Reinventing Schools: The Technology is Now!

DETAILS

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The eyes of the schoolchildren glisten with anticipation. Their fingers arch lightly over their computer terminals, waiting to tap out solutions to ever more difficult problems appearing on the screens before them. Any schoolteacher would be thrilled by such concentration and receptiveness. But these children are not in school; they're playing games in a video arcade.

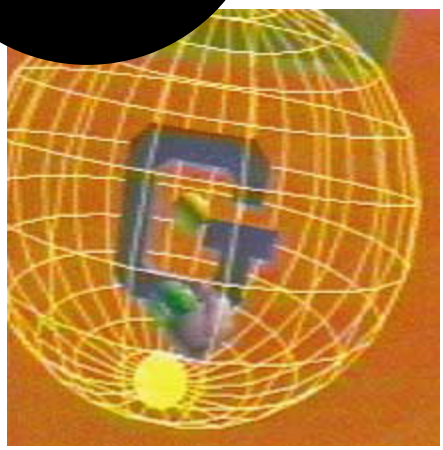
Today's schoolchildren have grown up immersed in a world of computers and other information technologies. They play video games; they listen to music on digital compact disks; they help their families program the computerized controls of videocassette players. These experiences have given children a different way of interacting with information compared with previous generations. Many familiar communications media—including television, movies, radio, newspapers, magazines, and books—are essentially linear. The users of those media have little if any control over the information they receive. They follow the flow of information from beginning to end along a path determined in advance by the providers of the information.

With today's technologies, the consumers of information can engage in dialogues instead of simply absorbing monologues. They can interrupt and redirect the flow of information. They can modify the complexity of information, the speed at which it is communicated, and its manner of presentation. They can control the elements of sophisticated multisensory experiences, combining audio, video, text, and graphics into a single immersive reality.

Information technologies are making it possible to create realistic new worlds filled with previously impossible experiences. In the virtual physics laboratory being developed by researchers at George Mason University and the University of Houston, students don a head-mounted display, headphones, and a data glove to enter an artificial reality where the laws of physics are under human—not nature's—control. Using the data glove, students move a disembodied hand through a room filled with simple physics experiments. They can turn gravity off or create antigravity and watch the effects on their surroundings. They can eliminate friction or slow the passage of time. With further develop-

"The technology gap between schools and the rest of the world is real and it is growing. Whether we like it or not, the increasing pervasiveness and vitality of this technology is changing the expectations of our children and their world view. Schools of the future could look dramatically different from those we attended. If we plan carefully, if we bring teachers along with us and implement new technology wisely together with other needed reforms, learning could be dramatically better."
—FRANK PRESS, PRESIDENT EMERITUS, NATIONAL ACADEMY OF SCIENCES

THE NINTENDO GENERATION



Using a data glove, students plugged in to the Virtual Physics Laboratory can use this globe to aim the force of gravity in any direction—including straight up. Immersion in artificial but plausible worlds such as this challenges students' preconceptions and can impart an intuitive understanding of complex phenomena.

Reader Rabbit, an animated cartoon character in a series of games developed by The Learning Company, rewards players who spell simple words, match rhyming words, and learn the alphabet.

Such games, which combine vivid animation with constant interaction between the player and the computer, represent a powerful learning tool that is underused by schools.

ment of the lab, students will be able to ride a light ray to experience relativity or participate as a molecule in a chemical reaction.

This kind of experience can be one of the best possible forms of education. Cognitive research has confirmed a commonsensical conclusion: students learn best when they are engaged with what they are studying, when they are making decisions, when they are thinking critically. In the Virtual Physics Laboratory, for example, students are constantly choosing how they want to interact with the computer-generated reality. By experiencing how the laboratory responds to their actions, they can gain an understanding of physical phenomena that is difficult to convey through traditional physics textbooks and laboratories.

Today there is a large and growing gap between the scant technology available in most schools and the rich technological environments students experience away from schools—and the gap is growing as societal change accelerates. Seventy-five percent of Americans now work in service and information jobs, with nearly half of all Americans involved in the generation, dissemination, and use of information. New technologies are creating workplaces where creativity, cooperation, and critical thinking are valued at all levels of an organization. If American education cannot equip young people with the skills they will need in an information-based world, they will not be able to play a productive role in society.

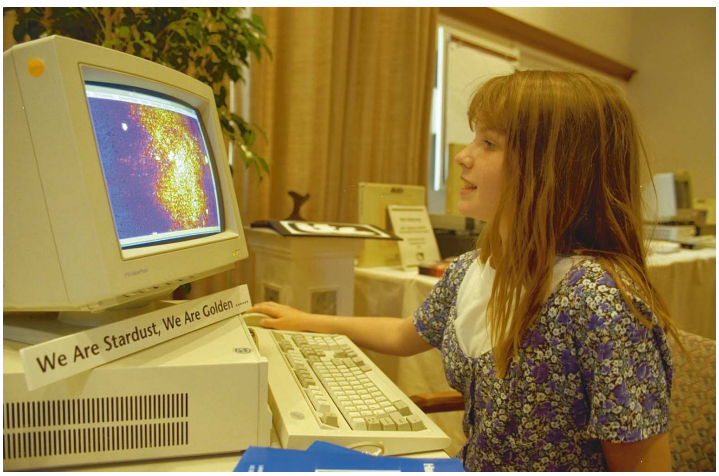
> "The coming levels of interactive technology hold the potential–if we take advantage of it–to create order-of-magnitude changes in productivity in American education."
> –David Britt, Children's Television Workshop

What can fill the technology gap between the in-school and out-of-school environments? It would be far too expensive to outfit every classroom with the most advanced technology. Instead, schools need to take advantage of the technology that increasingly permeates society. Doing so calls for rethinking many of the basic ideas behind education.

> "We must take advantage of students' interests in technology. . . . We must learn to use the technology students play with daily as educational resources."
> –Dorothy Strong, Chicago Public Schools

The technology to meet this challenge already exists and is in use outside of schools. This report is not about putting more computers into schools. It is dedicated to the idea that schools have to be reinvented to take advantage of the technology that is already ubiquitous in our everyday lives.

> "Kids are much more motivated to play games and use computers outside of school because of the level of interactivity. They have to make decisions frequently–every second or so–so they stay in charge. In school, if you're listening to a teacher lecture, you may only have to make a decision every half hour."
> –Joseph Smarr, Student



Video game or educational program? The engagement offered by state-of-the-art educational software (left) differs little from that offered by a Sega Genesis game (above).

Children have always been explorers, born with the ability to interact and learn about the world. But children today are growing up in a different world. Those between the ages of 3 and 18—and especially children entering school today—are being hailed as the "Nintendo Generation." They live in a world that is increasingly interactive, communications intensive, and knowledge based. They are standard bearers in the technological revolution, having never known anything else. Because of their ease in and with the information age, society needs their active involvement and interaction.

The changes going on today create an opportunity and necessity for a transformation in the way our schools function and our children are taught. If we cannot teach our children how to play and work in this world, our children will remain at risk. Education must be based on a model that is appropriate for an information-driven society. We must prepare children for a future of unforeseeable and rapid change.

THE TECHNOLOGICAL JUGGERNAUT

The majority of households with school-aged children in America contain a powerful computer. The computer has has extensive processing power, features sophisticated graphics, and is controlled by a lightning-fast input device. Its cost: about $100.

When most people hear the word "computer," they think of an IBM-compatible or a Macintosh. But video game boxes are also computers, and the majority of American students, spread across all racial, ethnic, and income groups, have a game box at home. In fact, the rapid spread of video games is one reason why outdated business systems donated to schools often sit unused—they do not offer the capabilities schoolchildren expect.

Video games are only one part of a wave of computing power that is sweeping into American households. New videocassette recorders, televisions, compact disk players, telephone answering machines, stereos, and telephones are gaining new capabilities every year. Soon new televisions and VCRs will be able to learn the viewing preferences of a household and program themselves accordingly. Telephones and home facsimile machines will screen calls, take messages, and send away for information.

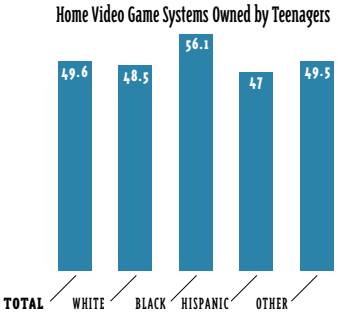
Furthermore, more and more of these technological devices are being interconnected, paving the way toward what many predict will be fully integrated home information and communications centers. In such systems, digital signals will flow into homes over copper wire, coaxial cable, fiber optic cable, or various wireless links. Equally important, digital signals will flow back out, carrying electronic mail, conversations, or video clips. Households will have the capacity to be connected to unlimited supplies of information, from college courses to the holdings of the Library of Congress to the latest Hollywood films.

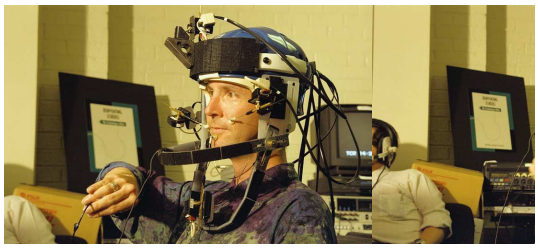
This communications revolution is happening at breakneck speed, and the pace of change will continue to accelerate. New satellite systems, for example, will soon enable "anywhere, anytime" communication, so that people will be able to maintain continuous links with the rest of the world.

The speed of the information revolution can be daunting for educators who want to take advantage of new technologies. But educators do not need to focus exclusively on leading-edge devices. Video

> **"In the future, computers will mutate beyond recognition. . . . They will tuck under your arm, into your valise, into your kid's backpack. After that they will fit onto your face, plug into your ear. And after that they will simply melt. They will become fabric. What does a computer need? Not glass boxes. It needs thread, power wiring, glass fiber optics, cellular antennas, microcircuitry. These are woven things, fabric and air and electrons and light. . . . Computers will be everywhere, throwaway, like denim, like paper."**
> —Bruce Sterling, Author

> **"What do you think is the largest software company in Redmond, Washington? The answer is not Microsoft. It is Nintendo."**
> —John Doerr, Kleiner, Perkins, Caufield & Byers





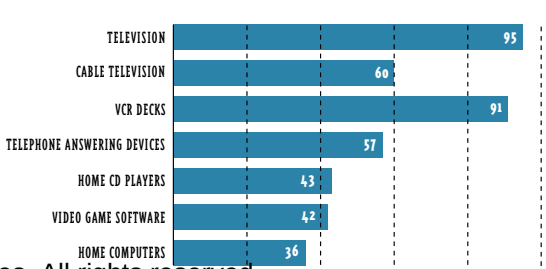
Elaborately hard-wired to a computer, an actor using a system developed by SimGraphics Engineering Corporation can control the features of an animated Mario in real time. When the virtual actor—or vactor—moves his head or gestures, the cartoon Mario does likewise. The result is animation that can be made for a fraction of the cost and in much less time than traditional animated films. This technology has been used at children's hospitals to do therapy

HOME GAME MACHINE VS. STANDARD EDUCATIONAL COMPUTER

	Sega Genesis and SegaCD (Sega)	Macintosh LC III (Apple Computers)
Type of Machine	Home Game Machine	School Computer
Price	$99 (Genesis) +$219 (CD Rom)	$999 (Computer) +$399 (CD ROM)
CPU/Speed	68000 @ 7.5MHz 2 x 6800 (7.5Mhz +12.5Mhz)	68030 @ 25MHz (25Mhz)
Memory	6MB RAM	4MB RAM
Color Palette	64	256
Resolution	320 x 200	640 x 480
Audio	16-bit stereo	16-bit stereo
Video Output	Composite, RF	RGB Color
PhotoCD Support	None	Yes
Audio Compact Disk	No	Yes
Hard Disk Storage	None	80Mb

Sega Genesis

Macintosh LC III



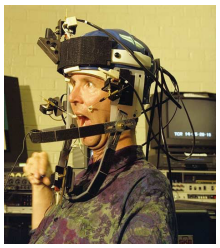
games, for example, offer many of the elements of successful learning: rich interaction, individual experience, and rewards for the completion of a task. Though most video games do not now serve an educational function, they could be modified to do so. In one of Nintendo's releases, for example, the Mario Brothers action figures teach drawing, and other video game manufacturers are similarly moving to enter the "edutainment" market.

Today, video game manufacturers are developing game boxes that can be connected to the outside world through television cables. Such devices have the capability to connect children in more than 60 million U.S. households. And because video game ownership cuts across all social and economic classes, networked video games could provide a way to bring information and new experiences to virtually all school-aged children.

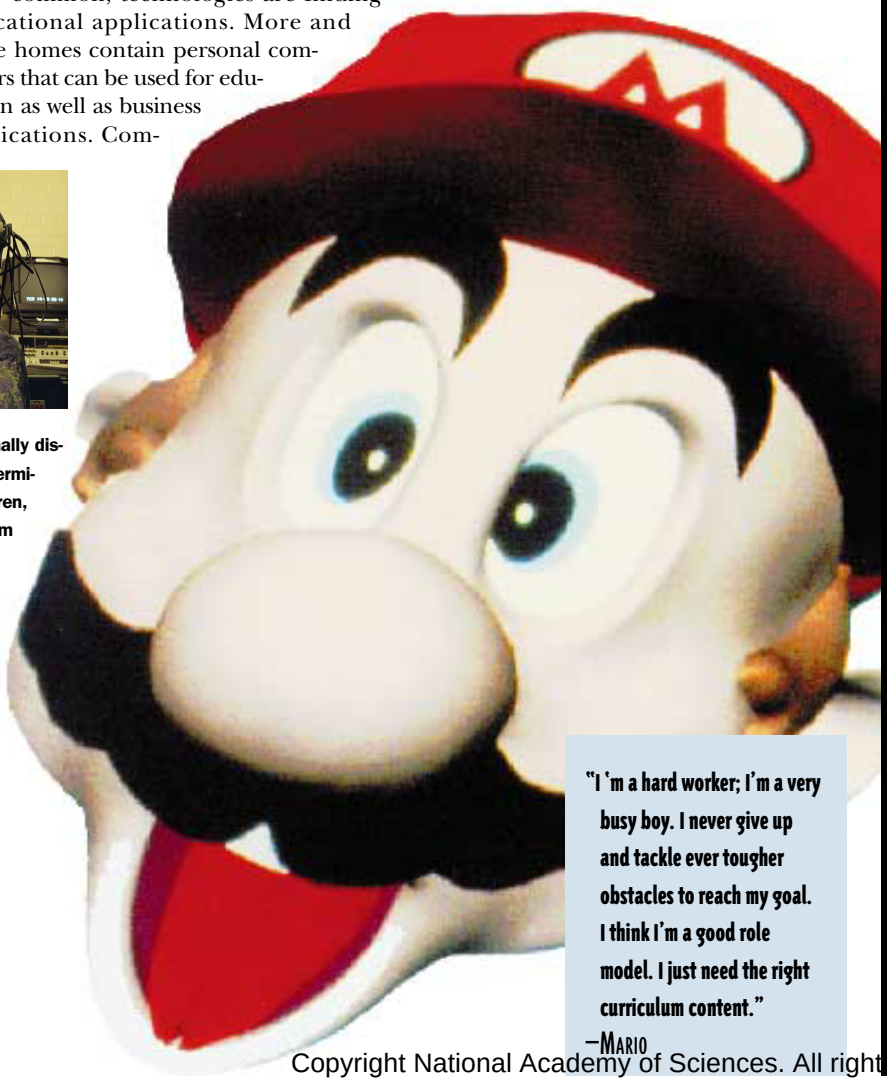
While much work needs to be done for video games to become a broad-based educational tool, a number of other, increasingly common, technologies are finding educational applications. More and more homes contain personal computers that can be used for education as well as business applications. Compact disk systems containing text, graphics, and video in addition to sound are offering interactive multimedia experiences on a rapidly growing range of subjects. As interactive television in the home moves past the prototype stage, new educational opportunities will emerge.

"We've designed video games for a long time. We understand what it takes to make software that kids will willingly spend hours with. With collaboration with educators, we can integrate more educational content into our games. We could even dream of reinforcing the entire curriculum with appropriate learning aids." —Doug Glen, Sega of America, Inc.

Technological and manufacturing advances are also continually driving down the cost of computers, software, and network links, bringing sophisticated technologies within reach of almost everyone. As hardware prices continue to drop, it may be possible to provide all students in a classroom with inexpensive notebook computers for use in class and at home. Students could use the computers to do homework, acquire new lessons, or consult with teachers and other experts outside of schools. Parents could use the same technology to check on a child's progress or ask questions of a teacher. By linking the activities of home and school, technology could expand and transform the learning that occurs in both places.



with emotionally disturbed and terminally ill children, many of whom find it easier to talk with a cartoon than with a real person.



"I 'm a hard worker; I'm a very busy boy. I never give up and tackle ever tougher obstacles to reach my goal. I think I'm a good role model. I just need the right curriculum content." —Mario

Home entertainment and video game technology is ubiquitous, creating a customer base that dwarfs that of the business market. The size of the consumer market has allowed manufacturers to offer sophisticated hardware and software at greatly reduced unit costs. The processors in even simple appliances like televisions and audio compact disk players have the capacity of business systems of just a few years ago. And in many ways—particularly with regard to the graphics and sound that are so engaging to children—home video game systems outstrip even current business systems.

The huge amounts of technology already in the hands of children offer the education community a low-cost way to bring technology into the classroom, in addition to the accepted approach of relying on more expensive systems from the business market. If accepted by educators, the convergence of superior educational software designed for business computers and the problem-solving approaches of game systems could prove a powerful force in K-12 education.

THE NETWORK REVOLUTION

Imagine a succession of images of the Earth from space showing the communication links between computers. In an image from the 1950s or 1960s, there would be only a few lines, generally between computers at large military and commercial institutions. In images from the 1970s and 1980s, the lines would be multiplying rapidly, as computers in universities and many businesses gained the ability to communicate with other each.

Now imagine an image from the 1990s. The number of lines would be exploding as a tightly woven net of information begins to link businesses, governments, homes, libraries, museums, and colleges. Furthermore, the links would no longer be limited to landlines, as computers begin communicating among themselves and with satellites by radio waves.

But there is something wrong with this picture. At present relatively few elementary and secondary school classrooms are linked to the rapidly growing grid of information. In their isolation, these classrooms risk missing out on a development that is rapidly changing the way we live, work, and play.

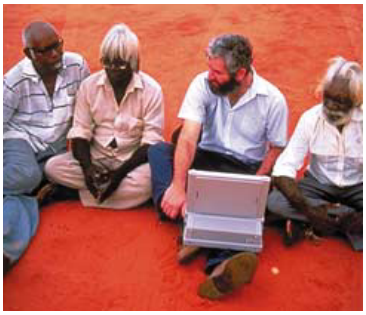
The most important driving force behind expansion of computer communications has been the Internet, a "network of networks" now used by over 20 million people around the world. The Internet was originally designed in the 1960s as a computer network that would remain functioning even if parts of the network were destroyed in a nuclear war. But the creators of the technology quickly realized that it had a far more immediate use. It enabled them to exchange written information quickly, easily, and among as many people as desired, fostering extended dialogues on any topic.

By the mid-1970s, the use of the Internet had spread far beyond the programmers and military planners who had originated it. University faculty, industrial researchers, and pioneering college students found in the Internet a way to tap into computing power not available to them locally—and not incidentally a way to exchange news and personal messages on topics of mutual interest.

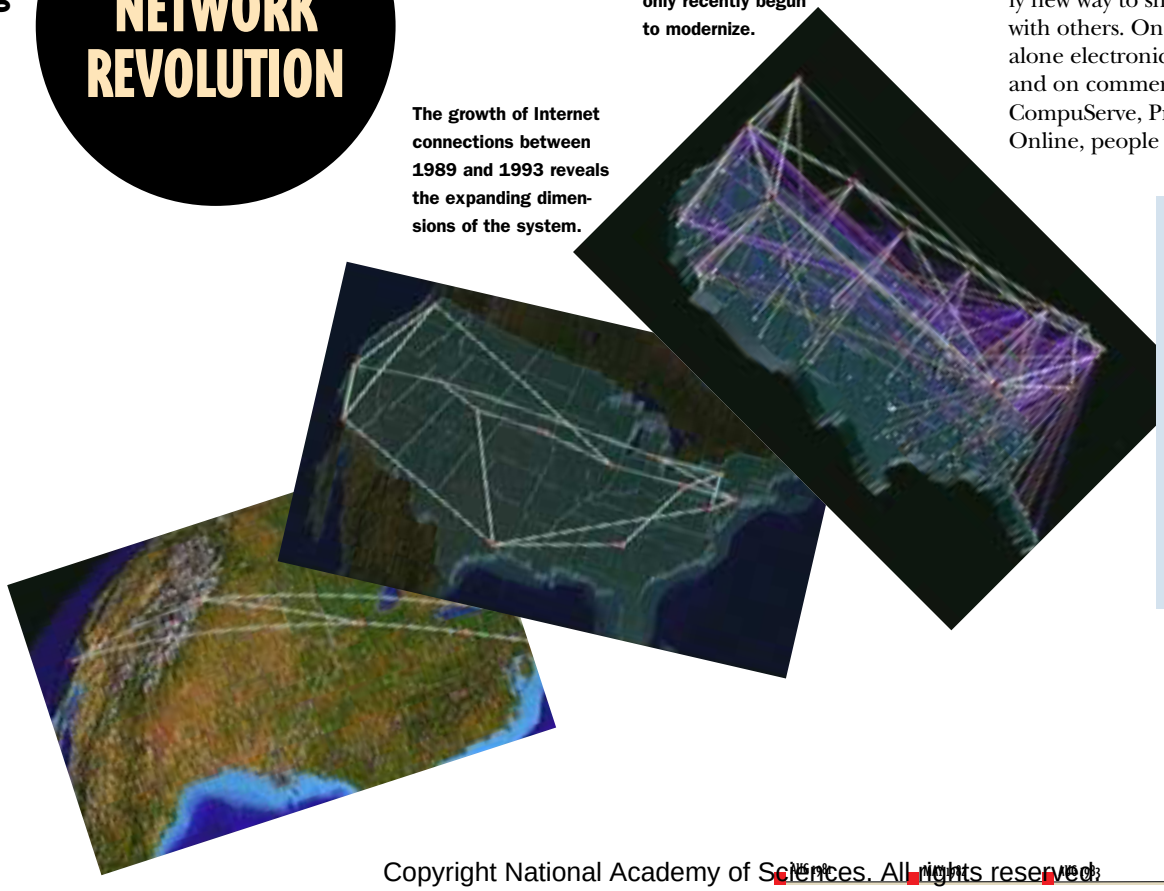
In the mid-1980s the growth of the Internet began to take off. More and more undergraduates got accounts through their colleges and universities. Computer centers in an increasing number of countries established Internet links. Networks established for other purposes connected themselves to the Internet. Today, the use of the Internet is growing at an incredible 10 to 20 percent per month—in effect, doubling the size of the system each year.

The most striking impact of computer networks has been among the least expected: their ability to create extended electronic communities. By connecting to computer networks, people gain an entirely new way to share ideas and information with others. On the Internet, on standalone electronic bulletin board systems, and on commercial networks like CompuServe, Prodigy, and America Online, people who would not otherwise

> "Don't buy a computer [for a school] unless you plan to connect it to a network. It allows for access to intraschool and interschool communications, it opens up informational data bases and services, and it allows for a more efficient method of classroom management."
> —Jesse Rodriguez, Tucson Unified Schools



Aborigines in Australia use a portable computer to access a college-level course. The global network of digitally linked computers known as the Internet now reaches from the Antarctic to the republics of the former Soviet Union to regions that have only recently begun to modernize.



The growth of Internet connections between 1989 and 1993 reveals the expanding dimensions of the system.

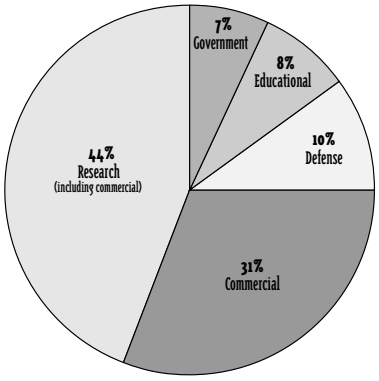
> "Our vision of the 1990s is not specific examples in one or two schools or in one or two districts. It is to have the same capabilities available everywhere–in business, at home, and in the schools as well."
> —Ellwood Kerkeslager, AT&T

have occasion to interact are coming together to discuss subjects of common interest. Social conventions are still being developed to govern communications in a medium where control is held collectively rather than by a small group. But even today's limited experience with computer networks has revealed the unprecedented potential of many-to-many communications.

This potential is now driving major projects in both the public and private sectors. The federal government is investing in a National Information Infrastructure by funding research, promoting communications and technology standards, and helping to link schools, government agencies, and other public institutions electronically. In the private sector, telephone companies, cable companies, computer hardware and software companies, and Hollywood production companies are all searching for profitable roles in the emerging world of digital communications, often through strategic alliances that bring together groups with differing expertise.

So far, relatively few of these initiatives have involved the nation's schools. But policymakers now recognize that schools must be part of the evolution of computer networks, and rapidly dropping prices will soon allow schools to take full advantage of new network technologies. Furthermore, the initial experiences of schools with digital technologies have become a powerful force for change, as teachers, education officials, parents, and students are beginning to recognize the power of these technologies to transform education.

"An on-line society is emerging. We have automated teller machines, computer-integrated manufacturing, computerized reservation systems, computer-aided college registration, and retail companies with point-of-sale requirements. Business is rapidly transforming itself to stay alive. But change is less rapid in education."
—James B. Hunt, Jr., Governor of North Carolina



As the Internet grows, commercial applications are expanding most rapidly, with educational uses still a relatively minor component.

INTERNET DYNAMICS

The use of the Internet has been growing exponentially—with no end in sight.

GROWTH OF THE INTERNET

A national and international digital network called the Internet currently ties together millions of people electronically around the world. Over the next decade electronic networks will rapidly evolve to provide information, services, and interaction to virtually all Americans. They will encompass the telephone system, cable television, wireless communications, shopping, libraries, higher and continuing education, and other services now provided in person. This evolution will be fueled by public policies designed to foster competition, equity, and individual rights. It will also be fueled by massive private investment in infrastructure and content.

The Internet, which is now rooted largely in institutions of higher education, has tremendous potential to change K-12 education. Yet today, despite promising starts in some schools, that potential remains largely untapped. As the network's focus shifts from institutions to individuals, ubiquitous access will become a practical tool for education both at home and in schools.

INTERNATIONAL CONNECTIVITY

- INTERNET
- BITNET BUT NOT INTERNET
- EMAIL ONLY (UUCP, DIDONET OR OSI)
- NO CONNECTIVITY

The collision of the comet Shoemaker-Levy 9 with Jupiter left a string of impact sites wrapped around the planet like a pearl necklace. This picture was taken with the 3.5-meter telescope of the German-Spanish Alto Observatory in southern Spain. Available via World Wide Web.

http://dept.physics.upenn.edu:80/sl9/observatories/CAO

"In bringing computer and network literacy to the teachers of our children, it would pay for itself in wonderful and unimaginable ways"
—William Gibson, author

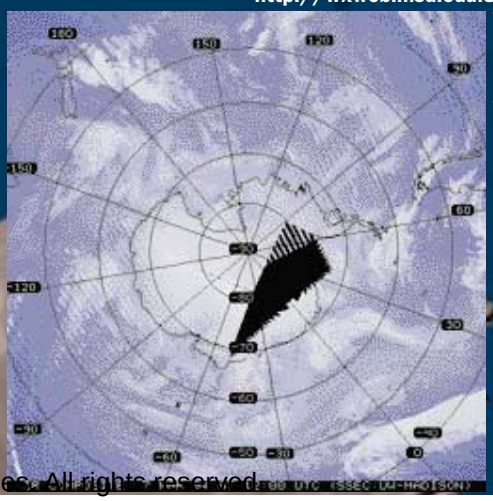
http://141.142.3.130/SDG/Experimental/vatican.exhibit/exhibit/b-archeology/Extra_objects2.html.

Image of ancient Rome drawn by an unknown artist in the 15th century–part of the collection in the Vatican Library–can be seen by the public only over the Internet via World Wide Web.

http://www.memst.edu/egypt/egypt.html.

The Pyramid of Khufu is the largest of the three major pyramids on the Giza Plateau, which is part of the necropolis of Memphis. Available via World Wide Web.

http://wxweb.msu.edu:80/weather/antartica.html.



Satellite photograph of the south pole shows a storm over Antarctica. Current photographs are available via World Wide Web

In North Carolina, classrooms are becoming "virtual" as learning goes long distance. Using the initial links in a high-speed digital video network that will soon connect over 3,400 North Carolina classrooms, colleges, libraries, hospitals, and government offices, students are learning foreign languages, mathematics, and science from teachers hundreds of miles away. Professors at colleges of education are observing and counseling student teachers over the network. High school teachers are participating in subject matter workshops and development seminars without leaving their schools. High school groups and clubs are using the network to conduct long-distance joint meetings after school hours.

The ferment in North Carolina reflects distance learning experiments that are taking shape across the country. Using the National Geographic Kids Network, students are comparing environmental data they have gathered, such as the acidity of their local rainfall, with similar measurements made by students around the world. Through the Jason Project, oceanographer Robert Ballard is interacting with hundreds of thousands of students in real time as they view images from undersea submersibles—even as scientists use the submersibles to do research in such places as the Mediterranean Sea or mid-ocean ridges. During the Gulf War, students in the United States communicated regularly over the Internet with students in Israel, discussing such subjects as what it feels like to be under attack by Scud missiles.

Distance learning multiplies the resources available to schools and teachers, greatly increasing opportunities for both teaching and learning. It invites students anywhere in the country to acquire the information they want directly from experts. Network links expand and enrich the pool of teachers in mathematics, sci-

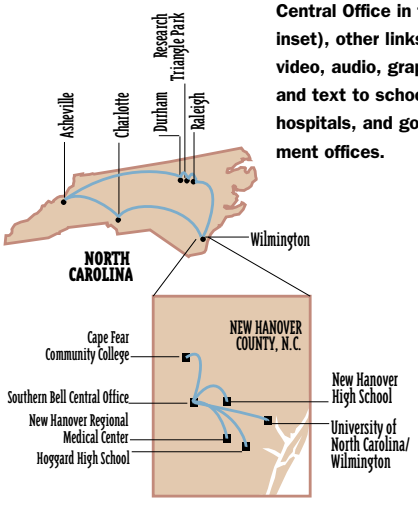
"If I ever have a problem with my homework, I can always get on the Internet, whereas in the classroom a teacher doesn't always have the time for all 30 students. They never have the time, as a matter of fact."
—Brandy Justice, Student

Brandy Justice

"An information superhighway is only as good as the on-ramps that you have to get onto it. . . . If there isn't a low-cost, effective, and simple way for a school or a classroom to get on the Internet, then it is not really doing any good."
—Mitchell Kapor, Electronic Frontier Foundation

"At this very moment, there are students in a small rural school in Mississippi learning the Russian language. There is a group of students in an inner city school in Detroit working on linear equations. There are students in a remote Maine fishing village reciting Japanese."
—Richard Riley, Secretary of the U.S. Department of Education

NETWORKING K–12 EDUCATION



A high-speed digital "backbone" connects major cities in North Carolina through optical fiber. At each node (the Southern Bell Central Office in the inset), other links carry video, audio, graphics, and text to schools, hospitals, and government offices.

Global Reach of National Geographic Kids Network

Students from countries around the world (marked in red) interact through the National Geographic Kids Network to study local environmental issues and compare the results with their peers. Below, students conduct an acid rain experiment to gather results that will be discussed on the network.

ence, or other fields. Moreover, the information students receive via networks can be individualized to fit their specific needs.

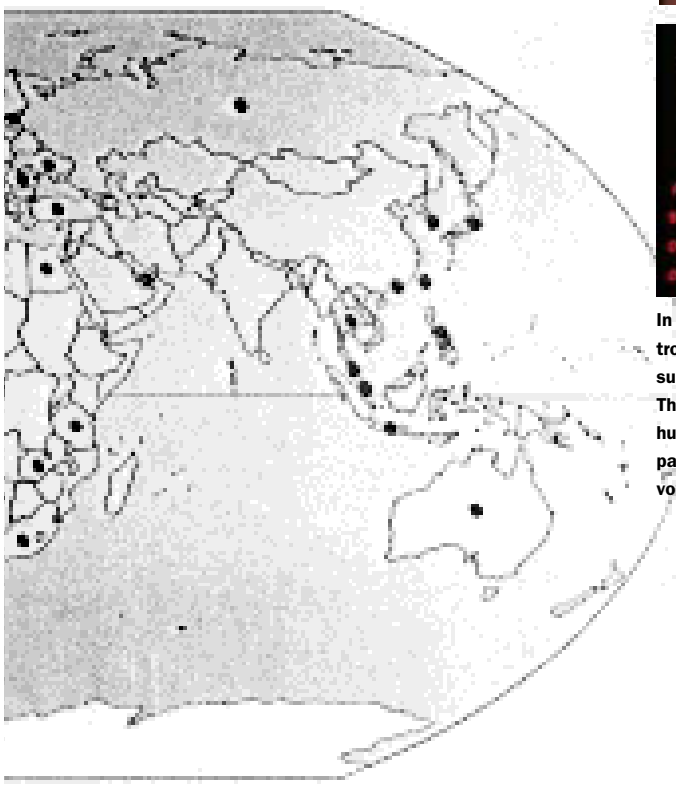
The new information technologies can foster a much more cooperative approach to learning. The discovery-oriented learning made possible by computers can be used to evoke discussion, negotiation, and critical thinking. Students can work in groups to solve problems and use the computer to compare their efforts with digitally stored information and with similar efforts outside their school.

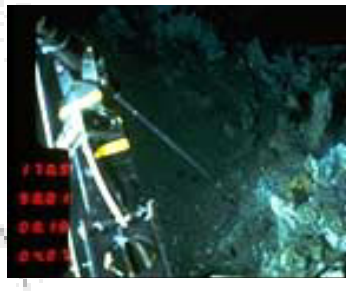
Yet computer networks, despite their benefits, remain unused by most schools. According to data for the 1993-94 school year gathered by Quality Education Data, only 23 percent of public schools use educational networks in at least one classroom. Even more significantly, inner city schools and rural schools, which many experts say could profit most from the resources made available by computer networks, are the schools most likely to be passed by.

By contrast, 99 percent of American public schools have computers, and 93 percent of students use them during the school year. But these numbers can be deceiving. Many of the computers in schools are older, cannot be networked, and cannot run the newest software. Furthermore, many of these computers are not being used in ways that exploit their full capabilities. Instead, they are being used to reinforce outdated models of education that fall far short of the goal of providing students with what they need in today's world.

For networks to be used effectively in schools, a new model of education is needed. This new model goes to the heart of the educational enterprise, reshaping the roles of teachers, students, and technology.

"Advances in networking technologies provide the potential for access to educational resources that may not otherwise be available in many rural school systems and also in financially disadvantaged urban school settings. Distance learning is now possible using full motion video and providing interaction between instructors and students. Network connections that lead to new types of collaborations between students, teachers, and university faculties at remote locations are becoming available."
—Rick Boucher, U.S. Representative





In the Jason Project, students help control and gather data from a deep-sea submersible exploring the seafloor. Through satellite downlinks to schools, hundreds of thousands of children have participated in the Jason Project's voyages of discovery.

The Internet is the prototype of the information superhighway. A reflection of many communities and individuals, it has been built upon both public and private initiatives. It provides a means for collaboration and research not bound by walls, distance, or time.

The Internet is a key element in reinventing K-12 education. Children and adults alike who have access find that the Internet's boundless information resources and communications capabilities are not only enlightening but fun.

But for the Internet to be successfully used in teaching and learning, the 16,500 school districts across America need both to have access to it and to be able to use it. Both the public and private sectors have an opportunity to expand access to the Internet, linking our nation's schools, libraries, universities, research centers, private companies, and homes. Phone lines, interactive cable television, satellite links, and fiber optic cable all should be options for connecting to the net.

A NEW MODEL FOR EDUCATION

Schools tend to reflect the societies in which they are embedded. In America before the Civil War, little book learning was needed to manage what was for most people still an agrarian life. School started relatively late in the day and ended early to leave time for chores. In summer, school let out entirely so children could help their parents in the fields. Education was narrow in scope, controlled largely by the teacher, and focused predominantly on basic skills.

In that world, the model of education embodied in the one-room schoolhouse was sufficient. Teachers taught reading, writing, and elementary mathematics to complement the skills students learned outside school. Since relatively few students progressed even as far as high school, the need for higher levels of education was minimal.

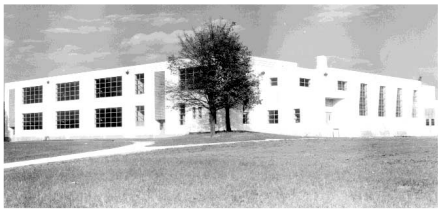
By the end of the 19th century, more and more of the population was settling in cities and going to work in factories. To teach students the basic skills and simple facts they needed for industrial jobs, the first great revolution in schooling took place: the factory school model appeared. Large buildings enclosed labyrinths of classrooms where students sat in neat rows with the teacher in front. Schools sought to be an efficient social institution that could turn out identical products. Students learned enough to work at jobs that they would probably keep for much of their lives.

> "In the information age, the human beings that industry needs are those who can do their own thinking, get actively involved, work in teams, and be innovative, not merely industrious. The problem is, the factory model school, which doesn't encourage those qualities, is still with us and needs to be replaced with a new kind of schooling that does."
> —Bill Blakemore, ABC News

Today many students still attend factory-model schools. Much of the day is spent passively listening to lectures. Many classes teach skills for jobs that either no longer exist or will not exist in their present form when students grow up.

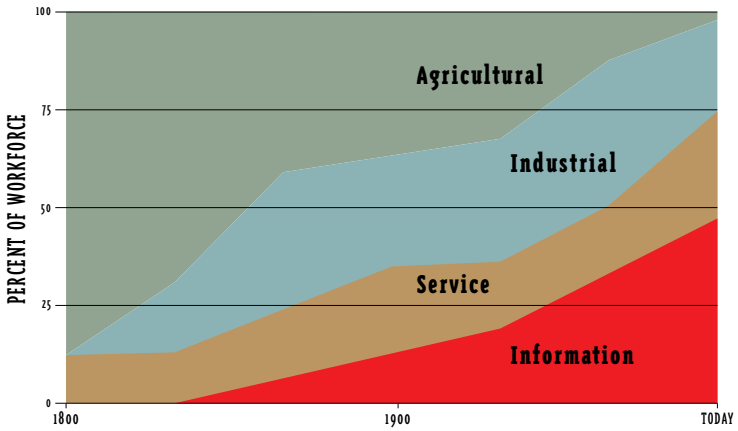
It is clear that yesterday's innovation has become today's obstacle to change. Only about 20 percent of the employed population now works in factories or on farms. People graduating from high school or college will average six to eight jobs over the course of a career, many of them requiring skills that are unforeseen today. About half of all employed Americans work with information—analyzing information that already exists, generating new information, storing and retrieving information. Soon a major portion of this group will not even work in an office, much less a factory, but at home.

This postindustrial form of society calls for a new, postindustrial form of education. Teachers, parents, school administrators, and policymakers have begun to



The rapid industrialization of 19th-century America caused an analogous transformation in American education, which previously had been characterized by the one-room schoolhouse. By the beginning of the 20th century, schools were increasingly mimicking the practices of factories, treating students as products to be shaped with assembly line precision. Though this model of education has proven effective at teaching basic skills to students, it is not suited to a society in which individual success often depends on a person's ability to adapt to change.

WORK IN AMERICA: 195 Years



realize that an entirely new model of education is needed. In this new kind of school, all students will be held to far higher standards of learning because everyone will have to be prepared to think for a living and everyone will have to be capable of learning many new skills over the course of a lifetime. This model of education will increase the links between students and their communities, bringing the resources of school to bear on the complex ethical, civic, and technical decisions that all citizens will have to make. The timing and location of education will be more flexible, to reflect and take advantage of changes in the workplace. The distinction between learning inside of school and outside of school will blur.

"The school reforms of the 1980s consisted mostly of an added program here, an improved strategy there, and a computer someplace else. These efforts were like taking aspirin for a life-threatening illness."
–Keith Geiger, National Education Association

Technology is a key transforming element in creating this new model of school. Just as technology is reshaping other institutions, it has the potential to reshape education, ending the disjunction between school and the broader society. Technology offers unlimited new ways of learning, of teaching, and of running schools. It provides new ways for everyone involved in education to be openly accountable to parents, to communities, and to students.

"Technology is merely a tool to help us improve the opportunities for learning and help us really approach the kind of teaching that we think is important in our schools."
–Linda Roberts, Department of Education

Yet technology by itself is clearly not enough. As applied in factory-model schools, technology can be as uninspiring as traditional mimeographed worksheets. Computers in schools have too often been used for drills, for word processing, and for remedial work. These applications fail to take advantage of the rich, interactive capabilities of today's information technologies.

Compare the use of computers for drill and practice to their use as effective learning machines. With imaginative, inspiring software, students are not forced to come up with the one right answer; rather, they learn to ask many questions and to devise multiple approaches to a problem. They learn at their own pace and in their own style, so that skilled students advance without restraint while other students have the various resources they need to meet high standards.

Traditional schools have emphasized individual performance and competition and have discouraged students from working or even talking together. In the new model of school, classroom experiences emphasize critical thinking, teamwork, compromise, and communication—the skills valued in today's workplace.

This model of education calls for changing the roles of students, teachers, and schools. In the new model of school, students assume many of the functions previously reserved for teachers. In small groups, individual students act as peer-tutors for others. Because they are often the ones most familiar with new technologies, students lead by example, helping their classmates work through problems. In this way, students begin learning from an early age how to communicate and how to assume greater responsibility for their own education.

Teachers, in contrast, change from being the repository of all knowledge to being guides or mentors who help students navigate >

"As we look to the major sectors of our economy, the educational system is the only sector that has not brought technology to bear upon its operations. And in a society so rich with information, we can no longer rely on skills appropriate only for the industrial age."
–Constance A. Morella, U.S. Representative

AND FACTORY-MODEL SCHOOL MUST YIELD TO A THIRD MODEL OF EDUCATION...

through the information made available by technology and interactive communications. They help students gather and organize information, judge its value, and decide how to present it to others. Moving from group to group and from student to student, teachers help students stay focused and working at the limits of their abilities. When the class meets as a whole, teachers share the responsibility for teaching with the students—each of whom has been forging ahead at his or her own pace.

In this new model of school, education looks different than it does in most schools today. Schools might be open all day and all year, with groups of students rotating in and out of session. Classrooms might include students of different ages. Traditional 50-minute classes will stretch or disappear to accommodate activities made possible by technology. Longer-term projects will cut across disciplines, combining the subject matter of previously separate classes. Multiple choice tests will be replaced by new kinds of assessments that measure the acquisition of higher-order skills.

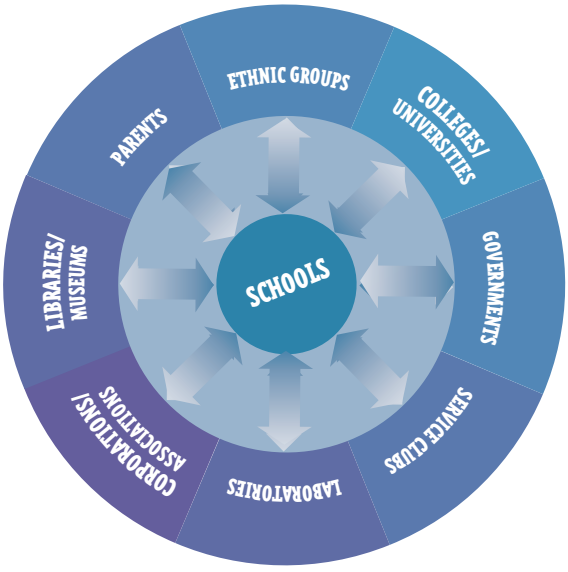
Schools may emerge in unlikely places —such as office buildings—or more conventional schools may have branch campuses integrated into businesses, hospitals, or homes. Secondary schools may forge new links with two-year colleges and community institutions to ease the transition from school to

"Integrating technology into [today's classrooms] makes about as much sense as integrating the internal combustion engine into the horse."
—Lewis Perelman,
Discovery Institute

"Technology itself is not the curriculum. Technology is a key that opens opportunities for students to learn in the classroom. It is a way in which we can bridge what in the past have been large gorges that have separated students from opportunity."
—John Dossey,
Illinois State University

"Education is an enterprise distinguished by its paucity of technology, and obviously that situation must change."
—Luther Williams,
National Science Foundation

The use of technology in classrooms—whether in the context of virtual reality devices (top), cooperative learning (center), or desktop video conferencing (bottom)—places students at the center of the educational process. Both teachers and the technology itself become tools that students draw upon to advance their own learning.



In the third model of education, schools draw upon a rich web of interconnections among societal institutions, with people and information from other sectors enriching and enabling the missions of schools.

...A MODEL THAT COMBINES THE BEST OF PAST PRACTICES WITH THE RICH INTERACTIVITY

work. Individual classes will be integrated into workplaces, providing a vocational education far richer and more useful than what is offered today. Technologies used at home will convey lesson plans, homework, and assessments both to students and to their parents.

The ultimate goal of this new model of education is to foster communities of lifelong learners, where intellect and cooperation are highly valued. Within these communities, decisions will be made by those in the best position to make them—by students, teachers, and educational administrators.

> "Kids retain 5 percent of what they hear and 10 percent of what they read but 80 percent of what they do and 90 percent of what they teach."
> —Robert Ballard, Woods Hole Oceanographic Institution

The elements of this new model of education are starting to appear in scattered communities across the United States. Schools are experimenting with new organizational structures, new forms of governance, and new uses of technology that are designed to reflect the constant flux of modern society. This trend is about to accelerate dramatically. As technology becomes more powerful and plentiful, and as the needs of society more urgently call for a new model of education, American schools will be caught up by irresistible forces of change.

Using satellite video technology, students in a Japanese class interact with an instructor and fellow students across the country.

Information technologies foster new ways of learning distinct from the traditional model of teachers in front of classrooms lecturing to rows of students. Students progress through curriculum sequences keyed to local, state, and national standards. Using the information available from broadband networks or CD-ROMs, groups of students can engage in cooperative projects that teach communication and negotiation skills as well as problem solving skills. Meanwhile, teachers take on a new role, that of advising and guiding students through the wealth of material that the new technologies offer.

For more than 200 years, from the founding of the 13 colonies in the 1600s until well after the Civil War, the nation's educational needs were largely met through the model of the one-room school. As the nation urbanized and industrialized in the latter part of the 1800s, today's factory model of K-12 education emerged. As the nation enters the next century, technology allows us to consider a new model of education, one that couples classroom learning and resources to education resources found quite literally throughout the world.

In the one-room school and in today's factory-model schools, the teacher is the heart of the education enterprise. In the new model of education, the teacher will emerge as the mentor, guide, and broker to the world of knowledge made accessible by technology.

SYSTEMIC REFORM

The following two problems functionally are very similar. But the differences between them highlight the contrast between education's past and its future.

EDUCATION'S PAST:
What percentage of 500 is 30?
A: 6%. B: 16.7%. C: 60%. D: 166.7%.
E. None of the above.

EDUCATION'S FUTURE:
The facts: In 1991 the education budget of a certain city was $30 million out of a total budget of $500 million. In 1992, the education budget of the same city is $35 million out of a total budget of $605 million. The inflation rate for the year was 10%. The tasks: 1. Use the facts to argue that the education budget increased from 1991 to 1992. 2. Use the facts to argue that the education budget decreased from 1991 to 1992.

The first problem aims at the objectives of the factory-model school. Aspiring to anything more sophisticated than the ability to do simple calculations would have seemed wasteful. Why would factory workers need to engage in careful analysis of a problem?

The second problem seeks to develop the skills required in an information age. It encourages students to work through problems in innovative and thoughtful ways, developing the skills they will need to cope with a rapidly changing world.

The recognition that schools must change their objectives for learning is reflected in one of the most important things to emerge from the school reform movement of the 1980s—a general consensus that U.S. schools should move toward "world class" national standards describing what a student should know and be able to do at different grade levels. To date, the content of education has often been a hit-or-miss proposition in the United States. Whenever a student moved, a teacher could never be sure just what he or she learned in a previous school. Parents had little idea what levels their children were expected to reach year after year.

In the 1970s and 1980s, many states and localities put in place minimum competency standards centered on low-level skills and scattered factual knowledge. But while these standards raised the performance of the students who had been doing worst on standardized tests, they did little

> **"When we bring technology into a school, we must make it a total part of the mission of education, not just a peripheral item.... But technology alone is not enough. If we leave the system as it is, we are not going to accomplish the changes that we need. To be successful, we need to bring technology and restructuring together with a focus on the right kind of standards. Together, these are the keys to systemic reform."**
> —Roy Romer,
> Governor of Colorado

Roy Romer.

1981
18% of schools have some sort of computer

1981
IBM introduces the IBM PC

1983
In "A Nation at Risk," the National Commission on Excellence in Education warns that "the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and a people."

1984
Apple Computer introduces the Macintosh and its graphical user interface.

1985
The business-based Committee for Economic Development calls for educational standards in its report "Investing in our Children."

1986
The National Governors Association recommends a broad range of reform initiatives, including opening schools year-round and greater choice among public schools in "A Time for Results."

1986
The National Science Foundation joins the Department of Defense in expanding the national network.

1988
T1 (1.54 Mbps) backbone of the National Research and Education Network is upgraded to T3 (4.5 Mbps) service.

1989
The National Research Council releases "Everybody Counts," which advocates dramatic reform of precollege mathematics education.

1989
At an "education summit" in Charlottesville, Virginia, President Bush and the nation's governors agree to set performance goals for the nation's schools.

1989 & 1991
The National Council of Teachers of Mathematics releases national standards for mathematics learning and teaching.

1990
Virtual reality, simulation, and edutainment software becomes the fastest-growing software market.

1990 – 1994
Coalitions of teachers and professional societies develop standards in science, history, geography, English, art, and civics.

1991
The National Science Foundation, working with 26 states, launches K-12 Statewide Systemic Initiatives (SSI's) to reform mathematics, science, and technology education.

1991
98% of schools have computers, though most do not have useful, up-to-date software.

to meet the broader needs of these students or their higher-performing peers.

Today, alliances of teachers and professional education organizations have developed or are developing national standards in mathematics, the arts, science, English, history, geography, foreign languages, civics, and physical education. These standards are voluntary and are meant to be adapted to the unique characteristics and needs of each classroom. Still, for the first time in this nation's history, they establish high national benchmarks toward which all schools, teachers, and students can aspire.

"Today, national standards serve as the basis for reform. They provide the guidance system for change. They are the articulation of the agreed-upon reform agenda. . . . This important insight has taken hold in the minds of all our leaders in a remarkably short span of time."
—Jim Ebert,
Johns Hopkins University

The development of national standards and the explosion of information technologies uniquely suited to education are occurring simultaneously, and each can build on the other. The national standards must be geared toward a future when technology will permeate our everyday lives. Technology, in turn, provides a means for students to achieve the standards. If standards establish goals for education, then technology provides a means to achieve those goals.

The cooperative development and widespread voluntary adoption of national standards will have a profound effect on American education. Striving for national standards will demand major changes in the ways that teachers and other educators are trained and sustained throughout their careers. It will require that all students be given the opportunity to learn, because it is unjust to hold students to high national standards and not give them the means to attain those standards. In this way, national standards touch upon virtually all aspects of education and provide the framework for system-wide reform.

"A statistical generation of students is passing through our schools largely untouched by our commitments to change and unaffected by our new standards of achievement. . . . We must begin now to change educational practices fundamentally to touch the lives of students today, to shape the teachers for tomorrow, and to invest in the technical infrastructure that will enable us to realize the possibilities of a future yet to be discovered."
—Pamela J. Keating,
University of Washington

In response to the many reports of serious inadequacies in U.S. schools, national thinking about the state of K-12 education underwent a remarkable change in the 1980s. The governors of various states emerged at the forefront of educational reform, turning the call for action into measurable changes within their states. By decade's end, the governors and President Bush had agreed to establish standards and performance goals to be in place by the year 2000—a process that has been formalized in the Goals 2000 legislation passed by Congress and signed by President Clinton.

In contrast to earlier reform activities, today's systemic reform efforts are broad-based, deeply rooted, and cognizant of the need to have national standards implemented through local reform. They recognize the need to support all components of the educational system consistently and continuously.

Over this same period information technology has moved from an era of mainframes to local area networks and network connectivity. By coupling the wider use of technology in education to the systemic reform effort and by using the emerging curriculum standards as guides to the development of educational software, new models of K-12 education can be catalyzed.

1993
The National Academy of Sciences and National Academy of Engineering sponsor the convocation "Reinventing Schools: The Technology Is Now."

1993
NCSA releases Mosiac for Macintosh and Windows computers, opening the door for distribution of government information, electronic publishing, and commerce via the World Wide Web of the Internet.

1993
3DO releases RISC-based (reduced instruction set computing) home entertainment systems with power equal to that of personal computers.

1994
Apple, IBM, and Motorola join forces to introduce RISC-based personal computers and servers.

1994
Cornell's CU-See-Me video conferencing software allows teachers and students to interact through desktop videoconferencing over Internet where there are no phones.

1994
President Clinton signs Goals 2000 legislation.

1995
National Research Council and cooperating scientific and teaching organizations release national science education standards.

(1997)
Large, flat-panel, high-resolution, high-definition color displays supporting three-dimensional graphics enable in-school creations of artificial realities to be shared in the classroom.

(1997)
Sega and Nintendo release RISC-based game machines with power equal to that of available personal computers.

(1997)-(1999)
Global digital cellular satellite systems go online.

(2000)
Standards for learning in all disciplines are defined, measurable, and in place in fulfillment of Goals 2000.

Teachers receive less technical support than does any other group of professionals.

Computers occupy the desktops of most professionals in the United States, but not in classrooms; there, computers are often used exclusively by students. The average worker in America can take advantage of $50,000 worth of capital invested in that job; the comparable figure for teachers is $1,000. Most teachers do not even have immediate access to a telephone.

Despite these obstacles, a small but rapidly growing number of teachers has discovered the power and scope of information technologies—often with computers they have at home. They are using computers and telecommunications to form networks of teachers, comparing experiences and exchanging ideas. They are acquiring curricula and other instructional information over educational networks. They are using computers to reduce administrative drudgery and to track and guide student development. In the process, they are using technology not only to reinvent schools but to reinvent their own roles as teachers.

But the natural diffusion of computer expertise through the teaching profession is proceeding far too slowly. The great majority of teachers will not be able to take full advantage of technology that is now available without technical support. And society cannot wait for a new generation of teachers more familiar with information technologies to enter the schools.

The professional development of teachers has often been an afterthought in American schools. When budgets get tight, career development is often one of the first things to go. But if teachers are to become comfortable with the technologies that will reshape schools, they must receive both preservice training during their college years and inservice training during their careers. They need after-school workshops, summer sessions, and time off from their classes to learn how technology is being used elsewhere. They need to be able to observe their colleagues' classrooms and talk with them so that they can unlearn old practices and build new ones. In the long run, for technology to succeed, as much time and money must be invested in teachers as is invested in the actual hardware and software.

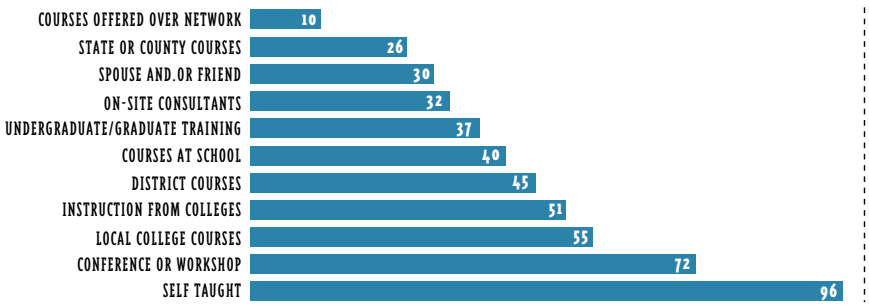
"When it comes to technology in education, you can create it, you can design it, you can produce it, you can legislate it, you can order it, restructure it, give it standards, and write outcomes for it. But the bottom line is that if it is going to happen, teachers have to make it happen."
—JACQUELINE GOODLOE, WASHINGTON, D.C., TEACHER

INVESTING IN TEACHERS

Teachers and administrators—shown here in North Carolina (top) and Tennessee (bottom)—must be given the opportunities and resources needed to use technology in the classroom, integrate it into the curriculum, and manage and monitor its use.

Sources of Training for Teachers Who Are Familiar with Computers

PERCENTAGE OF TEACHERS IN SURVEY



There are many ways to promote the familiarity of teachers with technology. One possibility is to tie pay scales not to the advanced degrees teachers acquire but to the completion of courses designed explicitly to upgrade professional skills.

Another possibility is to create a new kind of educational professional skilled in educational technologies. Such a person could work with individual teachers to integrate technology into classrooms and fully use its interactive and networking capabilities.

One of the most powerful methods of professional development is to establish explicit links between teachers and organizations outside schools such as corporations, universities, nonprofit institutions, and federal laboratories. For example, teachers can be paired with corresponding professionals in the broader community: science teachers with scientists, English teachers with writers, social studies teachers with historians and museum curators. Teachers involved in these partnerships can then act as resource teachers for their colleagues.

> "Good teaching will never be replaced. The right suggestion at just the right moment, the congratulatory pat, the admiring mentor–these will all continue to be essential to the processes of education, no matter how entertaining and high-tech our instructional media become."
> –Samuel Gibbon, Jr., Alfred P. Sloan Foundation

As American education begins to move toward a new model of school, the education of teachers must undergo a fundamental shift—toward a model that treats the lifelong education of teachers with the same importance as the education of students. Teachers must be given time to travel to meetings and share information with colleagues. They must have the authority to structure their classrooms in ways that allow them to meet high standards and simultaneously address the individual needs of their students. And as true professionals, they deserve the technological support that professionals need to do their jobs.

Kathleen Martinelli-Zaun teaches 6th grade at Dorcey Middle School in Fox Chapel, PA.: "Radio Shack started offering free classes to educators. Those classes gave me some basic skills. Later, I took two different computer workshops that I heard about through my college alumni newsletter. One workshop gave me the opportunity to see how other teachers were using technology."

> "There can be infinite uses of the computer and of new age technology, but if the teachers themselves are not able to bring it into the classroom and make it work, then it fails."
> –Nancy Kassebaum, U.S. Senator

A successful union of information technology and systemic reform of K-12 education requires a renewed commitment to teachers in the nation's schools. If teachers are to become the students' empowered managers and resource guides for the broader world of information available through networks, they must have opportunities for professional development to take on this new role.

Investment in teachers today for all forms of professional development is woefully inadequate. While their access to technology in the classroom and at home is growing, it is at far too slow a pace and at a level of financial commitment too low to address the needs. Nor can this shortfall be met by relying on a new generation of younger teachers that are more computer literate than their predecessors. That strategy is not consistent with systemic reform.

Teachers must be offered opportunities for coursework in information technology and the opportunity to engage in building links in their communities where experience with technology is already in place. Students must be brought into the reform strategy as they are experienced mentors in the emergent world of cyberspace. School systems that want to change must promote professional development of teachers with the same commitment they make to hardware and software availability and network access.

ENSURING EQUITY

One of the greatest fears of those who are skeptical about the potential for technology to help reinvent schools is that it will benefit only rich schools and will therefore widen the gap between the haves and the have-nots. But information technologies can transform education for any student. Already, in a handful of inner city schools around the country, students are riding the Internet to access information and talk to students throughout the world. They are participating in science experiments with tens of thousands of their peers. They are managing imaginary stock portfolios using information from Wall Street. They are working with desktop publishing programs to put out school newspapers and collections of their poems and short stories.

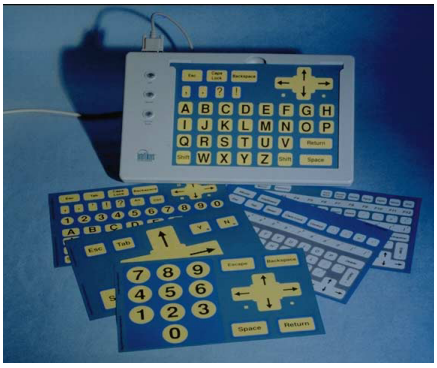
The problem is that for the majority of disadvantaged schoolchildren, such a transformation is nowhere in sight. It is not that poorer schools do not have computers; almost all schools in the United States now have some computers. But without the funds to maintain hardware and upgrade software, computers sit broken down in closets and computer labs. Without the resources to train teachers, computers are unwelcome interlopers in the classroom. Without the prod of a standards-based curriculum, computers tend to be used not for creative exploration but for drill and practice work, which is more likely to frustrate students than it is to inspire them.

"Many of America's bad dreams and scariest future scenarios stem from a single and terrible fact: this nation has a vast and disenfranchised underclass, drawn most shamefully along racial lines, and whose plight we are dangerously close to accepting as a simple fact of life, a permanent feature of the American landscape. What we are discussing represents nothing less than this nation's last and best hope of providing something like a level socioeconomic playing field for a true majority of its citizens."
—William Gibson, Author

It would be tragic if the selective application of technology in education were to widen the inequities in American education, because in other spheres the personal computer has been a powerful democratizing influence. Personal computers distribute capabilities from central locations to the machines on each individual's desk. They greatly increase the individual's ability to communicate, to learn, to work. They have helped undermine tyrannies, such as when personal computers and faxes were used both during the Tiananmen Square uprising and in the declining days of the Soviet Union to transmit information to the outside world.

Information technologies can also preserve the traditions that make communities strong. Consider the "virtual museum" now being built by the Smithsonian Institution's National Museum of the American Indian. A student in New Mexico will be able to call up on a computer screen an image of an artifact stored in the museum, rotate the image, read the curator's text describing the piece, and then

"Technology may well play a pivotal role in allowing native people to sustain a cultural present and build a cultural future that our cultural past deserves, indeed demands."
—Richard West, Smithsonian National Museum of the American Indian



Keyboards with large letters enable the visually impaired to use computers (right), while microphones such as the one shown at left allow people to communicate with their computers through speech. As Secretary of Education Richard Riley points out: "If a child is capable of any movement, even just the blinking of an eye, there is a technology available that can help him or her to learn."

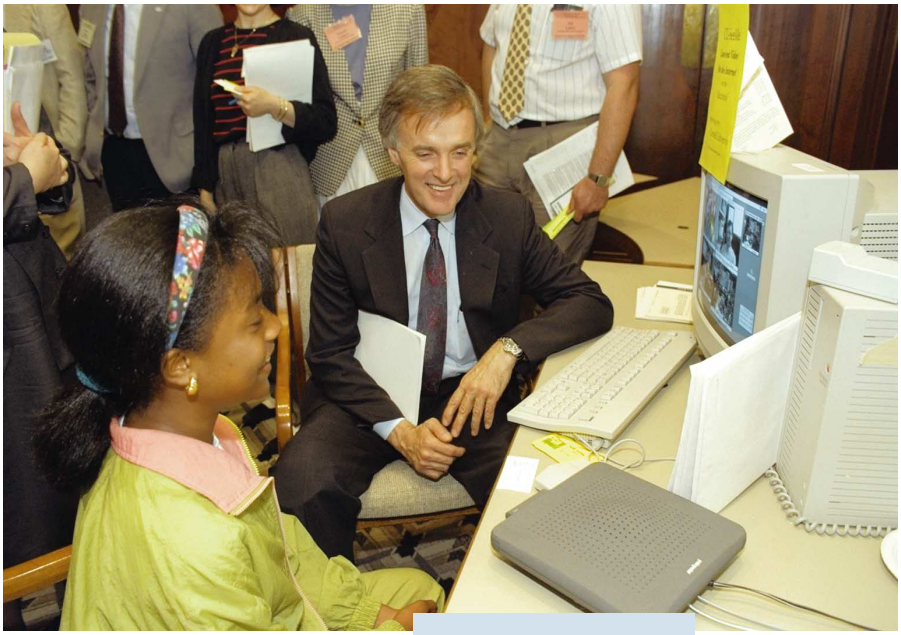
send a question to the curator. Huge libraries of film and photographs will be accessible from the archives. The museum's network will allow Native Americans to communicate with each other, take classes, or read the latest postings from Native American news sources.

Government has an important role in ensuring access to new technologies. It can pay for hardware for disadvantaged schools, educate teachers, link all schools to computer networks, and disseminate information about useful hardware and software. Access will also increase as computer prices drop and computing becomes even cheaper and more ubiquitous.

But government cannot ensure equity. Only a commitment by the public and by all levels of the educational system can do that. Society has a great interest in enabling all its citizens to participate in the economic and social mainstream. Technology offers one of the most powerful means available for breaching the barriers of class, race, and income that divide Americans.

Technology can also provide greatly increased opportunities for another group of disadvantaged Americans: people with physical disabilities. Technologies that allow disabled students to interact with computers can dramatically level the educational playing field. Hardware and software are now available that can translate written words into speech for the blind or allow paralyzed individuals to enter words into a computer. New speech systems can recognize and convert spoken words into words on a computer screen. By enabling the disabled to attend regular schools, work at jobs, and participate more fully in society, these systems are both tremendously fulfilling for the people who use them and cost-effective to society as a whole.

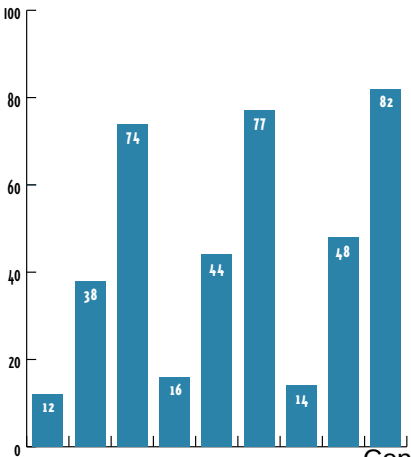
> "What is wonderful about computer is being independent instead of being coddled all the time, like a baby in arms, because of my blindness. It feels like being coddled like a baby sometimes, because everybody wants to help."
> —Janice Ware, Student



U.S. Senator Bob Kerrey and Washington, D.C., student Mia Robinson share a moment in cyberspace. Kerrey has introduced legislation that would establish electronic learning centers in communities to give all citizens access to information technologies.

> "We must make sure that the information highway does not bypass our urban centers like other transportation systems once did. To do so would disable yet another generation of educators and yet another generation of students."
> —Warren Simmons, National Center on Education and the Economy

Percentage of All U.S. Students Who Report a Computer in the Home by Socioeconomic Status



Through recent history there have been two views of technology. The first sees technology as available predominantly to the economically advantaged. The second sees technology as a means of lowering barriers between the financially well off and those less economically fortunate.

History suggests that the latter is most often the relationship of technology and society. Major technologies deployed today, such as the airplane, saw early acceptance by those with financial resources, but increasingly and especially in recent decades have become much more available, as evidenced by the wide use of air travel. Electronic technologies more than any in the past have spread rapidly at much lower costs. Today games played by children are purchased and played across all socioeconomic groups.

Though poor neighborhoods and families face daunting challenges, technology deployed in education can help remove inequities between the schools of the inner city and the suburbs, between cities and rural districts, and inequities faced by people with physical disabilities and by Native Americans. Technology can become the force that equalizes the educational opportunities of all children regardless of location and social and economic circumstance. This should be the national goal.

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.

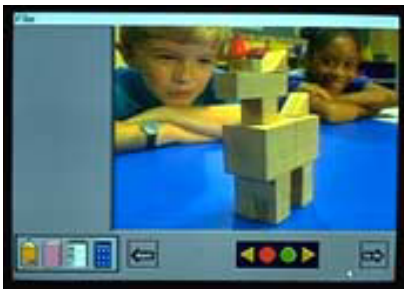
"Technology is competing with gymnasiums, with the acquisition of new school buses, with a wide range of things that schools have to spend their dollars on.... So while there is a very definite role for technology, we have to identify what the needs are in a school system. How can technology effectively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

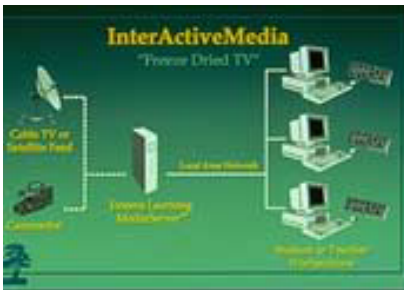
The market for software in the schools is even larger. In the 1993-94 school year, schools spent over $600 million on educational software, and the amount is projected to grow by 20 percent per year.

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-

"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

BURGEONING MARKETS





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.

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

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.

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

OPPORTUNITY TO CHANGE

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

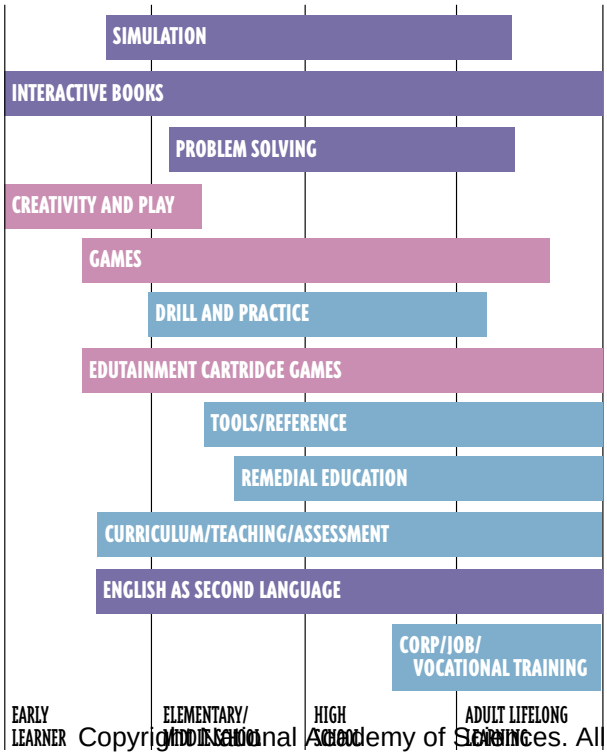
The much greater involvement of the private sector in education will inevitably be shaped by developments within both government and private industry. The consumer electronics, computer, software, entertainment, cable television, and telecommunications industries are all being drawn into a web of interconnections. 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.

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.

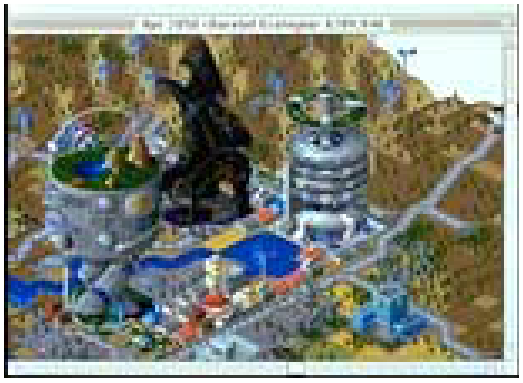
This model of learning has been turned on its head by the past two decades of cognitive research. Scientists have shown that even the youngest students come to school with quite sophisticated theories about the world. Children have an intuitive understanding of language, numbers, and science based on 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

LEARNING ABOUT LEARNING



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 class room, 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.

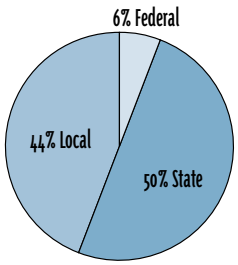
Beyond research and development, the federal government develops educational technologies for its own purposes. The Department of Defense, for example, spends hundreds of millions of dollars each year developing training software and systems for the armed services, much of which could be adapted for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

> "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

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.

> "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.