BURGEONING MARKETS

A five-year-old sitting in front of a computer monitor is interacting with an on-screen zookeeper who is feeding baby animals and giving a lesson in measuring. Nearby, a classmate is directing the movements of a computer-animated dog built from blocks that is teaching about combinations of shapes. On a third monitor a fellow student explores the properties of primary numbers with the computerized image of a boy blowing soap bubbles. All of these interactive lessons are being controlled by a single file-server computer, as are dozens of other lessons being shown on monitors throughout the school.

Just a few years ago such capabilities would have seemed many years away. But systems like this are already being used in some schools across the United States. To the extent that educators are able to use the full interactive capabilities of these powerful new devices, technology is already catalyzing the reinvention of schools.

Powerful learning systems are also showing up in homes. Today about a third of the households in the United States contain a personal computer of some kind, and purchases of hardware and software for home use are accelerating. Led by companies such as Broderbund Software Inc., Davidson & Associates, and the Learning Company, sales of home learning programs have been growing by 50 percent a year. With the entry of large firms like Nintendo, Microsoft, and Paramount into the home education market, sales of education software for the home are projected to surpass $1 billion annually by the end of the decade.

The market for software in the schools is even larger. In the 1993-94 school year, schools spent over $600 million on educational software, and the amount is projected to grow by 20 percent per year.

However, steady growth does not mean an easy road for the companies trying to serve the school market. Funding for public education is tight and comes from many different sources. The market is also fragmented and diverse, which makes it difficult for companies to target education customers. The best school software is different from home software, taking advantage of groups of students and teachers to promote communication and collabora-

"Technology is competing with gymnasiums, with the acquisition of new school buses, with a wide range of things that schools have to spend their dollars on.... So while there is a very definite role for technology, we have to identify what the needs are in a school system. How can technology effectively help a child and effectively support the needs of a teacher?"
—Proctor Houston, Josten's Learning Corporation

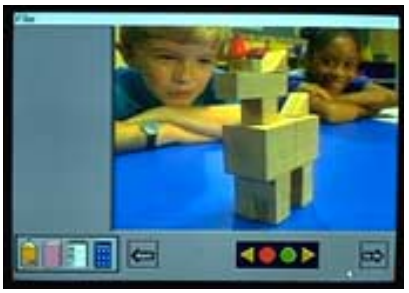
"Many of the products that are popular in the home or retail portion of the business are also products that are popular in the school market. So the home-school connection is not as far away as you may believe."
—Forest Barbieri, Educational Resources

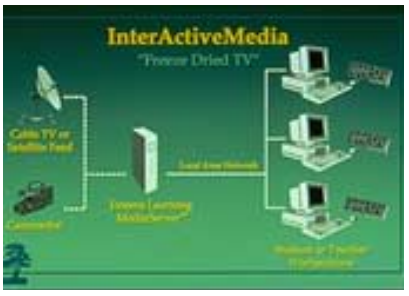
The Educational Hardware and Software Markets

Estimated K-12 Public School Technology Expenditures in Millions of Dollars

	1991-92	1992-93	1993-94
Non-ILS* Hardware	1,146.4	1,315.9	1,451.3
ILS Hardware	144.8	172.4	252.5
Non-ILS Software	347.4	412.8	459.6
ILS Software	90.1	158.6	168.1
Other	56.6	68.8	95.4
TOTAL	1,785.4	2,128.5	2,426.8

*ILS-Integrated Learning System





In "Feeding Time" (top), a videotaped zookeeper asks for help in feeding baby animals; in "Geodog" (middle), students use the computer to control an animated dog made of blocks. These two programs and dozens of others can run simultaneously under the control of a single computer, with additional input from satellite links or videocameras (bottom). These so-called Integrated Learning Systems (ILS) offer comprehensive and individualized instructional activities that are orchestrated by a central computer.

tion. And a suspicion of technology lingers among many educators, particularly among those who have seen highly touted technologies fail in the past.

Parents have been an important prod to many schools. As they buy digital technologies for use in the home, they see how significant these technologies are in the lives of their children. They then begin to ask why the same capabilities cannot be offered in schools.

Yet the job of outfitting schools with the most recent technologies will not be easy. Today U.S. schools have about 3 million computers installed, an average of about 30 per school. But many are older and cannot run the more sophisticated and interactive software being developed today. The numbers of more powerful computers, CD-ROM drives, videodisk players, and network connections are increasing, but not at a rate that will enable most students to use these technologies. Similarly, sophisticated educational software that takes advantage of the capabilities of new systems is just starting to appear.

> **"One of the exciting things that we can do with this wonderful new technology is to engage young people's minds in a way that has never been done before. With the kinds of simulations that we can create, we can actually take children and put them into worlds that they have never seen before."**
> —Laura London, Autodesk, Inc.

Given the pace at which the market is changing, many school systems are reluctant to make a strong commitment to educational technologies. But their reluctance is misplaced. The rapid rate of change today is an opportunity, not a problem. The objective for schools should not be to buy into a given technology and then set about using that technology to do what they have always done. Schools need to use constantly changing technology to achieve their underlying objective of preparing students to live in a constantly changing world.

The allure of video games spans all ethnic groups and many ages, offering an engaging entrée into the world of information technologies. As schools embrace the goal of educating students for the information age, the line between education technologies and information technologies will blur, forcing educators to reexamine the educational potential of technologies that are used widely outside of school.

> **"When you ask a parent what is the number one thing that is important in an educational piece of software, surprisingly the answer is 'that my child likes it.' It has to be fun enough to compete with video games."**
> —Bill Dinsmore, The Learning Company

With more than 23 million computers in American homes, the consumer demand for educational and entertainment products and services has created a substantial economic market that is surpassing the professional and business markets for new information technologies. This new and quickly growing market is supporting new ventures and services and is transforming the companies that helped create the information revolution.

Expansion and turbulence within the entertainment industry, the textbook publishing industry, and the computer hardware and software industry are translating K-12 educational possibilities into K-12 educational realities. Educators, parents, and students are quickly learning with their home computers what new products and services offer. And as the cost of buying and using these new products drops, these consumers are building a base of experience that will contribute to lifelong learning.

OPPORTUNITY TO CHANGE

The integration of computers into the classroom is just one small part of what will be needed to reinvent schools. Consider, for example, what an average day could be like for the high school student of the future. After breakfast, Jane logs onto the school's mainframe from home to upload her homework assignment. The work is stored in her electronic portfolio, where she and her teachers have been tracking Jane's progress throughout her high school years. Then Jane spends some time reviewing the original manuscripts of the Federalist papers, all fed to her house by fiber optic cable from the National Archives in Washington, D.C.

Jane is scheduled to take part in her practicum this morning, so when she leaves the house she heads for the hospital, where she and a group of other students are learning the principles behind a new imaging device and how to operate it. On the terminal at the hospital she reads a note from her biology teacher that a video-conference has been scheduled for one o'clock that afternoon. Still there's enough time to stop by an arcade at lunchtime to check out the hot new virtual reality game.

"Why, at the beginning of the 1980s, did 500 of the top Fortune 1,000 companies not survive into the nineties? They couldn't learn how to improve or dramatically revolutionize what they were doing."
—Margaret Evans Gayle, Triangle Management Group and 21st Century Future Corporation

The video conference at Jane's school involves students from five different classrooms around the country. They've been studying evolutionary pressures on microorganisms caused by groundwater contamination. The virtual classroom is joined today by a professor from Canada who has been studying the same subject, and he briefly describes some of his findings and takes questions from the assembled students.

The day has been a busy one for Jane, but she'll need to catch up with a few subjects after school that she missed during her practicum. When she leaves the school she takes with her a CD-textbook—a text that includes a CD-ROM illustrating the principles described in the book.

All of the technologies needed to conduct this kind of education already exist. Only the information infrastructure and personal skills needed to make such an education a reality are still missing. This new, all-encompassing form of education—termed hyperlearning by writer Lewis Perelman—combines new technologies, new educational arrangements, and a

(Above) In the interactive program "School Life" from Jostens Learning Corporation, students put together a sequence of scenes for a movie they are creating. The use of technologies that span activities that are now largely separated—time spent at home, at school, at the movies—offers a way for educational endeavors to permeate everyday life.

The latest virtual reality devices, such as this system from Virtuality Entertainment, Inc., can be networked to allow more than one person to share the same virtual experience. The use of such technologies for education will open up large and rapidly expanding markets for business, creating an entrepreneurial engine that will help drive the reinvention of schools.

"It isn't a matter of intellectual debate as to whether or not we will or will not have technology. We will have technology, and it will change education. One of these days, every student will have access to a large database and a computer, and then we will have to ask the question: What is the educational enterprise going to do?"
—Alvin Trivelpiece, Oak Ridge National Laboratory

much deeper understanding of how people think and learn to imbue the entire day with learning. In its effects on schools, it reflects similar changes going on in business, where the transition to a knowledge economy and intense competition are forcing companies to reengineer their basic procedures.

As technology moves from the periphery to the center of education, it is creating many new opportunities for established businesses, for startup companies, and for venture capitalists to make a profit while serving educational ends. The linkages between technologies used in school and technologies used at home further increase the size of this market. By making educational technologies profitable, these trends could unleash a powerful entrepreneurial force within education.

> "Educational technology is an perfect example of an outstanding dual use technology where [the defense department] can undertake collaborative activities that will push to the forefront the application of technology in education."
> —John M. Deutch, Deputy Secretary of Defense

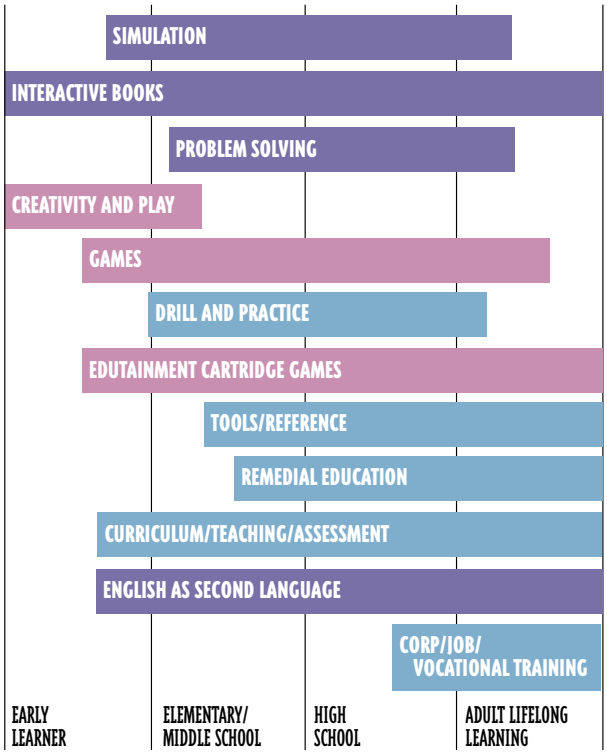
The much greater involvement of the private sector in education will inevitably be shaped by developments within both government and private industry. The consumer electronics, computer, software, entertainment, cable television, and telecommunications industries are all being drawn into a web of interconnections. These partnerships and synergies will provide new ways to use and interact with information beyond what we see today.

Government at all levels must ensure that education receives adequate attention in this communications revolution. The huge markets for entertainment, personal communication, and business information could be powerful levers for educational technologies, but the public and private sectors must work together to make education a priority.

Cecilia Lenk and David Dockterman of Tom Snyder Productions, Inc., lead the convocation audience through a session of "The Great Solar System Rescue." In the interactive, videodisc-based program, groups of students search for space probes lost in the solar system. Using data they uncover during their search, such as the relative mass of the Earth and Venus (below), students work cooperatively to form theories about each probe's location.

Though it incorporates many of the elements of a game, "The Great Solar System Rescue" is a carefully constructed educational tool. Many of the other educational products now available through the information technologies shown at right draw on role playing, reward structures, and cooperative activities to encourage learning.

THE EDUCATIONAL MARKET



Businesses and venture capital are attracted to good ideas, and the new markets for educational technologies are already drawing considerable attention. But for these investments to pay off they must lead to products and services that are both interesting and based on national standards and systemic reform.

The potential for crossover between the educational and business systems is great. Educators can use new technologies to invest in learning activities, while venture capitalists can invest in educational products and services as a way of developing new markets. Children can gain access to interesting educational technologies, educators can benefit from children who are more interested in learning, and investments made today will produce both short-term and long-term economic returns for the companies and individuals who make them.

LEARNING ABOUT LEARNING

What is the difference between a student learning multiplication tables from a textbook and another student solving similar problems with an interactive computer?

Aren't both simply acquiring new information that they can later apply to real-world problems?

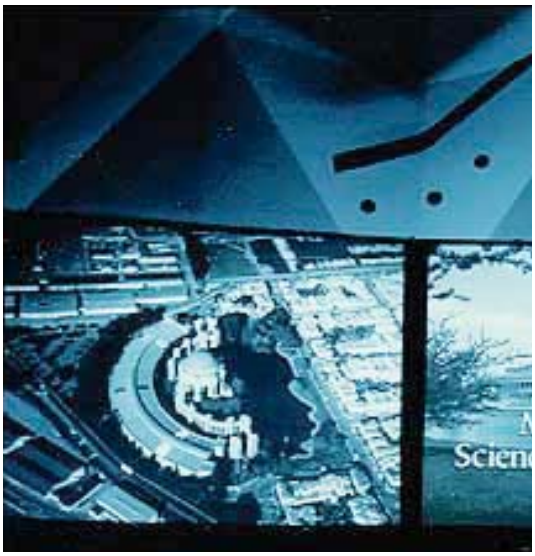
Recent research into how children learn has provided surprising new answers to these questions. In the past, the student learning straightforward tasks from a book was the model upon which education was based. According to this view, students first had to master basic skills before they could move on to higher-order skills. School curricula therefore built up knowledge layer by layer, with each layer dependent upon what went before. Multiple choice tests measured whether the basic skills had been learned. Once students had demonstrated their mastery of the material, they could move on to the next level.

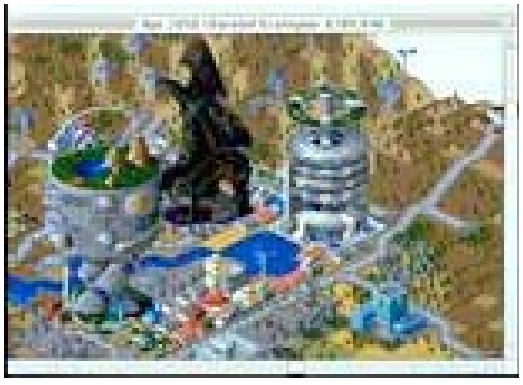
This model of learning has been turned on its head by the past two decades of cognitive research. Scientists have shown that even the youngest students come to school with quite sophisticated theories about the world. Children have an intuitive understanding of language, numbers, and science based on their previous experiences. They have complex thinking processes that they apply to problems, even without a mastery of basic skills. By ignoring this preexisting base of knowledge, schools miss a tremendous opportunity both to place new knowledge in context and to challenge preexisting ideas that are mistaken.

> "Kids have considerable knowledge. They have an intuitive physics. They have invented algorithms and mathematics before they come to school. They have substantial oral literacy. They invent spelling systems. All of these are facts that educators must come to hear, see, and learn to use as resources for new learning."—Roy Pea, Northwestern University

True, students may master the basic skills schools strive to teach, as measured by multiple choice tests. But change the terms of a test slightly, or ask students to apply their knowledge to real-world problems, and they fail. For example, students may learn all about the tilt of the Earth and its orbit around the sun, but they remain unable to tell you why the northern hemisphere is colder in winter and hotter in summer.

> "Kids learn well in conditions where they have to actively grapple with stuff, interpret, judge, make sense, in some sense argue about it. They have to have their hands on the materials."
> —Jan Hawkins, Bank Street College of Education





In the computer simulation SimCity created by Maxis, Inc., users build a city of the future that behaves according to the complex dynamics of current cities. Says Jeff Braun, the President of Maxis: "People learn best through direct experience and experimentation. Many things a child would like to participate in are not available to them. So simulations are the next best things to actually doing."

In the SuperSchool demonstration area at Chicago's Museum of Science and Industry (above), students control monitors that explain how light acts as a messenger in fiber optic cables.

A student learns about the defense mechanisms used by the body to combat viral infections at the "Viral Attack" exhibit at San Francisco's Exploratorium. The exhibit was built as part of the National AIDS Exhibit Consortium.

Cognitive research is also demonstrating that intelligence is a much more multidimensional attribute than previously supposed. Schools have tended to focus on just a few facets of intelligence—logical analysis and language, in particular. But individuals can also excel in other areas, including the grasp of spatial relationships, the understanding of music and sound, the use of the body to solve problems, or the intuitive understanding of other people and of themselves. These dimensions of intelligence give every individual a particular set of strengths as unique as a fingerprint.

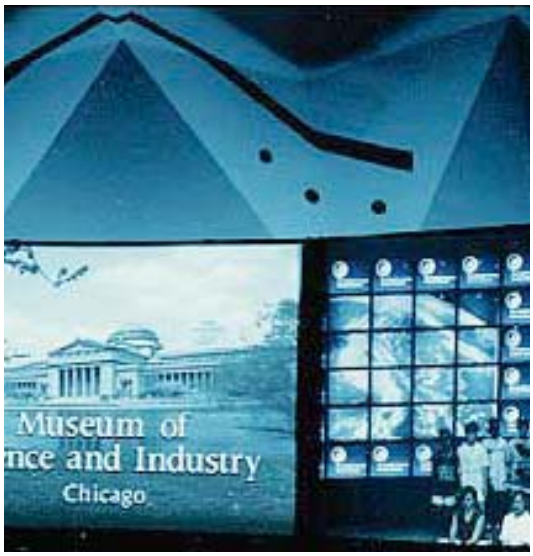
> "Individualizing the instructional process is certainly a necessary provision, but it is not sufficient. Students have to have an opportunity to engage in what might be called playful exploration."
> —Richard Atkinson, University of California at San Diego

The new findings of cognitive research provide a blueprint for the restructuring of education. In classrooms that have sought to apply these findings, students are making their own scientific hypotheses and are testing them with experiments of their own design. Students are working together in groups to solve problems, giving knowledge a much-needed social context. Traditional pencil-and-paper tests are giving way to assessments embedded in learning that are based on student portfolios, notebooks, and projects.

This style of education looks strikingly similar to the learning that is going on in another kind of educational institution: science museums. In science museums throughout the country, students are learning by interacting with displays, manipulating objects, and solving problems posed by an exhibit. The successes and limitations of science museums in education are providing valuable lessons both for schools and for parents.

The recent findings of cognitive research reemphasize the tremendous potential of the new technologies now beginning to appear in schools. Through multimedia or networking technologies, computers are now powerful enough to place new knowledge within a proper context for learning. For example, an analytic thinker might study a play through a careful reading of the text. Another student more attuned to the spoken voice may learn best through an acted-out version of the play. The range of experience made possible by digital technologies allows education to take advantage of each person's individual strengths.

> "We live in an interesting time where each of us every day lives a little less in the real world and a little more inside of different kinds of synthetic environments. . . . And as we develop technologies that empower even deeper immersion in a wider variety of artificial realities, what are the implications for learning and what are the implications for redesigning education?"
> —Chris Dede, George Mason University



The Exploratorium in San Francisco, the Museum of Science and Industry in Chicago, and the Franklin Institute in Philadelphia (shown from left to right in the auditorium at the National Academy of Sciences) have been pioneers in building exhibits that engage visitors through hands-on and interactive learning.

Cognitive research of recent decades has shown that earlier theories of learning did not take into account the intuitive capability that young children have to process complex thoughts, even in the absence of basic skills traditionally instilled in the young as "building blocks" of learning. Nor did earlier theories recognize the extent to which complex learning skills begin developing at preschool ages.

The innate learning capabilities of the young are now being joined with interactive learning skills achieved through encounters with game and other information technology. The new challenge for education is twofold: First, what has already been learned about learning must be applied to aid the general teaching and eduscational reform effort. Second, while systemic reform goes forward, research into the changes in learning posed by interactive technologies must be vigorously supported so tomorrow's schools will profit from improved understandings of learning in the information age.

Traditionally the federal government and a few philanthropic foundations have been the sources of support for cognitive research by scientists and scholars. These institutions must be encouraged support research that will improve our understanding of how the children of the information age will learn.

THE ROLE OF GOVERNMENT

Governments at all levels will drive the reinvention of schools. The local level is where reform will be implemented—classroom by classroom, school by school, community by community. Thorough reforms cannot take root without a commitment at the local level.

The state level is where many reforms will originate. Since the mid-1980s the governors have been leading the school reform movement, and many of the boldest reforms are taking place on a statewide level. California is already teaching science to many of its middle school students using multimedia systems. In Texas, teachers can get unlimited access to the Internet and to local educational networks through the Texas Educational Network.

The federal government, though it provides only 6 percent of the funding for K-12 education, will also play a critical role. Through programs like the Statewide Systemic Initiatives supported by the National Science Foundation, the federal government can catalyze reform at the state and local level. Also, through its policymaking functions, the federal government helps set the educational agenda. The Goals 2000: Educate America Act, for example, is designed to lead the way in establishing national education standards and provides grants to states and districts that implement reform plans. In addition, the federal government will influence the use of technology in schools through the policies it adopts in developing the National Information Infrastructure.

"The main reasons the President and the Vice President are so excited about information technology is because they believe it can fundamentally change the way we teach ourselves and the way we teach our children."
–Jack Gibbons, White House Office of Science and Technology Policy

Jack Gibbons

Closely related to its policymaking role is the federal government's regulation of telecommunications. The federal government is now considering comprehensive legislation that would reformulate telecommunications regulations dating back to the 1930s. These regulations, together with those imposed by states, ensured universal access to telephone service and widespread public access to other forms of media. The federal government and states now face the much greater challenge of ensuring access in a telecommunications system characterized by fierce competition among companies and technologies and by constant change.

The government can have an important influence on information technologies through its demonstrations of new capabilities. In making its own vast stores of information available electronically, for example, the government can highlight the scope of information technologies, help

Roy Romer, Governor of Colorado, addresses the convocation through a satellite link. Bill Blakemore of ABC-TV, at the podium, served as the convocation's interlocutor.

"Technology is a tool which, if properly applied, can help transform our educational system so that our students can lead the world in math and science achievement rather than watching TV."
–E. Benjamin Nelson, Governor of Nebraska

establish markets for new technologies, and shape standards that will allow different systems to communicate.

The government's traditional support for research and development will also influence educational technology. Government-supported work on advanced hardware, educational software, networks, experimental testbeds, demonstration projects, and other pioneering endeavors can lead to both new kinds of devices and new ways of using those devices. The federal government also sponsors much of the research into cognitive processes and how schools can use new cognitive findings to further education.

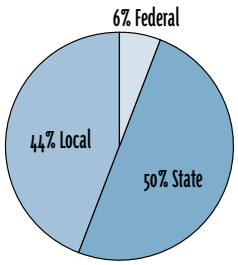
Beyond research and development, the federal government develops educational technologies for its own purposes. The Department of Defense, for example, spends hundreds of millions of dollars each year developing training software and systems for the armed services, much of which could be adapted for public education.

Education has traditionally been a local concern in the United States. But U.S. schools are now being challenged by forces that are global in scope: changes in national economies, changes in worldwide technologies, changes in culture and in the nature of societies.

The reinvention of schools must occur at a local level. But institutions and individuals at all levels must begin working together to make change happen. The nation cannot wait for the next generation of hardware, for the software now on the drawing boards, or for the next generation of teachers. The tools are available. The time to act is now.

"I have always believed that no matter what the technology, if we don't have a basic respect for learning and some sense of why it is important to us as a society, we cannot accomplish much."
—NANCY KASSEBAUM, U.S. SENATOR

"Schools are ready to use technology, but what they need are resources. They need to be freed of regulations. They need to have incentives. They need to have support to make the kinds of changes that people think are important."
—LINDA ROBERTS, DEPARTMENT OF EDUCATION



SOURCES FOR FUNDING FOR K-12 EDUCATION

Though the federal government provides only 6 percent of the funding for public K-12 education, it plays a major role in precollege education through its policymaking, regulatory, and research and development activities.

The federal system of government in the United States creates a shared responsibility for the management of the Nation's schools. Greatest responsibility for education is vested at the local level. Local leaders of education reform must ensure that their school systems adapt to change and demand access to the technologies they need for educational reform.

In recent years leaders of government at the state level have been a crucible for educational reform and the early applications of technology to connect services, libraries, universities, and schools into networks. States will continue to lead in the use of technology in schools just as they do in educational reform.

The federal government establishes national policy through legislation, regulates telecommunications, supports research and demonstrates technology useful to education, sponsors research on learning itself and has vast information holdings important in education.

All levels and functions of government must be brought together to make change happen in the nation's schools.