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The development of high performance computing and communications is creating new media, such as the WorldWide Web and virtual realities. In turn, these new media enable new types of messages and experiences; for example, interpersonal interactions in immersive, synthetic environments lead to the formation of virtual communities. The innovative kinds of pedagogy empowered by these emerging media, messages, and experiences are driving a transformation of traditional "teaching by telling" to an alternative instructional paradigm: distributed learning. If the substantial barriers to change discussed later in this testimony are overcome, within two decades American schooling will shift to new models of teaching/learning better suited to developing 21st century workers and citizens for a knowledge-based society.

Implications of New Media for K-12 Education

What does the evolution of new media mean for precollege educators? A medium is in part a channel for conveying content; new media such as the Internet mean that one can readily reach wider, more diverse audiences. Just as important, however, is that a medium is a representational container enabling new types of messages (e.g., sometimes a picture is worth a thousand words). Since the process of thinking is based on representations such as language and imagery, the process of learning is strongly shaped by the types of instructional messages we can exchange with students. Emerging representational containers, such as multimedia, enable a broader, more powerful repertoire of pedagogical strategies.

The global marketplace and the communications and entertainment industries are driving the rapid evolution of high performance computing and communications. Regional, national, and global information infrastructures are developing that enhance our abilities to sense and act and learn across barriers of distance and time; within two decades, the process of building these physical and technical infrastructures will be complete. How information is created, delivered, and used in business, government and society is swiftly changing. In the future, to successfully prepare students as workers and citizens, teachers will incorporate into the school curriculum experiences with creating and utilizing new forms of expression, such as virtual reality. Information infrastructures will provide channels for delivering such technology-intensive learning experiences just-in-time, anyplace, and on-demand, enabling partnerships for effective K-12 education among schools, parents, businesses, communities, and the media.

Many people are still reeling from the first impact of high performance computing and communications: shifting from the challenge of not getting enough information to the new challenge of surviving too much information. In a few years, the core skill for American workplaces will not be foraging for data, but filtering and synthesizing a plethora of incoming information. The new type of literacy students must master will require diving into a sea of information, immersing oneself in data to harvest patterns of knowledge just as fish extract oxygen from water via their gills. Understanding how to structure learning experiences to make such immersion possible will be the core of the new rhetoric. Expanding traditional definitions of literacy and rhetoric into immersion-centered experiences of interacting with information will be central in schools preparing K-12 students for full participation in 21st century society.

Emerging forms of distributed learning are empowering the reconceptualization of K-12 education’s mission, process, and content. This new instructional paradigm is based both on shifts in what learners need to be prepared for the future and on additional capabilities information technology is adding to the pedagogical repertoire of teachers. By 2015, at least four new forms of expression will shape the emergence of distributed learning as American schools’ primary pedagogical model:

- knowledge webs will complement teachers, texts, libraries, and archives as sources of information;
- interactions in virtual communities will complement face-to-face relationships in classrooms;
- experiences in synthetic environments will extend learning-by-doing in real world settings; and
- sensory immersion will help learners grasp reality through illusion.

We are just beginning to understand how these representational containers can reshape the content, process, and delivery of conventional classroom education. Information infrastructures are the lever for this evolution, just as the steam engine was the driver for the industrial revolution.

Knowledge Webs

In two decades, “knowledge webs" will routinely enable K-12 students distributed access to experts, archival resources, authentic environments, and shared investigations. Via information infrastructures, educators and pupils will regularly join distributed conferences that provide an instant network of contacts with useful skills, a personal brain trust with just-in-time answers to immediate questions. In time, these informal sources of expertise will utilize embedded “groupware” tools to enhance collaboration. Even on today’s Internet, on-line archival resources are increasingly linked into the WorldWide Web, accessible through “webcrawlers” such as Mosaic™ and Netscape™. In the future, artificial intelligence-based guides and filters will facilitate learners navigating through huge amounts of stored information.

Virtual exhibits that duplicate real-world settings (e.g., museums) will form the basis of most field trips; these environments make possible a wide variety of experiences without the necessity of travel or scheduling. Distributed science projects will enable conducting shared experiments dispersed across time and space, each team member learning more than would be possible in isolation about the phenomenon being studied and about scientific investigation.

However, access to data does not automatically expand students' knowledge, nor will the mere availability of information intrinsically create an internal framework of ideas that learners can apply in real world settings. While presentational approaches transmit material rapidly from source to student, often this content evaporates quickly from learners' minds. To be motivated to master concepts and skills, precollege students need to see the connection of what they are learning to the rest of their lives and to the mental models they already use. Helping students progress from access through assimilation to appropriation requires educational experiences that empower knowledge construction by unsophisticated learners, aiding them in making sense of massive, incomplete, and inconsistent information sources. As part of using knowledge webs, to move students beyond assimilating inert facts into generating better mental models, teachers will structure learning experiences that highlight how new ideas can provide insights in intriguing, challenging situations.

In two decades, a vital form of literacy that educators will communicate is how to transform archival information into personal knowledge. Access to knowledge webs on information infrastructures will provide powerful ways of accomplishing that instructional goal. However, to leverage this access into better educational outcomes, classrooms will incorporate sophisticated learning-through-doing strategies so that learners can interpret the data they receive.

Virtual Communities

Two decades hence, virtual communities that provide support from others who share common joys and trials will also enhance distributed learning in American schools. We are accustomed to face-to-face interaction as a means of getting to know people, sharing ideas and experiences, enjoying others' humor and fellowship, and finding solace. In the future, distributed learning via information infrastructures will satisfy many of these needs at any time, any place. Some students (shy, reflective, comfortable with emotional distance) even find asynchronous, low bandwidth communication more “authentic” than face-to-face verbal exchange. They take time before replying to carefully compose a message, as well as to refine the emotional nuances they wish to convey. This alternative conception of personal authenticity may help us understand how better to tailor instruction for diverse learning styles.

Within two decades, K-12 educators will use the virtual communities information infrastructures make possible to dramatically improve learning outcomes. Learning is social as well as intellectual; individual, isolated attempts to make sense of complex data can easily fail unless the learner is encouraged by some larger group that is constructing shared knowledge. Virtual communities enable new pedagogical strategies that facilitate such encouragement and motivation. For example, peer tutoring aids all students involved both intellectually and emotionally, but has been difficult to implement in traditional classroom settings. In the future, virtual interactions will readily enable such student-student relationships outside of school, as well as preparing their participants for later use of distributed problem solving techniques in adult workplace settings. Telementoring and teleapprenticeships between students and workplace experts will be similar examples of applying virtual community and “groupware” capabilities to distributed learning.

In addition, educators themselves need emotional and intellectual support from others who have similar challenges in their lives. In the future, virtual communities will provide a means of helping teachers find the strength to help schooling keep pace with our rapidly changing and increasingly diverse society.

Moreover, formal education comprises only a small fraction of how students spend their time. No matter how well schooling is done, achieving major gains in learning requires that the rest of pupils' lives be educationally fulfilling as well. This necessitates close cooperation and shared responsibility for distributed learning among society's educational agents (families, social service agencies, workplaces, mass media, schools, higher education). By 2015, virtual communities will routinely enhance this collaboration among stakeholders in quality education. For example, involving families more deeply in their children's education may be the single most powerful lever for better learning outcomes. Virtual parent-teacher conferences and less formal social interchanges will make such involvement more likely for parents who would never come to a PTA meeting or a school-based event.

This future is prefigured today in many regions across America, as community networks are emerging that enhance education by enabling distributed discourse among all those concerned with improving schooling. However, the completely virtual school will never be practical, as face-to-face interactions will continue to be important in fulfilling schools’ educational, socialization, and custodial responsibilities.

Shared Synthetic Environments that Complement Real World Experiences

Two decades from now, another capability for enhancing distributed learning will be shared synthetic environments that extend students’ experiences beyond what they can encounter in the real world. Information infrastructures are not only channels for transmitting content, but also virtual worlds that students can enter and explore. Just as single-user simulations allow an individual to interact with a model of reality (e.g., flying a virtual airplane), distributed simulations enable many people at different locations to inhabit and shape a common synthetic environment. For example, the U.S. Department of Defense today uses distributed simulation technology to create virtual battlefields on which learners at remote sites develop collective military skills. The appearance and capabilities of graphically represented military equipment alter second-by-second as the virtual battle evolves.

In the future, distributed simulation will be a representational container that can empower a broad range of educational uses (e.g., virtual factories, hospitals, cities). The vignette below depicts a hypothetical future application that promotes distributed learning outside the classroom through “edutainment.”

EDUTAINMENT IN CYBERSPACE

Roger was unobtrusively sidling across the Bridge of the Starship Enterprise when the Captain spotted him out of the corner of his eye. “Take the helm, Ensign Pulver,” growled Captain Jean-Luc Picard, “and pilot a course through the corona of that star at lightspeed 0.999. We have astrophysical samples to collect. You’ll have to guard against strange relativistic effects at that speed, but our shields cannot stand the radiation flux we would experience through traveling less quickly.” Roger had intended to sneak onto the Ecology Deck of the Starship and put in a little work on his biology class project in controlling closed-system pollution levels, but no such luck. Worse yet, he suspected that the Vulcan communications officer watching him while she translated a message in French was in fact the “avatar” *(computer-graphics representation of a person)* of a girl he admired who sat three rows behind him in his languages class. Of course, he could be wrong; she might be someone teleporting into this simulation from who knows where or could even be a “knowbot” *(a machine-based simulated personality used to simplify the job of instructors directing an instructional simulation).*

Buying a little time by summoning up the flight log, Roger glanced curiously around the bridge to see what new artifacts his fellow students had added since yesterday to this MUD *(Multi-User-Dungeon or Dimension, a current type of adventure game in which participants mutually evolve an elaborate, shared synthetic environment by continuously modifying its contents)*. In one corner, an intriguing creature was sitting in a transparent box, breathing a bluish-green atmosphere—maybe this was the long-awaited alien the anthropology and biology majors were creating as a mutual project. The 3-D goggles from his Nintendo++ set intensified the illusion that the lizard-like countenance was staring right at him...

“Impulse Engines to full speed, Mister,” barked Captain Picard! “This Mage *(human expert guiding the evolution of a virtual environment)* seems rather grumpy for a regular teacher,” thought Roger, “maybe he’s a visiting fireman from the new Net-the-Experts program.” On his Console, Roger rapidly selected equations that he hoped would yield the appropriate relativistic corrections for successfully navigating through the star’s corona. He hoped to impress Captain Picard as a means of improving his chances for promotion. Last week’s setback, getting motion sick while “riding” on a virtual gas molecule that was illustrating Brownian motion, had not helped his chances...

This vignette shows how by 2015 education could be situated in a synthetic universe analogous to a authentic real-world environment, but more intriguing. Moreover, such a distributed learning strategy would leverage a huge installed base of sophisticated information technology—home videogame consoles—as well as the substantial motivation inculcated by the entertainment industry. In the future, videogame consoles will provide sophisticated platforms for implementing such visually-based distributed learning technologies and will be ubiquitous even in poor and rural households.

Sensory Immersion to Grasp Reality Through Illusion

In addition to distributed simulation, within two decades advances in high performance computing and communications will also enable learners’ sensory immersion in “artificial realities.” Via an immersion interface based on computerized clothing and a head-mounted display, the student will feel “inside” an artificial reality rather than viewing a synthetic environment through a computer monitor’s screen; virtual reality is analogous to diving rather than looking into an aquarium window. Scientific data visualization research has already established that using sensory immersion to present abstract, symbolic data in tangible form is a powerful means of attaining insights into real world phenomena.

For example, “visualization” is an emerging type of rhetoric that enhances learning by using the human visual system to find patterns in large amounts of information. People have very powerful pattern recognition capabilities for images; much of our brain is "wetware" dedicated to this purpose. As a result, when tabular data of numerical variables such as temperature, pressure, and velocity are transfigured into graphical objects whose shifts in shape, texture, size, color, and motion convey the changing values of each variable, increased insights are often attained. For example, graphical data visualizations that model thunderstorm-related phenomena (e.g., downbursts, air flows, cloud movements) are valuable in helping meteorologists and students understand the dynamics of these weather systems.

In the future, when information infrastructures routinely allow people to access large databases across distance, visualization tools will expand pupils' perceptions so that they recognize underlying relationships that would otherwise be swamped in a sea of numbers. One good way to enhance creativity is to make the familiar strange and the strange, familiar; adding sonification and even tactile sensations to visual imagery will make abstract things tangible and vice versa. For example, expanding human perceptions (e.g. allowing a medical student—like Superman—to see the human body through X-ray vision) is a powerful method for deepening learners' motivation and their intuitions about physical phenomena. My current research centers on assessing the potential value of sensory immersion and synthetic environments for pre-college students learning material as disparate as electromagnetic fields and intercultural sensitivities.

The vignette below illustrates how sensory immersion might someday be combined with knowledge webs, virtual collaboration, and synthetic environments to enable powerful forms of distributed learning.

COLLABORATIVE TRAINING IN A SHARED SYNTHETIC ENVIRONMENT

Karen sat down at her educational workstation, currently configured as an electronics diagnosis/repair training device. When sign-in was complete, the workstation acknowledged her readiness to begin Lesson Twelve: Teamed Correction of Malfunctioning Communications Sensor. Her "knowbot" *(machine-based agent)* established a telecommunications link to Phil, her partner in the exercise, who was sitting at a similar device in his home thirty miles away. "Why did I have the bad luck to get paired with this clown?" she thought, noting a hung-over expression on his face in the video window. "He probably spent last night partying instead of preparing for the lesson." A favorite saying of the problem solving expert to whom she was apprenticed flitted through her mind, "The effectiveness of computer-supported cooperative work can be severely limited by the team's weakest member."

"Let's begin," Karen said decisively. "I'll put on the DataArm to find and remove the faulty component. You use the CT (cognitive transducer) to locate the appropriate repair procedure." Without giving him time to reply, she put on her head-mounted display, brought up an AR *(artificial reality)* depicting the interior of a TransStar communications groundstation receiver, and began strapping on the DataArm. The reality-engine's meshing of computer graphics and video images presented a near-perfect simulation, although too rapid movements could cause objects to blur slightly. Slowly, she "grasped" a microwrench with her "hand" on the screen and began to loosen the first fastener on the amplifier's cover. Haptic feedback from the DataArm to her hand completed the illusion, and she winced as she realized the bolt was rusty and would require care to remove without breaking.

Meanwhile, Phil called up the CT for Electronics Repair; on the screen, a multicolored, three-dimensional network of interconnections appeared and began slowly rotating. He groaned; just looking at the knowledge web made his eyes hurt. Since the screen resolution was excellent, he suspected that last night's football party was the culprit. Phil said slowly, "Lesson Twelve," and a trail was highlighted in the network. He began to skim through a sea of stories, harvesting metaphors and analogies, while simultaneously monitoring a small window in the upper left-hand corner of the screen that was beginning to fill with data from the diagnostic sensors on Karen's DataArm.

Several paragraphs of text were displayed at the bottom of the screen, ignored by Phil. Since his learning style is predominantly visual and auditory rather than symbolic, he listens to the web as it vocalizes this textual material, watching a graphical pointer maneuver over a blueprint. Three figurines are gesturing near the top of the display, indicating that they know related stories. On the right hand side of the monitor, an interest-based browser shows index entries grouped by issue, hardware configuration, functional system, diagnostic symptoms, and potential causes.

Traversing the network at the speed with which Karen was working was difficult, given his tiredness, and he made several missteps. “Knowledge Base,” Phil said slowly, “infer what the optical memory chip does to the three-dimensional quantum well superlattice.” The voice of his knowbot suddenly responded, ”You seem to be assuming a sensor flaw when the amplifier may be the problem.” “Shut up!” Phil thought savagely, hitting the cut-off switch. He groaned when he visualized his knowbot feeding the cognitive audit trail of his actions into the workstations of his teacher and the communications repair expert serving as his business mentor; he could not terminate those incriminating records. Phil cringed when he imagined his teacher’s “avatar” giving him another lecture on his shortcomings. Mentally, he began phrasing an elaborate excuse to send his instructors via video teleconferencing at the termination of this disastrous lesson.

Meanwhile, Karen was exasperatedly watching the window on her AR display in which Phil’s diagnostic responses should have been appearing. “He’s hopeless,” she thought. Her knowbot’s “consciousness sensor” *(a biofeedback link that monitors user attention and mood)* interrupted with a warning: “Your blood pressure is rising rapidly; this could trigger a migraine headache.” “Why,” Karen said sadly, “couldn’t I have lived in the age when students learned from textbooks...”

Young people like magical alternate realities; and today’s entertainment industry profits by providing amusement parks, videogames, movies, and television programs that build on this fascination. By 2015 educators too will profit, in a different way, through building eerily beautiful environments for sensory immersion that arouse curiosity and empower shared fantasy, leading to learning via guided inquiry.

In addition to knowledge webs, virtual communities, synthetic environments, and sensory immersion, the generation growing up with high performance computing and communications will invent many uses for sophisticated information technologies, applications difficult for us to imagine today. Providing these K-12 students the type of schooling that encourages creativity, curiosity, and the desire to continue learning is vital to America’s future economic well-being. Imagining civilization two decades from now may be as difficult for us today as visualizing a commodities broker electronically monitoring soybean options would have been for eighteenth century farmers contemplating a steam tractor. America doesn’t have much time to understand and shape what is happening; the Industrial Revolution took more than a century to reach fruition, but global economic competition and the pace of technological advance will drive the next transformation much more quickly. Examining how workforce skills are changing today can aid in comprehending why transforming industrial-age approaches to schooling is vital for our future prosperity—as well as empowering the other important purposes of education beyond preparing learners for employment.

Information Technologies Are Creating a Knowledge-Based Economy

In the past, graduates of K-12 schooling were prepared to compete effectively with other Americans in our domestic economy. However, the evolution of worldwide markets based on high performance computing and communications means that U.S. employers and employees must be more adept than their global competitors at meeting the needs of a very diverse range of customers. In this new economic “ecology,” each nation is seeking a range of specialized niches based on its financial, human, and natural resources. Developed countries, which no longer have easily available natural resources and cheap labor, have difficulty competing with rising-star developing nations in manufacturing standardized industrial commodities. However, America is utilizing her strengths (technological expertise, an advanced industrial base, an educated citizenry) to develop an economy that uses sophisticated people and information tools to produce customized, value-added products.

Two opposite types of information technologies are now reshaping the workplace: smart machines and intelligent tools. Smart machines take control of the job, telling the worker what to do next; one example is the automated devices that guide medical technicians through analyzing blood samples. In contrast, intelligent tools provide workers with powerful capabilities to be utilized as they choose; an illustration is a graphic artist using a computerized animation program to create a cartoon. One way of understanding the impact of these two types of workplace devices on workers’ occupational skills is to contrast how information technology has changed the job roles of the supermarket checker and the typist. Many supermarkets now have bar code readers; rather than finding the price on each item and punching it into the register, the checker needs only to pass the goods over the scanner. Efficiency and productivity have increased, but the food you buy tastes the same as before, and less skills are needed to do the job. Smart machines tend to increase efficiency, but also deskill jobs, lower salaries, and make work more mechanical—the person becomes the eyes, arms, and personality for a device that does the recording, storing, "thinking," and decision making.

In contrast, substituting a office automation system for a typewriter requires a secretary to function in more sophisticated ways. To use the information tool for customizing a mass of data to the individual needs of recipients, the clerical role must shift from keyboarding to utilizing database, desktop publishing, and groupware applications. The job now demands higher-order cognitive skills to extract and tailor knowledge from the enormous information capacity of the tool, and the occupational role shifts to the new profession of information manager. Intelligent tools increase effectiveness rather than efficiency; new, more skilled roles are created that pay higher salaries.

America's niche in the global economy—customized, value-added products—necessitates a shift in work roles away from smart machines manufacturing standardized commodities toward cognitive partnerships with intelligent tools. As this transformation to a post-industrial economy occurs, an evolution of job requirements toward higher-order thinking skills is taking place in all types of occupations, blue-collar as well as white-collar. By 2015, people's creativity and flexibility will be vital as job skills, because the standardized aspects of problem solving will be increasingly absorbed by machines.

American schooling must alter its focus to prepare learners for cognitive partnerships with intelligent tools. Until the need for these new types of skills is routine in workplace settings, shifting the emphasis of education is difficult for society to initiate—but by then a generation of our workers will be ill-prepared to compete in the global economic arena. The core challenge is to prepare today's students for a future workplace more disparate from present experience than at any time since the Industrial Revolution. Fortunately, sophisticated information technologies can provide the leverage to make evolution to a new educational model possible; the same advances that are transforming the economy can empower new models of teaching/learning. However, for a transfiguration of K-12 schooling to occur, profound barriers that have nothing to do directly with technology must be overcome.

Overcoming Barriers to A Transformation of Schooling

In 1975, in the early days of microcomputers, accurate forecasts of the extent and power of today's educational technology would have seemed preposterous to the business sector, technologists, and educators. Few would have believed that two decades later desktop machines much more powerful than supercomputers at that time would be routinely available in workplaces, schools, and many homes, with sophisticated applications and high speed networking/telecommunications.

Assume that someone had convinced them such a forecast was accurate. That these powerful, available technologies would not have completely transformed schooling and learning would have seemed even more incredible. And yet, widespread major gains in learning outcomes or motivation have not occurred, even though isolated examples of innovation have demonstrated very significant effects. If all computers and telecommunications were to disappear tomorrow, education would be the least affected of society's institutions.

The next two decades will likely see comparable increases in the power and dissemination of computers and telecommunications. Those who do not understand history are doomed to repeat it. What lessons can we learn from our experience to prevent a comparable lack of impact on educational outcomes from again occurring?

Understanding the Problem

Economic and technical barriers to change, while significant, are not the primary problems; by shifting how current resources are allocated, educational institutions can deploy and utilize powerful technologies. A lack of evidence on effectiveness is also not the major barrier to transforming schools with the help of technology, even though more studies and better methodologies would be useful.

Research documenting the utility of educational technology has been widely disseminated without inducing substantial changes in practice.

Five major reasons that educational technology has made a limited impact to date are:

- Education has been seen as something that happens through teaching students in isolated schooling settings, rather than through empowering and interrelating learning in homes, classrooms, communities, workplaces, and via the media.
- The major focus of educational technology implementation so far has been automating marginally effective models of presentational teaching, rather than innovating by making more effective models of learning-through-doing affordable and sustainable.
- Psychological, organizational, political, and cultural barriers from every type of stakeholder in education (students, teachers, administrators, parents, business, universities, accrediting associations) have impeded implementing educational innovations that undercut traditional models of pedagogy, content, assessment, and institutional organization.
- Cost and productivity calculations for educational technology have largely been framed in the limited context of a budget for schooling (e.g., dollars divided by students), rather than assessed against the larger economic context of human resource issues in our society (i.e., international competitiveness, workforce productivity, costs of crime and welfare, more complex responsibilities for citizens).
- Teachers and school administrators are overwhelmed by their current responsibilities and do not have the support systems necessary to enable reconceptualizing their role to enable learning with the aid of technology.

This situation is parallel to similar shortfalls in expected outcomes from the initial implementation of computers in business. However, educational institutions do not face the same types of pressures to move beyond impediments to innovation that businesses do. As a result, schools are stagnating at a time when our country urgently needs skilled workers and citizens for a knowledge-based society.

What actions should the U.S. Congress take to create a climate for innovation and experimentation that undermines these barriers to improving education? What are the roles of educational research and of federal policy in resolving gridlocks constraining effective usage of educational technology?

Creating a Climate for Innovation and Experimentation

As the five barriers above suggest, the largest impediment to effective use of new technologies for learning is the outmoded paradigm of education deeply rooted in our culture. Using the stature of the U.S. Congress as a vehicle to aid people in evolving their mental models of teaching and learning involves many strategies, including:

- helping parents recognize that changes they see in their current workplace—new types of career paths, shifts in the skills and knowledge most valued by employers—have dramatic implications for the education of their children;
- helping teachers who feel frustrated by the rigid structure of conventional classrooms to envision alternative forms of instruction that enable more fulfilling relationships with pupils;
- helping the corporate sector to see that the employee attitudes most valuable for the knowledge-based workplace are best inculcated through learning partnerships among parents, communities, businesses, the media, and schools;
- helping groups with sometimes opposing goals (e.g., school administrators, teachers' unions) to work together toward technology-based educational innovation as a win/win situation;
- helping taxpayers to realize that, in a knowledge-based economy and democracy, individuals can realize the American Dream only when all members of our society realize their full capabilities to contribute to the common good; and

- helping citizens understand that the most dangerous experiment we can conduct with our children is to keep schooling the same when every other aspect of our society is dramatically changing.

Vital in creating this climate for educational innovation and experimentation is that the federal government “walk its talk” by exemplifying leading edge goals, curriculum standards, and strategies for technology-based reform in the educational programs it manages (e.g., the Job Corps).

Shifting the Emphasis of Educational Research

Educational research can provide vital knowledge for informed, reflective innovation and experimentation. At least two types of studies on educational technology are currently underfunded:

- research on active, collaborative strategies for learning based on real world problems
- research on empowering and interrelating learning in multiple settings

Altering the thrust of current federal research initiatives is one means of funding such studies even during this time of tight fiscal resources. We must shift from analyzing our current, marginally effective instructional paradigm to synthesizing and evaluating emerging models of new educational approaches.

Research on active, collaborative, problem-centered strategies for learning (e.g., teleapprenticeships) is crucial to developing and assessing new types of technology-based applications for schools. For example, I and my colleagues are studying how virtual reality can enhance learning in fields as varied as physics and anthropology. As discussed earlier, a decade from now the largest installed base of sophisticated information technology available to learners will be home videogames, which will then have the capabilities of today’s high-end engineering workstations and will be ubiquitous even in poor and rural households. Using this resource external to classrooms as a delivery mechanism for motivating learning-through-doing experiences could enrich students’ lives both inside and outside of school. However, with recent budgetary cuts, the only sources of funding for these studies and other research on new models for technology-based learning are the small Applications of Advanced Technology Program in the National Science Foundation and limited resources from the U. S. Department of Defense Advanced Research Projects Agency. This stands in sharp contrast to relatively large amounts of federal resources provided for other emerging application areas in high performance computing and communications and for the National Information Infrastructure.

Research on empowering and interrelating learning in multiple settings is also critical and similarly underfunded. As discussed earlier, the increasing bandwidth of communications networks is enabling “telepresence,” the ability to add an affective dimension to the exchange of information across barriers of distance and time. As a result, virtual relationships and communities are forming among people who share ideas and experiences via new media such as the Internet. Virtual communities are potentially a powerful force for aiding educational restructuring and reform, which depends on widely scattered stakeholders forming common bonds of commitment and trust. However, only a few small federal programs in the U.S. Departments of Education and Commerce and in the National Science Foundation are funding the development and evaluation of projects building virtual bridges among groups that could collaboratively enhance students’ learning. In particular, resources are needed for developing sophisticated evaluation methodologies capable of handling problems of scale and interacting variables intrinsic in this type of educational research.

The important emphasis in these two areas of study is on formative assessments that emphasize understanding educational problems, developing evolving solution strategies, and relating outcomes to the nation’s overall challenges in human resource development. Such an approach is much more useful than conducting summative evaluations of educational technology that seek final measures of cost-effectiveness or productivity only from the narrow perspective of a fixed schooling or training budget. Educational technology is expanding its capabilities too rapidly for static measures of mature innovations to be useful, so federal funding for educational research should alter to emphasis formative development and evaluation.

One major barrier to educational change is that, despite the rich “lessons learned” in many diverse school-based technology projects, no systematic mechanism exists for sharing ideas or providing information on issues as basic as how to design and implement viable projects, what technology and financing options are available, and how to overcome common problems and barriers. Because guidebooks, proven strategies, and resources that could help them find their way are not readily available, educators who are interested in using technology to improve learning often needlessly feel like pioneers in the wilderness . For those who are not interested in technology--or who are already overwhelmed by the challenges of numerous other problems besetting their institutions--this lack of information and encouragement prevents technology from being part of the solution. The federal government should champion establishing a non-profit resource center whose mission is to improve the quality of schooling and lifelong learning in this country by facilitating the use of National Information Infrastructure technologies. If formed through combined public/private sector initiatives, such a center for learning and technology could collect and generate useful information, deliver innovative support services, and proactively reach out to communities who need assistance.

Reassessing Federal Policies that Implicitly Undercut Educational Innovation

Federal policies that on the surface seem unrelated to educational technology can have a negative effect on its development. Any federal action or regulation that indirectly constrains educational innovation via locking out alternative models of teaching/learning or of school management can severely hamper educators' abilities to use innovative technologies. Policies that have this impact include those that:

- isolate classrooms and schools from other learning settings in society
- automate traditional models of schooling with fifty minute periods and separate disciplines
- evaluate only educational outcomes readily developed by conventional "teaching by telling"
- omit a technological infrastructure in providing support for school reform
- sanction groups that accredit educational institutions by applying only traditional models of curriculum and instruction

An informal "impact assessment" of all federal policies related to education is needed to identify actions and regulations that implicitly stifle innovative uses of technology through emphasizing traditional, marginally effective approaches to schooling. Similarly, federally managed schools, such as the U.S. Department of Defense Education Activities, should exemplify leading edge approaches to educational reform through technology. Finally, as vital resources such as access to wireless bandwidth are distributed by the federal government, allocating sufficient capacity for a twenty-first century educational system is crucial.

Conclusion

Information technologies are more like clothes than like fire. Fire is a wonderful technology because, without knowing anything about how it operates, you can get warm just standing close by. People sometimes find computers, televisions, and telecommunications frustrating because they expect these devices to radiate knowledge. But all information technologies are more like clothes; to get a benefit, you must make them a part of your personal space, tailored to your needs. New media complement existing approaches to widen our repertoire of communication; properly designed, they do not eliminate choices or force us into high tech, low touch situations.

How a medium shapes its users, as well as its message, is a central issue in understanding distributed learning in K-12 schools. The telephone creates conversationalists; the book develops imaginers, who can conjure a rich mental image from sparse symbols on a printed page. Some television induces passive observers; other shows, such as Sesame Street and public affairs programs, can spark users' enthusiasm and enrich their perspectives. High performance computing and communications are creating new interactive media capable of great good or ill. Unless we apply innovative policies to shape the NII's evolution, today's "couch potatoes," vicariously living in the fantasy world of television, could become tomorrow's "couch funguses," immersed as protagonists in 3-D soap operas while the real world deteriorates. The most significant influence on education will not be the building of a ubiquitous, top-down computing and communications infrastructure for our society; but the development of a second, bottom-up human infrastructure of wise designers, educators, and learners.