Paper presented at the International conference on technology and education. New York, NY: Teachers College, Columbia University. (ERIC Document Reproduction Service No. 327 141)

Mizell, A. P. (1992a). Communicating through computers in the global village. Ft. Lauderdale, FL: NOVA University and the Center for the Advancement of Education, NOVA University,.

Mizell, A. P. (1992b). Kids-92 project. Ft. Lauderdale, FL: NOVA University and the Center for the Advancement of Education, NOVA University,.

Mizell, A. P. (1992c). The national cluster in the child and youth studies doctoral program. Ft. Lauderdale, FL: Study conducted with the University School of NOVA University and the Center for the Advancement of Education, NOVA University.

Mizell, A. P. (1992d). University school technology project. Ft. Lauderdale, FL: Study conducted with the University School of NOVA University and the Center for the Advancement of Education, NOVA University.

Mizer, R., Howe, R., & Blosser, P. (1990, December). Mathematics: Promising and exemplary programs and materials in elementary and secondary schools. Mathematics education information report. Washington, DC: Office of Educational Research and Improvement. (ERIC Document Reproduction Service No. 335 230)

Mokros, J. R., & Tinker, R. F. (1987). The impact of microcomputer-based labs on children's ability to interpret graphs. Journal of Research in Science Teaching, 24, 369-384.

Monahan, B., & Wimber, C. (1988, July). Distance learning and public school finance. Educational Technology, 40-42.

Mondeaux, F. P. (1992). Evaluation report: The computer assisted instruction program at Matoaca High School, Matoaca Middle School and Matoaca Elementary School. Charlottesville, VA: Evaluation Research Center.

Montague, M. (1990). Computers and writing process instruction. Computers in the schools, 7(3), 5-20.

Montler, J., & Geroy, G. (1988, August). A model to address design constraints of training delivered via satellite (Study Number Eight). PA: Study conducted at the Institute for Research in Training and Development at The Pennsylvania State University. (ERIC Document Reproduction Service No. 309 319)

Moody, G., & Robison, B. (1992). Windows development tools. Chapel Hill, NC: Institute for Academic Technology.

Morariu, J. (1988, November). Hypermedia in instruction and training: The power and the promise. Educational Technology, 17-20.

Morehouse, D. L., Hoaglund, M. L., & Schmidt, R. H. (1987, February). Interactive television findings, issues, and recommendations: An analysis based on evaluation of Minnesota's Technology Demonstration Program. Denver: Quality Education Data.

Morrison, A. (1989). Computers in the curriculum of secondary schools. Great Britain: The Scottish Council for Research in Education. Practitioner minipaper 8 SCR Publication 106. (ERIC Document Reproduction Service No. 320 543)

Moursund, D., & Ricketts, D. (1988, November). Long-rage planning for computers in schools (2nd ed.). Eugene, OR: Information Age Education.

Moursund, D. (1992, April). Restructuring education for the information age part 7: Competition. The Computing Teacher, 4.

Mowe, R. (1990). Evaluating computer integration in the elementary school: A step by step guide. Eugene, OR: International Society for Technology in Education.

Mulligan, P. A. (1987). Effectiveness of the writing to read program in the Phoenix elementary school district (Arizona). Unpublished doctoral dissertation, Arizona State University, Phoenix.

Murgatroyd, S., & Woudstra, A. (1989). Issues in the management of distance education. The American Journal of Distance Education, 3(1), 4-19.

Murphy, K. L. (1987/1988). Turkey's open education policy. International Review, 122-125.

Nachmias, R., & Linn, M. C. (1987). Evaluation of science laboratory data: The role of computer presented information. Journal of Research in Science Teaching, 24, 491-506.

Nachmias, R., Stein, J. S., & Kirkpatrick, D. (1987, April). Computer as lab partner: Students' subject-matter achievements. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Washington, DC.

National Computer Systems, Inc. (1992). Performance Plus: Performance-based assessment instructional management software. Minneapolis.

National Governors' Association. (1990). Results in education: 1990. The governors' 1991 report on education. Washington, DC: National Governors' Association (ERIC Document Reproduction Service No. ED 327 969)

National Governors' Association. (1991). Time for results: The Governors' 1991 report on education. Washington, DC: The Center for Policy Research and Analysis.

National Task Force on Educational Technology. (1986). A report on the Secretary of Education, US Department of Education. Tech Trends, 31(4).

Neef, N., Trachtenberg, S., Loeb, J., & Sterner, K. (1991, Fall). Video-based training of respite care providers: An interactional analysis of presentation format. Journal of Applied Behavior Analysis, 24(3), 473-486.

Nelson, C. S., Watson, J. A., & Busch, J. C. (1989, Summer). The interactive videodisc as an educational tool. Journal of Interactive Instruction Development, 11-16.

New Mexico State Department of Education. (1990, September). New Mexico State Board of Education's Consolidating Initiatives for Tomorrow's Education (CITE Plan. (ERIC Document Reproduction Service No. 347 017)

Newman, D. (1987, June). Local and long distance computer networking for science classrooms. Educational Technology, 20-23.

Newman, F. M. (1993, January). What is a restructured school? Principal, 5-8.

New York City Public Schools. (1989, May). Evaluation section report, computer pilot program Part I: 1987-88. New York, NY: Instructional Support Evaluation Unit, Office of Research, Evaluation and Assessment.

New York City Public Schools. (1989, May). Evaluation section report, computer pilot program Part II: 1987-88. New York, NY: Instructional Support Evaluation Unit, Office of Research, Evaluation, and Assessment.

New York City Public Schools. (1990, April). Writing to Read 1988-1989. Evaluation Section Report. NYC Board of Education, Office of Research, Evaluation, and Assessment. (ERIC Document Reproduction Service No. ED 319 050)

Nichols, T., & Frazer, L. (1992). Project A+ elementary technology demonstration schools 1991-92 The second year. Austin, TX: Office of research and Evaluation, Austin Independent School District.

Niemiec, R. P., & Walberg, H. J. (1987). Comparative effects of computer-assisted instruction: A Synthesis of reviews. Journal of Educational Computing Research, 3, 19-37.

Niemiec, R. P., & Walberg, H. J. (1989, Spring). From teaching machines to microcomputers: Some milestones in the history of computer-based instruction. Journal of Research on Computing Education, 263-276.

Nieminen, G. & others. (1987). Computers in education. Hinsdale District #181. Institute for Educational Research, Glen Ellyn, IL. (ERIC Document Reproduction Service No. ED 309 765)

North Carolina Department of Public Instruction. (1991, October). Media automation ... Impact on students. Raleigh, NC: Computer Services Division of Media and Technology Services North Carolina Department of Public Instruction.

Norton, P., & Heiman, B. (1988, September). Computer literacy and communication disordered students: A research study. Educational Technology, 36-41.

Nye, E. F. (1991, March). Computers and gender: Noticing what perpetuates inequality. English Journal, 80(3), 94-95.

Oates, R. (1989, Fall). Computer concerns for minorities and women. Florida Educational Computing Quarterly, 2(1), 55-62.

Office of Technology Assessment. (1990, February). Distance education: Linking learning and lives. Electronic Learning, 8-9.

Ognibene, R. (1989, July). Computers in the classroom: A status report. Paper presented at the Summer Meeting of the Association of Teacher Educators, Tacoma, WA. (ERIC Document Reproduction Service No. ED 316 216)

Ohio Educational Library/Media Association, Columbus. (1989). How do you measure up? Guidelines for school library media programs. (ERIC Document Reproduction Service No. ED 317 195)

Okebukola, P. A., Sumampouw, W., & Jegede, O. J. (1991/1992). The experience factor in computer anxiety and interest. Journal of Educational Technology Systems. 20(3), 221-229.

Oliveira, J. B. A. (1988). Computer education in developing countries: Facing hard choices. Education & Computing, 4, 301-311.

Ollila, K. (1987). A comparison of the effectiveness of the computer-based writing to read program with a more traditional language arts program with respect to their impact on the development of writing skills at the grade 1 level. University of Minnesota: Unpublished master's thesis.

Olson, B., & Krendl, K. A. (1990/1991). At-risk students and microcomputers: What do we know and how do we know it? Journal of Educational Technology Systems. 19(2), 165-175.

Opuni, K. A. (1987, January). School of the future: F. M. Black Middle School process report #1, 1986-87. Houston, TX: First process report for Houston Independent School District.

Opuni, K. A. (1987, November). School of the future: F. M. Black Middle School final report, 1986-87. Houston, TX: Final report for Houston Independent School District, Houston, TX.

Opuni, K. A. (1988, December). School of the future: F. M. Black Middle School final report, 1987-88. Houston, TX: Final report for Houston Independent School District, Houston, TX.

Orey, M. A. (1990, September). Interface design for high bandwidth diagnosis: The case of POSIT. Educational Technology, 43-48.

Orey, M. A., Legree, P. J., Gillis, P. D., & Bloom, E. (1991). Evaluation of intelligent tutoring systems: What's been done and what can be done. Proceedings of Selected Research Presentations at the Annual Convention of the Association for Educational Communications and Technology, IR 015 132. (ERIC Document Reproduction Service No. ED 335 002)

Orlando, L. C. (1990, March/April). The lessons of logo. Teaching and Computers, 20-24.

Ortner, J. M. (1990). The effectiveness of a computer assisted instruction program in rhythm for secondary school instrumental music students. Unpublished doctoral dissertation, State University of New York, Buffalo.

Outcome-based education is bolstered by network. (1992, August). T.H.E. Journal, 56-58.

Pack, R. (1991, June). Physics: How do you relate the generation of electricity to the deforestation of the Amazon? In G. Salomon (Ed.), From theory to practice: The international science classroom - a technology-intensive, exploratory, team-based and interdisciplinary high school project. [Introduction to special section]. Learning: New conceptions, new opportunities. Educational Technology, 49-51.

Paddock, J. (1991, June). Social studies: Comparison with previous projects. In G. Salomon (Ed.), From theory to practice: The international science classroom - a technology-intensive, exploratory, team-based and interdisciplinary high school project. [Introduction to special section]. Learning: New conceptions, new opportunities. Educational Technology, 47-49.

Page, M. (1989, November). Active learning in secondary schools: Educational media and technology. (ERIC Document Reproduction Service No. ED 323 987)

Paleologos, N. (1992, July). Investing in technology a must for American schools Replacing the three Rs with the three Ts: Teachers, Technology and Telecommunications. The Boston Globe.

Palij, M. (1991, October). Computers in science education: A survey of previously trained and new teachers. Newark, NJ: A program evaluation report of the Office of Planning, Evaluation and Testing, Board of Education.

Panasonic Communications and Systems Company. (1991, October). Laptops for Education Project. Laptop Notes, 1(1).

Pea, R. D., & Soloway, E. (1990). Mechanisms for facilitating a vital and dynamic education system: Fundamental roles for education science and technology. Educational Media and Technology Yearbook, 16, 31-90.

Perelman, L. J. (1988, September). Restructuring the system is the solution. Phi Delta Kappan, 70(1), 20-24.

Perelman, L. J. (1987, October). Technology and transformation of schools (An NSBA Technology Leadership Network Special Report, ES-14). Alexandria, VA: National School Boards Association.

Pelgrum, W. J., & Plomp, T. (1991). The use of computer in education worldwide. Oxford: Pergamon Press.

Pet, W. J. A. (1991, July). Multimedia standards (An IAT Technical Brief). Chapel Hill, NC: The Institute for Academic Technology.

Peterson, D., & Webb, C. (1988, April). The effect of video-assisted instruction on student achievement and attitude in first grade mathematics. Educational Technology, 49-53.

Picciano, A. G. (1991). Computers, City, and Suburb: A study of New York City and Westchester County Public Schools. The Urban Review, 23(3), 191-206.

Pierno, M., Endress, K., Carter, D., & Isk, K. (1992). Applying statistical process control/SPC. Birmingham, MI: Project at Seaholm High School.

Pinheiro, E. J., & Pet, W. J. A. (1992). Developing applications for windows. Chapel Hill, NC: Institute for Academic Technology.

Piller, C. (1992, September). Separate realities: The creation of the technological underclass in America's public schools. MAC World, 218-230.

Pisapia, J. & Perlman, S. (1992, December). Learning Technologies in the Classroom: A Survey of Results. Richmond, VA: Metropolitan Educational Research Consortium.

Pogrow, S. (1990, January). Challenging at-risk students: Findings from the HOTS program. Phi Delta Kappan, 389-397.

Polin, L. (1990, April). Research windows. The Computing Teacher, 6-8.

Polin, L. (1990, October). Research windows. Computer environments and the organization of classroom tasks. The Computing Teacher, 5-7.

Portsmouth Public Schools. Computer assisted instruction in the chapter 1 program of the Portsmouth public schools. Portsmouth, VA: Portsmouth Public Schools (no date cited).

Post, P. E. (1987). The effect of field independence/field dependence on computer assisted instruction achievement. Journal of Industrial Teacher Education, 25(1), 60-67.

Post, P., Howell, R., & Rakocy, L. (1988, January). Robot technology: Implications for education. Educational Technology, 39-45.

Potter, S., Ostrowski, S., Lemon, M., Muir, A., & Timco, R. (1992). Exploring alternative forms of energy and communication systems. Birmingham, MI: Project at Midvale Elementary School.

Preston, N. R. (1990, May). Trends and issues in educational technology: 1989. ERIC Clearinghouse on Information Resources. (ERIC Document Reproduction Service No. ED 320 569)

Price, R. (1989). An historical perspective on the design of computer-assisted instruction: Lessons from the past. Computers in the Schools, 6(1/2), 145-157.

Price, R. V., & Frisbie, A. G. (1988). The videodisc: Past, present, and future. Computers in the Schools, 5(1/2), 299-315.

Prisciandaro, J., Klein, L., & Crosby, J. (1992). Designing and building programmable logic controller (PLC). Birmingham, MI: Mini-grant project facilitated at Groves High School.

Productive School Systems for a Nonrational World. (Author and Date Unknown). Strategic Planning, 57-67.

Pyper, J. R. (1998, July). Evaluation report of WICAT and ESC in HISD 1988-89. Houston, TX: Report prepared for the Houston Independent School District.

Quality Educational Data, Inc. (QED). (1991a). Microcomputer and VCR usage in schools. Denver, CO.

Quality Educational Data, Inc. (1991b). Technology in schools, 1990-1991 school year. Denver, CO: Author.

Quinn, D. W., & Quinn, N. W. (1992, August 6). Buddy system project evaluation 1991-1992 school year report. St. Charles, IN: Prepared for The Buddy System Project and the Indiana Department of Education. Quality Performance Associated.

Rawitsch, D. (1987). The computerized database: Not a simple solution. The Computing Teacher, 15, 34-37.

Rawitsch, D. (1988). The effect of computer use and student work style on database analysis activities in the social studies. (Doctoral dissertation, University of Minnesota, 1987). Dissertation Abstracts International, 49, 423A.

Rawitsch, D., Bart, W. M., & Earle, J. F. (1988). Using computer database programs to facilitate higher-order thinking skills. St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology, Research Bulletin, 1(1), 7-9.

Ray, D. (1992, January). Removing barriers of social organization in schooling so technology can aid restructuring. The Education Digest, 57, 14-17.

Ray, D. (1991a, March). Technology and restructuring--Part I: New organizational directions. The Computing Teacher, 18(6), 9-20.

Ray, D. (1991b, April). Technology and restructuring--Part II: New organizational directions. The Computing Teacher, 18(7), 8-12.

Redmond, W. K. (1991, Fall). Pinpointing the technological fault in applied behavior analysis. Journal of Applied Behavior Analysis, 24(3), 441-444.

Reed, W. M., & Palumbo, D. B. (1987/1988, Fall/Winter). The effect of the BASIC programming language on problem-solving skills and computer anxiety. Computers in the Schools, 4(3&4), 91-104.

Rees, W., Rohdo, N. F., & Bolan, R. (1991). Legal issues for an integrated information center. Journal of the American Society for Information Science, 42(2), 132-136.

Reeves, T. C. (1992, August). Evaluating schools infused with technology. Education and Urban Society, 24(4), 519-534.

Reeves, T. C. (1990). Redirecting evaluation of interactive video: The case for complexity. Studies in Educational Evaluation, 16, 115-131.

Rieber, L. P. (1987, February). Logo and its promise: A research report. Educational Technology, 12-16.

Reid, D. H. (1991, Fall). Technological behavior analysis and societal impact: A human services perspective. Journal of Applied Behavior Analysis, 24(3), 437-439.

Riel, M. (1989). Telecommunications: A tool for reconnecting kids with society. Proceedings of the International Symposium on Telecommunication in Education: Learners and the Global Village. International Society of Technology in Education.

Reil, M. (1989, Winter). The impact of computers in classrooms. Journal of Research on Computing in Education, 22(2), 180-189.

Reinhold, F. (1986, October). Computing in America: Electronic learning's annual survey of the states. Electronic Learning.

Rescigno, R. C. (1991, November). Educational Technology in the Hueneme School District focusing innovation on student instruction. Port Hueneme, CA.

Research for Better Schools, Inc. (1989, February). The impact of a computer-managed instructional system on two small rural schools in the middle Atlantic region. Philadelphia, PA: Author.

Rieber, L. P. (1991). The effects of visual grouping on learning from computer animated presentations. Proceedings at the Annual Convention of the Association for Educational Communications and Technology. (ERIC Document Reproduction Service No. 335 006)

Riegel, N. B. (1987, January). The Richardson instructional management system: A solution for administering outcome-based education. Educational Technology, 29-32.

Riel, M. (1989, Winter). The impact of computers in classrooms. Journal of Research on Computing in Education, 22(2), 180-189 .

Roblyer, M. D., Castine, W. H., & King, F. J. (1988a). The effectiveness of computer applications for instruction: A review and synthesis of recent research findings, 30, 54, 100. Unpublished manuscript.

Roblyer, M. D., Castine, W. H., & King, F. J. (1988b). Assessing the impact of computer based instruction. Computers in the Schools, 5(3/4).

Roblyer, M. D., Castine, W. H., & King, F. J. (1988c). Assessing the impact of computer-based instruction, a review of current research. New York: The Haworth Press.

Rodamar, D., & Rodamar, J. (1990, March). Education and technology: Building a consensus for change. Paper presented at the Seventh International Conference on Technology and Education. (ERIC Document Reproduction Service No. 326 193)

Rooney, P. O. (1990, July). The report of the evaluation of the model technology school program in the Hueneme School District. University of Southern California.

Rooney, P. O. (1991, September). The report of the evaluation of the model technology school program in the Hueneme School District. University of Southern California.

Rooney, P. O. (1992, September). The report of the evaluation of the model technology school program in the Hueneme School District. University of Southern California.

Root, T. L. and Rowe, R. H. (1987, February). Principals' Perceptions of Computer Use in Administration and Instruction. (ERIC Document Reproduction Service No. 302 336)

Rosenberg, R. (1987, November). A critical analysis of research on intelligent tutoring systems. Educational Technology, 7-13.

Rosenthal, N. R., & Demetrulias, D. M. (1988). Assessing gender bias in computer software. Computers in the Schools, 5(1/2), 153-163.

Ross, S., Anand, P., & Morrison, G. (1988, May). Personalizing math problems: A modern technology approach to an old idea. Educational Technology, 20-25.

Ross, S., Smith, L., Morrison, G., & Erickson, A. (1989). Helping at-risk children learn through distance tutoring: The Memphis ACOT program. Technological Horizons in Education, 16, 68-71.

Ross, S. M., Smith, L. J., & Morrison, G. R. (1990, June). Helping at-risk children through distance tutoring (ACOT Report No. 4). Research Bulletin #3: Technology As An Instructional Tool: What We Are Learning. St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Ross, S. M., Smith, L. J., Morrison, G. R., O'Dell, J., Perry, G., Martin, J., & Lohr, L. (1989, August). What happens after ACOT: Outcomes for program graduates one year later. Memphis, TN: Memphis State University.

Ross, S. M., Smith, L. J., Morrison, G. R., & O'Dell, J. (1990, June). What happens after ACOT: Outcomes for program graduates one year later (ACOT Report No. 5). Research Bulletin #3: Technology As An Instructional Tool: What We Are Learning. St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Ruane, M., Feerick, S., Harnett, H., & Calmy, B. (1989). Video: Multifaceted tool or window on passivity. Le Francais dans le Monde, 216. Reviewed by J. Mitchell, Educational Technology Research & Development, 37(1), 97-98.

Ryan, T. F. (1992). Keynote address: Using technology: A college of education's experience. In Carey, D., & Carey, R. (Eds.), Technology and Teacher Education Annual (pp. 1-11). Charlottesville, VA: Association for Advancement of Computing.

Rysavy, S. D. (1990). Frequency and spacing of drill and practice in the learning of verbal information using a computer-based drill (Project No. 89-5). St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology, 24-27.

Rysavy, S. D., & Sales, G. C. (1990, June). Cooperative learning in computer-based instruction (Project No. 90-1). Research Bulletin #3: Technology As An Instructional Tool: What We Are Learning. St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Salehi, S., Mullinix, P., Wode, J., & Dreighton, N. (1989, March). Maryland's statewide educational technology network: Description and evaluation. Maryland State Department of Education. (ERIC Document Reproduction Service No. ED 316 188)

Salehi, S., Mullinix, P., & Wode, J. (1990, April). Promoting equity through educational technology networks. Baltimore, MD: Maryland State Department of Education. (ERIC Document Reproduction Service No. ED 322 897)

Sales, G. C. (1988). Designing feedback for CBI: Matching feedback to the learner and learner outcomes. Computers in the Schools, 5(1/2), 225-239.

Sales, G. C. (1990). Factors influencing the design, development, and implementation of instructional software. Computers in the Schools, 7(4), 135-148.

Sales, G. C., & Damyanovich, M. (1990). A model for making decisions about computer and technology implementation. In C. Warger (Ed .), Technology in Today's Schools, 22-31.

Sales, G., & Earle, J. (1990). At-home remediation via technology: An exploratory study of a computer loan program (Project No. 89-3). St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Sales, G., Tasi, B., & MacLeod, R. (1990, June). The evolution of K-12 instructional software: An analysis of leading microcomputer-based programs (Project No. 906). Research Bulletin #3: Technology As An Instructional Tool: What We Are Learning. St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Salisbury, D. F. (1992, July). Toward a new generation of schools: The Florida school year 2000 initiative. Educational Technology, 32, 7-12.

Salomon, G. (1990). Cognitive effects with and of computers. Communication Research, 17, 26-44.

Salomon, G. (1990). Studying the flute and the orchestra: Controlled vs. classroom research on computers. In R. E. Clark (Ed.), International Journal Educational Research, 14, 507-520. Great Britain: Pergamon Press.

Salomon, G. (Ed.). (1991, June). From theory to practice: The international science classroom - a technology-intensive, exploratory, team-based and interdisciplinary high school project. [Introduction to special section]. Learning: New conceptions, new opportunities. Educational Technology, 41-44.

Santoli, A. (1990, January). First lesson: Believe in yourself. Parade Magazine, 12-13.

Sayers, J., & Miller, R. (1991). The year in review: A baker's dozen of top stories of 1990. Educational Media and Technology Yearbook, 17 63-71.

Scherer, M. J., & McKee, B. G. (1991, April). The development of two instruments assessing the predispositions people have toward technology use: The value of integrating quantitative and qualitative methods. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL. (ERIC Document Reproduction Service No. ED 334 206)

Schiller, S. S., & Noll, B. J. (1991). Utilizing distance learning in a large urban school system. Tech Trends, 36(1), 23-27.

Schmidt, S. C. (1991). "Technology" for the 21st century: The effects of an integrated distributive computer network system on student achievement (Twenty-first century, computer education). Dissertation Abstracts International, 52(07), 2513. (University Microfilms No. ADG92-01940)

Schofield, J. W., & Verhan, D. (1988). Barriers and incentives to computer usage in teaching (Tech Rep. No. 1). Pittsburgh, PA: University of Pittsburgh Learning Research and Development Center.

School District U-46. (1992, April). Educational technology committee report. Eglin, IL: Author.

Schubel, R. J., & Erickson, J. G. (1992, April). Model programs for increasing parent involvement through telephone technology. Language, Speech, and Hearing Services in Schools, 23, 125-129.

Schultz, C. W. and others. (1989, November). A study of how metropolitian secondary mathematics teachers are integrating microcomputers into their classrooms. Paper presented at the annual meeting of the Mid-South Educational Research Association, Little Rock, AR. (ERIC Document Reproduction Service No. ED 317 171)

Schwartz, E. (1990). Videodiscs in education--Are schools being left behind? Instruction Delivery Systems, 4(1), 26-29.

Schwartz, J. L. (1992, Summer). Of tinkertoys, technology, and the educational encounter. Technos, 1(2), 15-18.

Scioli, F. & others. (1987). Computers in the English classroom. New York City Board of Education, Brooklyn. (ERIC Document Reproduction Service No. ED 314 755)

See, J. (1992, May). Ten criteria for effective technology plans. The Computing Teacher 19(8). 34-35.

Seidenfeld, A. R. (1991). The effects of four spelling study strategies and student performance (CAI). Dissertation Abstracts International, 52(07), 2466. (University Microfilms No. ADG92-01056)

Shanker, A. (1990). The end of the traditional model of schooling -- and a proposal for using incentives to restructure our public schools. Phi Delta Kappan, 71, 345-357.

Shaw, C. C. (1991, July). Problem-solving styles of students using software of the 'second-and-a-half kind'. Educational Technology, 14-20.

Shaw, F. S. (1990). The videoMATH project video homework adventures in middle school mathematics. New York, NY: Project established at New York University through a grant by the U. S. Department of Education.

Sherry, M. (1990, September). An EPIE institute report: Integrated instructional systems. T.H.E.Journal, 86-89.

Sherwood, R., & Hasselbring, T. (1985/1986). A comparison of student achievement across three methods of presentation of a compputer-based science simulation. Computers in the Schools, 2(4), 43-50.

Sheingold, K. (1991, September). Restructuring for learning with technology: The potential for synergy. Phi Delta Kappan, 17-27.

Sheingold, K., & Hadley, M. (1990). Accomplished teachers: Integrating computers into classroom practice. New York, NY: Bank Street College of Education. (ERIC Document Reproduction Service No. 322 900)

Sheingold, K., Hawkins, & Char, C. (1984). Thou thinkist you're the typist: The interaction of technology and the social life of classrooms. Journal of Social Issues, 40, 49-61.

Sherry, M. (1992, October). The new ILSs: Branching out. Technology & Learning, 16-29.

Shlechter, T. M. (1988). The effects of small group and individual computer-based instruction on retention and on training lower ability soldiers (Research Report 1497). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Shlechter, T. M. (1990). The relative instructional efficiency of small group computer -based training. Journal of Educational Computing Research, 6(3), 329-341.

Siemankowski, R. (1991, June). Biology: Lessons to be learned. In G. Salomon (Ed.), From theory to practice: The international science classroom - a technology-intensive, exploratory, team-based and interdisciplinary high school project. [Introduction to special section]. Learning: New conceptions, new opportunities. Educational Technology, 51-54.

Simmons, B. S. (1988, July). An annotated bibliography of the literature dealing with the relationships between the integration of microcomputers and students learning of mathematics in secondary schools. Exit project, Indiana University at South Bend. (ERIC Document Reproduction Service No. ED 301 182)

Simmons, W. (1987). Beyond basic skills: Literacy and technology for minority schools. In R. Rea and K. Sheingold's (Eds.), Mirrors of Minds. Norwood, NJ: Ablex Publishing Co.

Simon, N. M., Sales, G. C., Johnston, M. D., & Haugen, J. (1990, June). The effectiveness of computer simulation as a follow-up activity compared to traditional classroom follow-up activities (Project No. 90-2). Research Bulletin #3: Technology As An Instructional Tool: What We Are Learning. St. Paul, MN: MECC/University of Minnesota Center for the Study of Educational Technology.

Skaburskis, A. (1987, October). Cost-benefit analysis Ethics and problem boundaries. Educational Review, 11(5), 591-611.

Slavin, R. E. (1991, Spring). Reading effects of IBM's "Writing to Read" program: A review of evaluations. Educational Evaluation and Policy Analysis, 13(1), pp. 1-11.

Sledge, P. S. (1987). Differences in language achievement of kindergartners with and without experiences on the IBM computer program "Writing to Read". Unpublished doctoral dissertation, University of Mississippi. Oxford, MS.

Slee, E. J. (1989, February). A review of the research on interactive video. Paper presented at the Association for Educational Communications and Technology annual meeting, Dallas, TX. (ERIC Document Reproduction Service No. 308 818)

Smith, E. E. (1987). Interactive video: An examination of use and effectiveness. Journal of Instruction Development, 10(2), 2-10.

Smith, R. A. (1990, February). Videodisc - The next temptation. The Computing Teacher. 12-13.

Smith, R., & Sassi, A. (1988). School of the future handbook: A guide for technology implementation F. M. Black Middle School. Houston, TX: Houston Independent School District.

Smith, R. E. (1990, August). Effectiveness of the interactive satellite method in the teaching of first-year German: A look at selected high schools in Arkansas and Mississippi. Unpublished doctoral dissertation, University of Mississippi.

South Carolina Department of Education. (1991, July). Report of the Educational Excellence Team on Instructional Technology.

Staveley, K. R., & Cooper, J. (1990). The use of computers for writing: Effects on an English composition class. Journal of Educational Computing Research, 6(1) 4148.

Steams, M. S., Middleton, T., Schneider, S., & Hanson, S. (1989). Second year report: Cupertino/Fremont Model Technology School Project. Menlo Park, CA: SRI International.

Stebbins, B. (1990). Hypercard: The tool for the classrooms of tomorrow. Computers in the Schools, 7(4), 7-73.

Stein, J. S., Nachmias, R., & Friedler, Y. (1990). An experimental comparison of two science laboratory environments: Traditional and microcomputer-based. Journal Educational Computing Research, 6(2), 183-202.

Stern, D., & Cox, G. (1988). Assessing cost-effectiveness of computer-based technology in public elementary and secondary schools. Springfield, VA: National Technical Information Service, 13-18.

Stern, D., Dayton, C., Paik, I-W., & Weisberg, A. (1989, Winter). Benefits and costs of dropout prevention in a high school program combining academic and vocational education: Third-year results from replications of the California Peninsula Academies. Educational Evaluation and Policy Analysis, 11(4), 405-416.

Sterns, M. S. & others. (1991, January). Teacher-centered model of technology integration: End of year 3. Cupertino-Fremont model technology schools project research findings. Menio Park, CA: SRI International. (ERIC Document Reproduction Service No. ED 332 326)

Stevens Institute of Technology. (1992). CIESE Project. Hoboken, NJ: Author.

Stevenson, P. (1990, April). Project '85: Educational networking in Jefferson County. T.H.E. Journal, 56-58.

Stoddart, J. (1989, Winter). Media manager's column Letting AV media work for you. CJEC, 18(1), 69-73.

Stout, C. (1991, April). Telecommunications: A statewide approach to link educators. Educational Technology, 44-46.

Straker, N. (1988). Interactive video: A cost-effective model for mathematics and science classrooms. British Journal of Educational Technology, 19(3), 202-210.

Streibel, M. J. (1988, Fall). A response to Robert Heinich and Suzanne Damarin. Educational Communications and Technology Journal, 36(3), 153-160.

Strittmatter, P. (1990). European research on media and technology in education: Current Status and future directions. In R. E. Clark (Ed.), International Journal Educational Research, 14, 489-505. Great Britain: Pergamon Press.

Sugiyama, J., & Smart, C. (1992, July). From visions to reality: A plan for the use of technology in the Alameda Unified School District. Alameda Unified School District.

Summers, E., Cartwright, G., & Lukasevich, A. (1987, February). Microcomputers in special education: Using CAI to meet inservice needs in educating special learners. Educational Technology, 23-31.

Sutton, R. E. (1991, Winter). Equity and computers in the schools: A decade of research. Review of Educational Research, 61(4), 475-503.

Sutton, R. E. (1989, September). Equity issues in educational computer use. Paper presented at the New Zealand Computers in Education Society, New Plymouth. (ERIC Document Reproduction Service No. ED 316 218)

Swadener, M., & Hannafin, M. (1987, January). Gender similarities and differences in sixth graders' attitudes toward computers: An exploratory study. Educational Technology, 37-42.

Swadener, M., & Jarrett, K. (1986, September). Gender differences in middle grade students' actual and preferred computer use. Educational Technology, 42-47.

Swope, H., & Worsey, C. (1988, May/June). The media center of the future: Transforming media centers, the Montgomery County experience. Media & Methods, 12-14.

Sydow, J. A., & Kirkpatrick, C. M. (1992, April). Inject reality into your technology planning. The School Administrator, 31-33.

Tabs, E. D. (1992, June). Public elementary and secondary schools and agencies in the United States and outlying areas: School year 1990-91. Washington, DC: National Center for Education Statistics, U.S. Department of Education, Office of Educational Research and Improvement.

Taylor, K. A. (1991, June). An annotated bibliography of current literature dealing with the effective teaching of computer programming in high schools. Student research project, Indiana University at South Bend. (ERIC Document Reproduction Service No. ED 338 217)

Tennyson, R. D. (1987, February). Computer-based enhancements for the improvement of learning. Paper presented at the annual meeting of the Association for Educational Communication and Technology, Atlanta, GA.

Tesolowski, D. G., Kurth, E. L., & Kaufman, J. J. (1988, Fall). Creating a comprehensive plan for computer based instruction in a local education agency. Journal of Research on Computing in Education, 2(1), 51-69.

The Computing Teacher. (1990, October). Guidelines for software manuals. 38-43.

Thompson, A. D., Simonson, M. R., & Hargrave, C. P. (1991). Educational technology: A review of the research. Curriculum and Instruction. Ames, IA: College of Education, Iowa State University.

Thormann, J. & Anderson, M. (Eds.). (1991, August). Taking action: Ideas to promote technology integration and administrator's desk reference: Readings to promote technology integration. Technology integration: A thematic focus. Council for Exceptional Children, Reston, VA. (ERIC Document Reproduction Service No. ED 338 007)

Tidhar, C. E. (1990). Evaluation of ETV programs in Israel. Studies in Educational Evaluation, 16, 73-96.

Tiene, D., Evans, A., Milheim, W., Callahan, V., & Buck, S. (1989). The instructional effectiveness of interactive video versus computer assisted instruction. Interact Journal, 1(1), 15-21.

Tierney, R. (1989). The influence of high computer access on student's thinking -First- and second-year findings (ACOT Report #3). Cupertino, CA: Apple Computer, Inc.

Tilak, J. B. G. (1989). Center-state relations in financing education in India. Comparative Education Review, 33(4), 450-479.

Trotter, A. (1992, January). Technology in the classroom: "That's Edutainment!" The Education Digest, 57, 3-7.

Troutman, A. P., & White, J. A. (1991). Using computer technology to effectively model for prospective teachers the use of computer technology to deliver, enhance, and manage instruction. Computers in the Schools, 8(1/2/3), 131-133.

Tyre, T. (1992, August). Jostens learning's interactive media: The ultimate ILS delivers networked video. T.H.E. Journal, 14.

Ulerich, S. L., Bybee, R., & Ellis, J. (1988). Research on computers in schools: From PLATO to LOGO and beyond. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Lick Ozark, MO.

Urban Institute. (1986). Technology and the schools, 2001: The views of twenty experts. In Frances Drummer Fisher (Ed.). Referenced in Marshal, et. al.

U.S. Congress, Office of Technology Assessment. (1988, September). Power on! new tools for teaching and learning (OTA-SET-379). Washington, DC: U. S. Government Printing Office, Author.

U.S. Congress, Office of Technology Assessment. (1989). Linking for learning: A new course for education (Summary). Washington, DC: U. S. Government Printing Office, Author.

U.S. Congress, Office of Technology Assessment. (1987, March). Trends and status of computers in school: Use in Chapter 1 Programs and use with limited English proficient students (Staff Paper). (ERIC Document Reproduction Service No. ED 291 337)

U. S. Department of Education. (1990). A national directory of technology education programs. Washington, DC: Author.

U. S. Department of Education. (1992, January). The national diffusion network sharing success. Washington, DC: Author.

VanBiervliet, A., & Parette, H. P, Jr. (1989). Technology access for Arkansans: Project TAARK. Proceedings of the Planning Conference Held at DeGray Lodge 1989. Arkansas University. (ERIC Document Reproduction Service No. ED 316 982)

Van Horn, R. (1991, March). Educational power tools: New instructional delivery systems. Phi Delta Kappan.

Van Vuuren, D., & Van der Walt, H. (1990). Broadcasting research: Change and credibility. Studies in Educational Evaluation, 16, 97-113.

Violato, C., Marini, A., & Hunter, W. (1989). A confirmatory factor analysis of a form-factor model of attitudes toward computers: A study of preservice teachers. Journal of Research on Computing in Education, 22(2), 199-213.

Violenus, A. A. (1989). Vitalizing instruction in the middle grades through staff development in technological methodology. Doctoral Dissertation, NOVA University. (ERIC Document Reproduction Service No. 310 764)

Virginia Beach City Public Schools. (1988). Five Year Technology Plan. Virginia Beach, VA: Board of Education.

Virginia Department of Education. (1989, June). Six-year technology plan for Virginia. Richmond, VA: Office of Educational Technology, Author.

Virginia Department of Education. (1992). Exemplary technology program for education Technology training for Virginia educators 1990-1994. Richmond, VA: Author.

Vogel, R. (1989). A comparison of third-grade student performance in division of whole numbers using a microcomputer drill program: An alternative view. Computers in the Schools, 6(3/4), 123-129.

Von Holzen, R. L., & Price, R. V. (1990, December). Five year trends in computer students' attitudes and skill-levels. Lubbock, TX: Texas Tech University. (ERIC Document Reproduction Service No. ED 333 860)

Vooijs, M. W., & Van Der Voort, T. H. A. (1990). Teaching television: The effects of critical television viewing curricula. In R. E. Clark (Ed.), International Journal Educational Research, 14, 543-552. Great Britain: Pergamon Press.

Washington, W. (1990, October). Beyond computer planning: Managing educational computer innovations. (ERIC Document Reproduction Service No. ED 327 977)

Watkins, B. T. (1991, September). The electronic classroom: Vanderbilt courses mix film, video, graphics, sound, and text; use of the facility spreads. The Chronicle of Higher Education, A26-A28.

Watkins, J. P. (1991). Long-term effects of an integrated microcomputer project on subsequent science and mathematics achievement in Arkansas "schools" (science achievement, CAI). Dissertation Abstracts International, 52(08), 2880. (University Microfilms No. ADG92-04757)

Watt, M., & Watt., D. (1986). Making a difference with computers: Successfully integrating computer tools into the school curriculum. International Council for Computers in Education.

Waugh, M. L. (1987). The influence of interactive videodisc laboratory instruction on student achievement in an introductory college chemistry course. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Washington, DC.

Weimer, D. R. (1991, March). Computer software and copyright law. CRS report for Congress. Library of Congress Research Service. (ERIC Document Reproduction Service No. ED 342 389)

Weiss, R. (1991, August). Regional course sharing through technology pilot project. NE: Final Report at Chadron State College, Nebraska.

Weller, H. G. (1988, February). Interactivity in microcomputer-based instruction: Its essential components and how it can be enhanced. Educational Technology, 23-27.

White, B. M., Matthews, K. M., & Holmes, C. T. (1989, December). The cost effectiveness of an interactive video system for science instruction. Educational Technology, 19-23.

White, C. S. (1987). Developing information-processing skills through structured activities with a computerized file-management program. Journal of Educational Computing Research, 3(3), 355-375.

White, C. S. (1988). Media and technology use in the social studies: A status report. Unpublished paper presented at the meeting of the National Council for the Social Studies, Orlando, FL.

White, C. S. (1991). Databases and thinking skill development in social studies. Fairfax, VA: George Mason University, Instructional Technology and Social Studies Education.

Whitmer, S. (1992, February). Language arts technology budget, phase II, extend word processors pilot. Birmingham, MI: Project underway in Birmingham Public Schools.

Whyte, M. M., Knirk, F. G., Casey, R. J., Jr., & Willard, M. L. (1990/1991). Individualistic versus pared/cooperative computer-assisted instruction: Matching instructional method with cognitive style. Journal Educational Technology Systems, 19(4), 299-312.

Wicat Systems, Inc. (1991). Meeting the challanges of today's classrooms. Utah.

Wicklein, R. C. Principles of technology: The Oklahoma experiment final report. OK: Oklahoma State Department of Vocational and Technical Education (no date cited).

Wild, P. (1991). The effectiveness of inset in CAL and IT: An evaluation of the work of any advisory teacher. Computers Educ., 16(4), 289-300. Great Britain.

Wilder, G., & Fowles, M. (1992, September). Assessing the outcomes of computer -based instruction: The experience of Maryland. T.H.E. Journal, 82-84.

Wilkinson, T. W., & Sherman, T. M. (1991, November). Telecommunications-based distance education: Who's doing what? Educational Technology, 54-59.

Willis, J. (1991). Research and instructional technology: What we have and what we need. Computers in the Schools, 8(4), 115-133.

Wilson, J. (1990, February). Integrated learning systems: A primer. Classroom Computer Learning, 22-36.

Wilson, K. (1991, April). New tools for new learning opportunities. Technology & Learning, 12-13.

Wilson, R. B. (1991, June). Reflections on the project. In G. Salomon (Ed.), From theory to practice: The international science classroom - a technology-intensive, exploratory, team-based and interdisciplinary high school project. [Introduction to special section]. Learning: New conceptions, new opportunities. Educational Technology, 57-58.

Winn, W. D. (1990). A theoretical framework for research on learning from graphics. In R. E. Clark (Ed.), International Journal Educational Research, 14, 553-564. Great Britain: Pergamon Press.

Wirthlin Group. (1989). The computer report card: How teachers grade computers in the classroom (Executive summary). McLean, VA: Author.

Wise, K. C. (1989). The effects of using computing technologies in science instruction: A synthesis of classroom-based research. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco.

Wiske, M. S., Zodhiates, P., et. al. (1988, March). How technology affects teaching. Educational Technology Center, Cambridge, MA. (ERIC Document Reproduction Service No. ED 296 706)

Witt, D., & Johnston, B. (1988, September). A study of the effects of IT figures with and without support materials (Research Report No. 104). Bloomington, IN: Agency for Instructional Technology.

Wolpa, B. A., & Merha, P. A. (1991, June). Chemistry: Too many students and technology that arrives too late. In G. Salomon (Ed.), From theory to practice: The international science classroom - a technology-intensive, exploratory, team-based and interdisciplinary high school project. [Introduction to special section]. Learning: New conceptions, new opportunities. Educational Technology, 45-47.

Wood County Schools. (1990/1992). Linc Interactive televisions evaluations. Parkersburg, WV.

Woodrow, J. E. J. (1989, Summer). Teacher's knowledge of educational applications of computers. Journal of Computers in Mathematics and Science Teaching, 8(4), 31-38.

Woodward, J., Carnine, D., & Gersten, R. (1988, Spring). Teaching problem solving through computer simulations. American Educational Research Journal, 25(1), 72-86.

Yang, J-S. (1987, March). Individualizing instruction through intelligent computer -assisted instruction: A perspective. Educational Technology, 7-15.

Yonai, B., Spuches, C., & LeBlanc, G. (1990, October). Formative and summative evaluation in a health curriculum development project: The role of the university-based consulting team. Paper presented at the annual meeting of the American Evaluation Association, Washington, DC.

Younger, S. M. (1992, July). Info-line Practical guidelines for training and development professionals Understanding benchmarking: The search for best practice. Alexandria, VA: American Society for Training and Development.

Yueh, J., & Alessi, S. (1988, Winter). The effect of reward structure and group ability composition on cooperative computer-assisted instruction. Journal of Computer-Based Instruction, 15, 18-22.

Zappone, F. (1991). Using technology in education -- steps to the future. Computers in the Schools. 8(1/2/3), 83-87.

Zbiek, R. M., & Heid, M. K. (1990, October). The skateboard experiment: Math modeling for beginning algebra. In J. Johnson & K. Heid (Eds.), Computers in the curriculum: Math. The Computing Teacher, 32-36.

Zehavi, N. (1988). Evaluation of the effectiveness of mathematics software in shaping students' intuitions. Journal Educational Computing Research, 4(4), 391-401.

Zurn, M. R. (1987). A comparison of kindergartners' written and word-processor generated writing. Unpublished doctoral dissertation, Georgia State University.

APPENDIX A

TABLE 1

PARADIGMS OF TEACHING

PARADIGMS	OLD	NEW
KNOWLEDGE	TRANSFERRED FROM FACULTY TO STUDENTS	JOINTLY CONSTRUCTED BY STUDENTS AND FACULTY
STUDENTS	PASSIVE VESSEL TO BE FILLED BY FACULTY'S KNOWLEDGE	ACTIVE CONSTRUCTOR, DISCOVERER, TRANSFORMER OF OWN KNOWLEDGE
FACULTY PURPOSE	CLASSIFY AND SORT STUDENTS	DEVELOP STUDENTS' COMPETENCIES AND TALENTS
RELATIONSHIPS	IMPERSONAL RELATIONSHIPS AMONG STUDENTS AND BETWEEN FACULTY AND STUDENTS	PERSONAL TRANSACTION AMONG STUDENTS AND BETWEEN FACULTY AND STUDENTS
CONTEXT	COMPETITIVE INDIVIDUALISTIC	COOPERATIVE CLASSROOM LEARNING AND COOPERATIVE FACULTY TEAMS
ASSUMPTION	ANY EXPERT CAN TEACH	TEACHING IS COMPLEX AND REQUIRES CONSIDERABLE TRAINING

TABLE 2

HOW TECHNOLOGY CAN SUPPORT LEARNER-CENTERED ENVIRONMENTS

Component	Technology Support
1. HOTS	Simulation, tools, state of art media center to learn research skills
2. Past, Present, Future, Focus	Simulations/ scenario construction, point-of-view, historical time-line
3. Whole Person Education	Multimedia: video reports/ presentations, computer/midi interface, musical composition, desktop publishing
4. General Education	Keyboard..., computer literacy application, programming
5. Transdiciplinary Education	Voyage of Mimi, problem solving software
6. Collaboration	Discourse, cooperative products
7. Communication	Word processing, graphics, hypermedia presentations
8. Reflective Practice (Meta cognition	LOGO< screen reorder
9. Global Stewardship	Kidsnet, AppleLink, Apple Global Series
10. Human Values	Debate about intellectual property, equity
11. Active Learning	Interactive learning technology
12. Service Learning	Desktop Publishing, graphics arts
13. Life-long Learning	Computer is life-long learning tool
14. Personalized Learning	ILSs
15. Process and Inquiry Approach	Word processing, probeware research tool
16. Master Apprentice Approach	Database of masters
17. Communication and Information Processing	Network for E-mail, info transfer television broadcasting. Enlarge library resources through use of data bases. Voice mail messages link home and school.
18. Increase Redundant skills in staff	Networks - databases-ability to share information among teams.
19. Learning to Learn	Create Information Center to support research and inquiry.
20. Match Technological Diversity of Community	

Sources:

Ray, D. (1991a, March). Technology and Restructuring. Part I: New Organizational Directions. The Computing Teacher, 18(6), 9-20.

Ray, D. (1991b, April). Technology and Restructuring. Part II: New Organizational Directions. The Computing Teacher, 18(7), 8-12.

TABLE 3

COMPUTER USE IN SCHOOLS

	ELEMENTARY	MIDDLE	HIGH
TYPE	Apple, Commodore	Apple, Commodore	Apple, IBM, Tandy
ADMINISTRATIVE USE	attendance, wordprocessing	attendance, wordprocessing	attendance, wordprocessing, grades schedule
TEACHER USE	room decorations-banners, wordprocessing, assignment sheets, worksheets, tests	room decorations-banners, wordprocessing, assignment sheets, worksheets, tests	wordprocessing, assignment sheets, worksheets, tests
INSTRUCTIONAL	drill & practice	wordprocessing, discovery, problem-solving	work-processing, discovery, problem-solving
CURRICULAR	language arts, spelling, general math, science, social studies	general math, science, social studies	algebra/geometry, business math, accounting
SOFTWARE USED	logo, basic	basic, science	Wordperfect, Cobol, Fort, Basic
PRINCIPALS RATING AS VERY IMPORTANT	21%	61%	75%

Source:

Root, T. & Rowe, R. (February 1987). Principals' perceptions of computer use in administration and instruction. (ERIC Document Reproduction Service #302 336)

TABLE 4

TRAINING COMPONENTS OF STATE PLANS FOR TECHNOLOGY

Component	States who have identified components in their plans
State funding for technology training	AR, CA, DE, DC, FL, HI, IL, IN, MD, MA, MI, MN, MO, NH, NJ, NY, NC, OH, OR, PA, WA, WY
Preservice and/or inservice technology training	AR, CA, CT, DC, FL, HI, IN, KS, DE, GA, ID, KY, LA, TX, MN, MT, TN, UT, NE, VA, NC,WA, WV, OH, WI, WY, OK, PA, SC, SD
Professional development/training center	VA, CA, CT, IL, IA, MI, MA, NJ, NY, OH, PA, UT, WA, WI
State-level technology training offered to teachers	AL, IN, NJ, TN, WV
District-level technology training offered to teachers	AK, CO, DE, DC, FL, GA, HI, ID, KN, KS, KY, LA, ME, MD, MN, MS, MO, NH, MI, NC, OR, PA, TX, UT, VA
School-level technology training offered to teachers	AZ
Technology training by a for-credit course paid for by teacher	ND, NE, SC, VT
Teacher education	TX, SC, CA, VA, RI, TN, VA, WV, WI, NJ, NY, OH, OK, MA, MI, MN, MO, MT, NH, PA
Staff development	CT, HI, IL, NY, NC, OR, SC, WA, WI
Core service training	TX, VT, CA

Sources:

Brennan, M. A. (March 1992). Trends in Educational Technology 1991 ERIC Digest. (ERIC Document Reproduction Service No. ED 343 617)

Bruder, I. (October 1988). Eighth annual survey of the states. Electronic Learning, 8(2), 38-45.

Bruder, I. (October 1989). Ninth annual survey of the states. Electronic Learning, 9(2), 22-28.

U. S. Congress, Office of Technology Assessment. (September, 1988). Power on! New tools for teaching and learning (OTA-SET-379). Washington, DC: U.S. Government Printing Office.

TABLE 5

COMPONENTS OF STATE PLANNING FOR TECHNOLOGY IN EDUCATION

Component	States who have identified components in their plans	Comments
FUNDING		
State grant monies available for educational technology	AL, CA, CT, GA, IL, IA, KY, ME, MD, MS, MI, MN, NV, NH, OK, PA, SC, UT, VA, WA, WV	Funding remains the most important aspect in the advancement of educational technology.
Chapter 1 funding	AL, DC, IN, LA, MI, MO, NV, NJ, RI, WA	
Chapter 2 funding	AL, CO, DC, GA, ID, IL, IN, LA, ME, MI, MO, MT, ND, NE, NH, OH, OR, PA, SD, TN, TX, WA, WY	
Federal Title II funds used for technology	AK, AZ, IN, KS, MI, MO, NV, NH, NC, OH, PA, RI, TN	
Centralized purchasing agent(s)	AZ, CT, IA, TX, VA, VT	
Low interest loans	IN	
Incentives for business partnerships	TX, VT, SC	
Business community involvement	AR, CA, CT, GA, HI, IL, KY, MA, MD, MN, MO, NH, OK, OR, UT, VA, WA, WV	

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TABLE 5 (continued)

Component	States who have identified components in their plans	Comments
Educational Technology Funded by:		
State funding only	AR, CA, CT, DE, RI, SC	
Federal funding only	CO, MS, MT, TN, TX, VT	
Both state and federal funding	AL, AK, AZ, FL, GA, HI, IA, ID, IL, IN, KS, KY, MA, MD, ME, MI, MN, MO, NC, ND, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SD, UT, VA, WA, WI, WV, WY	
No funding for educational technology	LA, NE	
State funding for technology	AR, CA, DE, DC, FL, HI, IL, IN, MD, MA, MI, MI, MN, MO, NH, NJ, NY, NC, OH, OR, PA, WY	Computers for Teachers program which gives teachers a computer for home or school use, or both. Teachers are supplied with training, soft-ware, and maintenance.

Sources:

Brennan, M. A. (March 1992). Trends in Educational Technology 1991 ERIC Digest. (ERIC Document Reproduction Service No. ED 343 617).

Bruder, I. (October 1988). Eighth annual survey of the states. Electronic Learning, 8(2), 38-45.

Bruder, I. (October 1989). Ninth annual survey of the states. Electronic Learning, 9(2), 22-28.

U.S. Congress, Office of Technology Assessment. (1988, September). Power on! New tools for teaching and learning (OTA-SET-379). Washington, DC: U.S. Government Printing Office.

TABLE 6

STATE EDUCATION FUNDING

	AL	AK	AR	AZ	CA	CO	CT	DC	DE	FL	GA	HI	ID	IL	IN	IO	KS
Development of Instructional Software			X		X	N/A			N/A								
Development of curriculum materials that use commercial software	X		X		X		X	X		X		X			X		X
Development of instruct-ional television or video	X	X	X	X	X		X	X		X		X	X	X			
Development of instructional materials that use commercial video	X		X		X												
Development of guidelines that encourage or require the use of technology in the curriculum		X	X		X		X	X		X		X	X		X	X	X
Operation or development of processes to review instructional software	X		X	X	X			X		X	X	X			X		X
Operation or development of distance learning projects	X	X	X	X			X			X	X	X	X	X	X	X	X
Operation or development of software or video preview centers	X	X	X	X	X		X	X		X	X	X		X	X		X
Operation or development of systems to distribute soft-ware electronically			X	X				X					X				X
Operation or development of electronic bulletin boards	X	X	X	X			X	X		X		X	X	X	X		X

TABLE 6 (continued)

STATE EDUCATION FUNDING

	KY	LA	MA	MD	ME	MI	MN	MO	MS	MT	NC	ND	NE	NH	NJ	NM	NV
Development of Instructional Software	X	N/A					X	X				X				N/A	
Development of curriculum materials that use commercial software	X			X	X	X	X	X	X		X						
Development of instruct-ional television or video			X	X	X	X	X	X			X		X		X		
Development of instructional materials that use commercial video						X	X	X					X				
Development of guidelines that encourage or require the use of technology in the curriculum	X						X			X	X				X		X
Operation or development of processes to review instructional software				X			X		X	X	X				X		X
Operation or development of distance learning projects	X		X	X	X	X	X	X	X	X	X	X	X	X	X		
Operation or development of software or video preview centers	X			X	X	X	X	X	X	X	X		X		X		
Operation or development of systems to distribute soft-ware electronically	X			X			X	X							X		
Operation or development of electronic bulletin boards	X			X	X		X		X	X	X	X	X		X		

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STATE EDUCATION FUNDING

	NY	OH	OK	OR	PA	RI	SC	SD	TN	TX	UT	VA	VT	WA	WI	WV	WY
Development of Instructional Software	N/A				X	N/A			X	X	X		N/A			X	N/A
Development of curriculum materials that use commercial software					X					X	X					X	
Development of instruct-ional television or video		X			X		X	X			X	X				X	
Development of instructional materials that use commercial video					X											X	
Development of guidelines that encourage or require the use of technology in the curriculum					X				X	X	X			X	X	X	
Operation or development of processes to review instructional software			X	X	X		X	X	X	X	X					X	
Operation or development of distance learning projects		X		X	X		X	X	X	X	X	X			X	X	
Operation or development of software or video preview centers		X			X		X	X		X	X	X			X	X	
Operation or development of systems to distribute soft-ware electronically				X	X						X					X	
Operation or development of electronic bulletin boards				X	X		X		X	X	X	X		X	X	X	

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SOURCE: Bruder, I. (1989, October). Ninth annual survey of the states. Electronic Learning, 8(2), 41-42.

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TABLE 7

ANNUALIZATION FACTORS FOR FACILITIES AND EQUIPMENT RESOURCES

Resources	Values	Factors*
Classrooms	33	.0978
Furniture	20	.1115
Textbooks	5	.2588
Microcomputer hardware	8	.1824
Microcomputer software	4	.3104

*Lifetime annualization factors for an annual interest rate of 9.25 percent.

TABLE 8

COMPONENTS OF STATE PLANNING FOR TECHNOLOGY IN EDUCATION

Component	States who have identified components in their plans	Comments
PLANNING:		
Local plan required	CA, TX, VT, WI	
Long range plan established	AR, CA, DE, FL, GA, HI, ID, IL, IN, MA, ME, MI, MN, NC, NE, NH, NJ, NV, NY, TN, WI	
Long range plan being developed	AL, CO, CT, KY, ME, MS, ND, TX, VA, UT, VT, WY	
No long range plan	AZ, IA, KS, LA, MO, MT, NM, OH, OK, OR, PA, SC, SD, WA, WV	
Technology inventory	VT	
SEED (a multi state evaluation model)	AL, FL, GA, MS, NC, SC	
STANDARDS:		
Software/courseware	CT, FL, MN, MO, NC, ND, NM	
Textbook/material adoption	TX	
Facilities	WV	
Curriculum	CA, KY, MD, MI, MO, NY, OH, OK, OR, SC, TN, TX, UT, VT, WA, WV, WI	

TABLE 8 (continued)

Component	States who have identified components in their plans	Comments
Instruction	NY, WV	
Equipment	VA, VT	High variability exists regarding student access to computers within and across state and district levels.
Hardware	FL, MD, MO, NC, NH, NM, NY, PA, TN, TX	Hard/software adoption policies do not appear in many states.
PROGRAMS:		
Statewide Telecommunications increasingly networks	TX, SC, CA, VA, AL, CO, DE, IL, CT, GA, NJ, NY, PA, FL, ME, TX, WV	
Distance learning courses are utilized	AK, AZ, AR, CT, IL, IA, KS, MA, MN, MS, NC, ND, OK, TX, VA, WY, MO, NE, NH, NY,	Broadcasted by satellite to teaching centers in other areas. Many states employ distance education technology to extend educational improvements to rural schools. Some states offer foreign language distance learning courses. Distance education is evident at almost every education level in almost every sector.
States offering distance learning projects	AZ, CA, DE, FL, KY, LA, NJ, NH, ME, OR, TN, VT, WI	

TABLE 8 (continued)

Component	States who have identified components in their plans	Comments
Student computer literacy requirement/proficiency program	FL, LA, ME, NM, RI, SD, TN, TX, VA	State computer literacy requirements decreasedfrom 11 states to 9 states in 1988
RESEARCH AND DEVELOPMENT:		
Research/evaluation	DE, IN, KY, MD, MN, NH, NJ, NY, TX, VT, VA, WV, FL, CA, AZ, AR, MI, VA, MT, WV, WY	
Research consortium	TX, SC, VT, IN, CO	
Technology review center	TX, VT, CA	
Demonstration sites	TX, SC, CA, MN, OH	
Home/school projects	CA	

Sources:

Brennan, M. A. (March 1992). Trends in Educational Technology 1991 ERIC Digest. (ERIC Document Reproduction Service No. ED 343 617).

Bruder, I. (October 1988). Eighth annual survey of the states. Electronic Learning, 8(2), 38-45.

Bruder, I. (October 1989). Ninth annual survey of the states. Electronic Learning, 9(2), 22-28.

U. S. Congress, Office of Technology Assessment. (1988, September). Power on! New tools for teaching and learning (OTA-SET-379). Washington, DC: U. S. Government Printing Office.

APPENDIX B

Focus Questions for Literature Review

In order of priority determined by team voting:

A. Technology and Education

-How does technology change the format of texts, instructional materials, etc.?
-How is technology being used in early childhood, pre-adolescent, and adolescent?
-How does technology change as students move from early childhood to pre-adolescent to adolescent?
-How is technology used for informal instructional decision-making?
-How is technology essential to meeting needs of student learning styles?
-How does technology change the teacher role to learning facilitator?
-How technology drive may drive different instructional philosophies?
-How does technology enhance/detract from learning (developmentally appropriate environment)?

B. Restructuring

-How essential is technology in restructured school?
-Role of technology in restructured school.
-New teaching methods/courses.
-How is technology helpful in implementing a common core concept?
-How does technology change as restructuring is phased in?

C. Access

-Student use of technology in home--linkages.
-How to make technology more attractive to girls overcoming gender bias?
-How are resources allocated across grades, building areas, programs areas, schools and school divisions?
-How is technology used to eliminate disparity, increase information access, participate in resource sharing?
-What happens when technology is removed?

D. Planning Models

-How states follow up and evaluate plans and implementation .
-Current integrated state technology planning models.
-Identify what technology models have been successfully replicated and spread.
-How can a state plan incorporate planning needs at local level?
-What are policies concerning copyrights?

E. Training: Inservice and Staff Development

-Actual demos of technology.
-Staff/administration training.
-Where is technology training and how often does it occur?
-What are competencies of the year 2000 educator (teacher, central office, state department)?

F. Assessment of Student Performance

-Link to outcomes-based education.
-What gets biggest bang for buck, re achievement?
-Cost vs. increase in performance; skills vs. alternatives.
-What technology uses have increased standardized test scores? and by how much?
-How does technology promote outcome focused education (alternative assessments)?

G. Teacher Education: Preservice/Certification

-Most effective ways of teaching teachers about technology.
-How is standardization of personnel and educational technology handled? Technology for all teachers?
-What is current "best practice" in teacher education?
-How is technology education incorporated in and throughout curriculum?

H. External (parent, community, business, legislative)

-How much money is placed in schools by parents and community organizations?
-Ways technology can promote/prevent parental/community involvement in education.
-Cases of business-led partnerships, re: technology.
-How are jobs changing the role of technology in education?
-How justified for legislative spending? What states lead?
-What policies exist at state/local levels regarding gifts?

I. Facilities

-How changes in technology affect design of new schools.
-Implications for funding? physical plant renovations.
-What are the operating, personnel, capital, and maintenance costs of different technologies?
-Replacement vs. upgrade? When?

J. Evaluation of Technology Methods

-Capturing administrative/teacher/parent/student information on technology's effectiveness and value.
-Alternative methods of evaluation for technology-based learning.

Contract items:
timeliness? last five years?
holes which exist
ERIC as groundwork to set parameters
meta-analysis - synthesis of works
conclusions - implications for further research
format? (APA?)
prospectus
periodic reviews
DOE article submissions
intellectual property - publication
dissemination authority
record storage - articles
machine - readable format