School Improvement through Media in Education

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The Emergence and Challenges of Distributed Multimedia Learning Environments

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Introduction

All across America, students and teachers (and increasingly parents) are finding excitement in new technologies for learning and teaching. Stories abound of troubled students who suddenly come to life as their peers recognize talents they express in graphics programming, multimedia compositions, in video editing, or in building simulations. Professional meetings of computer-using educators are abuzz with talk of connectivity to the information superhighway and how no school can survive without direct Internet access and TCP/IP, gopher, and World Wide Web information servers, about the relative merits of computer chips such as the PowerPC and the Pentium. Schools and parents are buying CD-ROM players and deals among media conglomerates in interactive information services are front page news virtually everyday. What is all this chatter about? What's going on here? How does it relate to previous media use in education? And how might it bear on education? Is this just another hyped-up technology infatuation for education, like filmstrips or Skinner machines, which will not really make much of a difference for what or how students learn and teachers teach?

Media in education serve the fundamental role of providing representational systems, and artifacts built with them (such as documents), for use in instructional conversations. I will characterize several different perspectives on "communication" using media in education, distinguishing transmissional, ritual, and transformative communications, and then emphasizing the importance of transformative communications in pedagogy for developing learner understanding. I then contrast traditional media use in educational settings with emerging highly interactive uses of integrated multimedia computing and communications.

Preliminaries

In my view, before addressing media technologies, and my more specific topic of "distributed multimedia learning environments", we must start with conceptual preliminaries. First and foremost, education is about *learning*. But it is also about values and norms, which I will return to, before getting on to media technology and what it may mean for education. What is learning? And how does it relate to development? "Development" is often described, as in Piaget's account of stages of cognitive development from birth to adolescence, as the emergence of more powerful mental structures for the conduct of thought and action about the physical and social worlds. Such development, it is said, cannot be caused to happen, say by explicit instructional or training efforts. For this reason, "development" in Piaget's and related theories is often contrasted with learning which is thought to be brought about by education. But a considerable amount of learning occurs by virtue of observation, by imitation, and by participating in activities that are not education-oriented in nature. And the once tidy account of stages of mental development has become considerably, even irrevocably, muddied by empirical demonstrations of the "multiple intelligences", from verbal to spatial to interpersonal, which may proceed at different paces for different individuals. Many psychologists now view stage theory as providing some constraints on learning, but not as unitary age-related shifts in patterns of thought and action. What is learning? It is most fundamentally becoming more capable through the use of memories and mediational tools such as written language and other symbol systems to understand and act in new situations. It is increasingly recognized that a crucial aim of education is to development "understanding" in diverse knowledge and task domains, in terms of having the competencies required to create and manipulate representational systems in authentic tasks (such as design or problem solving) by members of a mature community of practice.

Learning may involve acquiring new understandings or skills, from riding a bike, to reasoning algebraically about gas mileage or compound interest, to explaining rainfall. It may bear the hallmarks of education – involving rather conscious study in order to learn, or the struggle to learn from a teacher. But more commonly it is an unreflective activity which takes place virtually at every moment, as we go through our days and encounters with new people, information from media and conversations, and our times involved in work, play, and with family and friends.

Values and norms appear as we distinguish learning from education. A great deal of learning takes place naturally by virtue of our genetic heritage as physical and social human beings, and that learning can be *about* anything. We can learn to steal, to use drugs, to assault others, to be racist or sexist. Surely education is not about just *any* learning. Educational institutions and practices have been established by societies in order to promote socially-valued learnings. The aims of education involve norms, and education establishes directive activities designed and implemented by agents of our society to provoke learning in particular directions, with particular objectives. We call such agents of intervention by the name of "teachers". How do they contribute to education, and how is it that media technology could contribute to what they do?

As I have described it here, *communication* is at the heart of the activities of learning and teaching that define education. As I have observed, learning is a *transformative* activity that empowers the individual to engage in new thoughts and actions, often in more generative or efficient ways. Expertise in teaching is the engagement of one's ability to listen to what a learner understands by observing what they say and do, and in finding and effectively using ways to guide them to more valued or useful ways of thinking and acting.

Now we move in on the themes of my title: in my portrayals of learning and teaching, education is not about curriculum per se and will never be replaced by technology – media or any other. Curriculum and media technology can only serve as *means* to these ends. When curriculum rules or technology is viewed as panacea, we know we are in trouble. This depiction of education as fundamentally about communication has profound implications for the teacher-centered approach that has dominated classroom practices. Communication has often been conceived of in education as a transmission of information from the curriculum to the mind of the learner. The well-crafted lecture, with demonstrations and media support, with state of the art information from subject matter specialists, is a fine goal as theater, but comes nowhere near a guarantee for learning that will result when students observe it. Because such theater represents only one side of the learning conversation. A real difficulty is that such well-crafted lectures are judged by one's adult peers, who already *know* the subject matter being depicted, whose careful organization and exposition they can therefore appreciate. But one's peers are not at all in the position of the learner in the audience, who does not yet think in the terms of the lecture as presented, and whose ways of thinking *must* be understood by the teacher and engaged in "bridging" to the more expert model by more subtle negotiations of systems of meaning between learner and teacher. To listen to the learner, the good teacher must find better ways to increase opportunities to see and hear the distinctiveness of individuals' "voices" as they think and act in order to better understand where they are coming from, and to serve as their guides to new levels of functioning.

Three Views of Communication and Their Bearing on Education

Part of the problem which has led to the teacher-centered approach to lecture and demonstration lies in the root metaphor of communication as *transmission* of information (Pea, in press). James Carey (1989) has described two contrasting definitions of communication in the history of Western thought: a *transmission* view and a *ritual* view. He claims the educational theorist and philosopher John Dewey exploited such a contrast in such remarks as: "Society exists not only by transmission, by communication, but it may be fairly said to exist in transmission, in communication" (1916, p. 5). Carey argues that both definitions appeared in common discourse as recently as the nineteenth century – the transmission view had primarily political and mercantilistic origins, and the ritual view, religious origins. The more common view of communication as transmission centers on the ancient practice of transmitting messages over distance in order to exert control, first through oral messengers, later through written languages, later yet by telegraph, and now by telecommunications. Its religious root is the sermon. The minority view of communication as ritual is associated with terms such as participation, sharing, taking part, fellowship and association. Carey claims that "a ritual view of communication is directed not toward the extension of messages in space but toward the maintenance of society in time; not the act of imparting information, but the representation of shared belief" (p. 18). The contrast is one where society creates symbolic forms – writings, dance, theater, architecture, science – that operate to provide *confirmation* not information, and thus the "construction and maintenance of an ordered, meaningful cultural world" (pp. 18-19).

These two definitions of communication lead to different questions and concerns in examinations of communicative action for education. If we take teaching *reading* as an example, the view of communication-as-transmission asks about the learner's acquisition of information conveyed by the text, the effects received by the learner from messages transmitted by the writer. The view of communication-as-ritual focuses not on receiving information from the author of the text but instead on the participation of the learner in the views and social roles of the world portrayed.

These contrasting views of communication provide a powerful dialectical opposition for conceiving of communicative action in education. While neither alone captures the whole truth about communication, it is evident that the transmission view has largely reigned in educational practice.

This one-way view of information conveyed by authorities to knowledge produced in (and not by) the learner must be enriched for a vital education to occur.

It is difficult to appropriately understand even the transmission aspects of communication in absence of the ritualistic. In a famous passage, Dewey frames the reason why we must not limit our attention to the transmission view of communication:

"There is more than a verbal tie between the words common, community, and communication. Men live in a community in virtue of the things which they have in common; and communication is the way in which they come to possess things in common. What they must have in common ... are aims, beliefs, aspiration, knowledge – a common understanding – likemindedness as sociologists say. Such things cannot be passed physically from one to another like bricks; they cannot be shared as persons would share a pie by dividing it into physical pieces ... Consensus demands communication." (Dewey, 1916, pp. 5-6).

But although two-way in its emphases, the foregrounding of a ritual view of communication for education is in itself not sufficient. Ritual is certainly important, in the significance it attaches to participation and belonging, and its highlighting of social roles. But it does not establish a *generativity* of the kind required for education. For learning is not only a conserving enterprise which seeks ritual belonging in order to perpetuate sameness and tradition. It is a quest to *expand* the ways of knowing. It seeks to expand the kinds of problems to which past concepts and strategies and beliefs can be fruitfully applied. It is one thing for the mathematics needed to plant a cornfield, quite another to launch a space shuttle. Education must establish in its communicative activities the grounds for its own evolution. I therefore propose describing a third view of communication as *transformative*. The initiate in new ways of thinking and knowing in education and learning practices is transformed by the process of communication with the cultural messages of others. But so, too, is the other (whether teacher or peer), in what is learned about the unique voice and understanding of the initiate (Pea, 1992). And each participant potentially provides creative resources for transforming existing practice, in going beyond the "common body of knowledge" of the field in their inquiries, and the conceptual tools developed to sustain these practices.

Roles for Interactive Multimedia Technology in Education

Where have we come so far? I have distinguished learning from education, emphasizing the latter's norms and values, which it is the teacher's role to ensure are advanced by means of the structuring of activities for learners. I have highlighted communication between the learner and the teacher as the primary means for fostering the advancement of education. And I have distinguished the *transmission* view of communication which commonly motivates a teacher-centered approach to education as lecture and demonstrations followed by memory-based tests from a *ritual* view of communication as fostering participation and belonging. The need for *generativity* in education led me to define a third view of communication as *transformative* which I believe to be central to your enterprise as teachers. Now where does technology fit into this picture? After over a decade of research with computers in education, we know that technology may have important contributory effects to learning, but that they are crucially mediated by social practices in the classroom by teachers and students (e.g., Pea & Sheingold, 1987; Means et al., 1993). In this regard, technologies may support educational reform, or simply sustain traditional practices, or lie stagnant in closets.

In my remarks on educational technologies as vehicles for reform, I will highlight "interactive multimedia technology" for education. You are likely to be familiar with such technology on computers which are not networked.

A few remarks help establish our present situation. Whereas computing using numbers and text has been common for several decades, desktop publishing incorporating graphics is little more than a decade old, about when microcomputers came into K-12 education. More recent yet is the increasingly common use of real-time data types such as sound, animations, and video, in applications such as computer voice mail, desktop video production, and document preparation. Dynamic documents that incorporate live animations, video clips, and sound "annotations" to cells in a spreadsheet or paragraphs in a word-processed document are now common on today's 16- and 32-bit personal computers. Today's desktop computers are becoming increasingly connected to hardware peripherals such as CD-ROM decks, videodisk or video cassette players, and still image digital cameras. Dozens of companies sell special add-on video and audio boards that enable the digital capture and use in multimedia software applications of these traditionally analog data types which will shortly become vanilla components of most computer systems. My emphasis will be on *telecommunication*-centered interactive multimedia technologies for the creation of what I call "distributed multimedia learning environments". Robust interactive communications will be central to the achievement of a learning society that can meet the demands of education and training during the next century (Pea & Gomez, 1992).

Distributed multimedia learning environments will extend the teaching, learning, and material resources beyond individual classrooms. The information network required for these environments is crucial for education because of:

(1) the communication-centered perspective on education I have emphasized;

(2) person-to-person communication needs for media-richness in their documents; and
(3) the media storage/access needs of multimedia information. (One cannot do even classroom-scale local storage on floppy disks, hard disks, or optical media like CD-ROMs of the vast video, audio, graphic, and text resources that are needed for learning and teaching. The network is essential.)

Network data communication of computer-created documents has now moved beyond ASCII text and numbers to include formatted documents with graphics and text. Innovative solutions have been demonstrated to allow for the interactive exchange of media-rich communications including video and sound over broadband private and public networks, and on diverse infrastructures from the standard telephone public-switched network to cable networks and their hybrids.

These changes in the communication and production environments of documents are evidence of the arrival at the desktop of the coalescing of the industries of print publishing, computing, cable and broadcast video, telecommunications, entertainment and consumer electronics. We call this trend the development of "new media" companies[1].

In my view, interactive multimedia technologies are not about technologies. They are most fundamentally about *interactions between people* that happen to involve interactions with computers in the loop (Pea & Gomez, 1992). In the stand-alone versions of these technologies, the educators include the designers of the programs – who have made certain things possible to do with the technology and others not – and the teachers who are using the programs. These tools augment the personal goals of expressing what one is thinking about, capturing traces of that thought in new forms of representation, and collaboratively working to create new artifacts or to learn.

[1] Nicholas Negroponte of MIT's Media Lab depicted these trends two decades ago, and Stewart Brand (1988) has traced the history of these developments in his book on the Media Lab.

The technology now available to support transformative communications of the kind I have described is at a revolutionary stage today for education. The skeptic may doubt this. But I believe that interactive multimedia technologies will not be yet another hyped-up widget for education, to be discarded by educators as we have seen with slide projectors, filmstrips, ditto masters, isolated microcomputers.

The reason is the unity of a single digital medium, or infrastructure, which integrates all media – no matter what the traditional medium has been, whether print, audio, graphics, video, or animations. This media fusion, and rapidly dropping price points for technology that can use it, is creating major new businesses and markets for homes and not only schools in the "National Information Infrastructure".

Education and the National Information Infrastructure

What is the National Information Infrastructure, also dubbed the "information superhighway"? What are some of its components that make evident how crucial it will be for education? What are its expected benefits generally?

First, the NII is not one thing but a variety of public-service networks and for-profit networks and information services.

- "A seamless web of communications networks, computers, databases, and consumer electronics that will put vast amounts of information at users' fingertips" (including high-quality video, voice, and data)
- under development and deployment by private sector firms today, including telephone companies, cable companies, computer companies, utility companies, and other new ventures (not by the government)
- to be influenced by major policy initiatives of the Federal Government, which "will work in close partnership with busi-

ness, labor, academia, the public, Congress, and state and local government".

(Source: *The National Information Infrastructure: Agenda for Action*, 1993)

Secondly, what are the major components of the NII?

- A *hybrid communications network* to include: fiber optic cable for the major arteries and portions of the distribution system, and existing copper wire and coaxial cable now used by telephone and cable television companies for the last few hundred yards to home, school, or business.
- *Diverse computers* including high-performance computers on the networks to provide switching, enhanced network services, and media storage and retrieval; high-speed computer workstations used in research and industry; powerful personal computers; cable set-top boxes that enable interactive home services; and portable wireless devices ranging from palmetto computers to phones.
- *Software applications* which are widely accessible over the network and which help people perform a wide variety of tasks quickly and easily.
- *Information* including: public and private databases and digital libraries including text, audio, image, and video formats; information services and network directories that assist users in locating, synthesizing, and updating information.
- *People* including: those of all ages and backgrounds who may use these rich and varied resources available through the National Information Infrastructure to improve how they learn, live, and work; and those who create, package, communicate, and sell information in many new ways made possible by the existence of the infrastructure.

(Sources: CSPP, 1993; Kapor, 1993; NII, 1993)

Thirdly, what are the expected impacts of the NII?

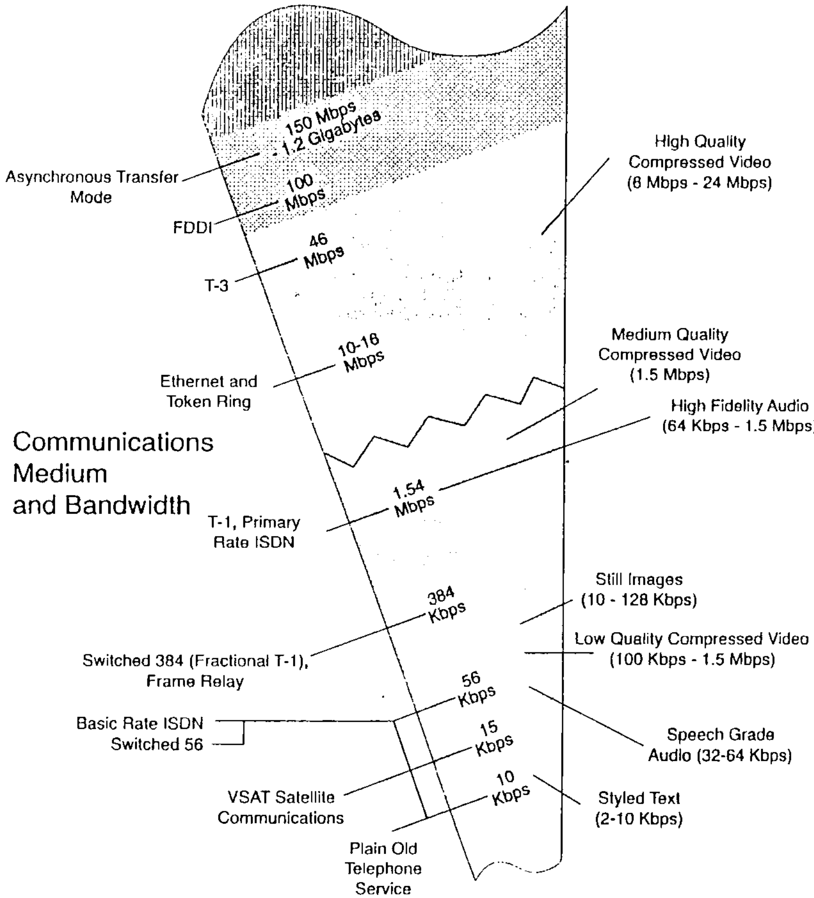
- "People could live almost anywhere they wanted, without foregoing opportunities for useful and fulfilling employment, by

'telecommuting' to their offices through an electronic highway."
- "The best schools, teachers, and courses would be available to all students, without regard to geography, distance, resources, or disability."
- "Services that improve America's health care system and respond to other important social needs could be available online, without waiting in line, when and where you needed them."
- "An advanced information infrastructure will enable US-firms to compete and win in the global economy, generating good jobs for the American people and economic growth for the nation."
- "Provide access to government information and improve government procurement ... ensuring that the immense reservoir of government information is available to the public easily and equitably."

(Source: *The National Information Infrastructure: Agenda for Action*, 1993)

Finally, what does it take to participate in the NII? At its most basic level, vanilla level computers with an inexpensive modem connection to a phone line are needed to establish Internet connectivity to millions of computers and other persons. While this level of computer offers suitable performance for text exchanges, as the richness of media for exchange increases, one needs considerably greater "bandwidth" in network services (Figure 1).

Figure 1: Multimedia Type and Transmission Bandwidth Required



(Source: Hargadon, 1992)

Distributed multimedia learning environments will require these broadband service levels which today suffer the problem of tariffs priced for business use. But states, the Federal government, and industry are fast at work to make broadband services accessible to K-12 communities at reasonable costs.

Technology Infrastructure in US Schools and Homes

Although there has been considerable growth in hardware, software, networks, and multimedia applications in schools, it is a common observation that until teachers use these technologies as facilely as pencil, paper, and chalk, their promise will have little chance of being realized. To understand how near or far we are from such conditions, I will present a few graphics from recent studies to characterize the lay of the land.

Figure 2 reveals how ubiquitous broadcast television, cable television services, telephones, and VCRs are in the United States. It is in upgrades from this near universal media infrastructure to interactive multimedia services that the NII will find its way into the vast home marketplace:

Figure 2

Television, video, and telephone resources in the United States

- 98% of estimated 93 million US households have access to broadcast television
- 90% of American TV households are passed by cable television services but only 60% are subscribers to cable; 20% of TV households have home satellite dish systems
- 72.5% of estimated 93 million US households have at least one VCR as of 1992
- 96% of estimated 93 million US households have installed telephones

(Source: Minow, 1992)

Figure 3 characterizes the installed base and infrastructures of computers in US schools, evidencing some of the central statistics on US educational computing. The most striking figure is how little of the school budget is directed toward these resources:

Figure 3

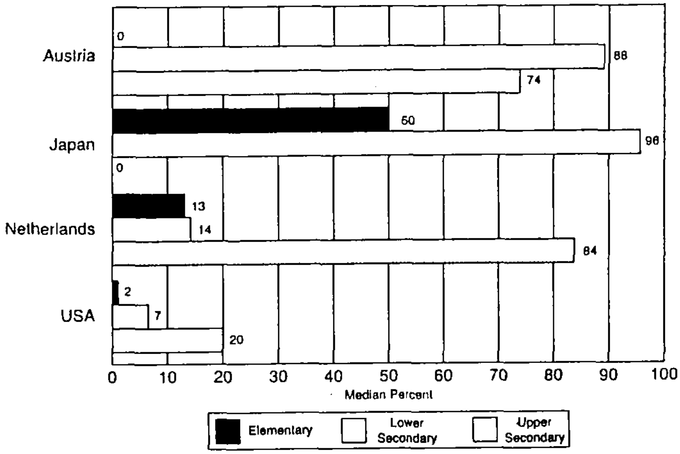
Technology Infrastructure of US Schools:
Installed base and expenditures

- 110,000 Schools including colleges, serving 60 million students with 3.5 million teachers and 4.5 million computers
- Colleges have twice as many computers as teachers; elementary and secondary schools had one to two computers per teacher
- 3.5 million computers in 1993 (one per 12 students nationally, one per 125 students ten years ago)
- Over 50% of these school computers are five years or older; 1 million new school purchases in 1993 were mainly Apple Macintoshs, 486 PCs (Software Publisher's Association, 1993).
- Precollege expenditures for software and hardware about $1 billion per year, but amount spent per student only $8 for software and $12 for hardware or 0.5% – against annual total expenditure of $250 billion, or $5500 per pupil for 45 million students
- Adding support costs for maintenance, administrative staffing, and teacher training, expenditure per students is $55 per student per year

(Source: Anderson, 1993 unless noted)

Figure 4 reveals just how outdated a majority of school computers are, in a striking international comparison of median percent of 16- or 32-bit computers in schools by school level and country. It illustrates how US school computer purchases have not kept pace at all with countries such as Austria, Japan, and the Netherlands, and make the 3.5 million computer figure for K-12 schools in the US a less impressive statistic.

Figure 4: Median Percent of 16- or 32-Bit Computers in Schools by School Level and Country, 1992



(Source: International IEA Computers in Education Study (Pelgrum and Plomp 1993)

Note: The percents of 16- or 32-bit computers do not include Apple IIgs nor IBM 8086s because major parts of their systems operate on only 8-bits.

Figure 5 documents very rapid growth of software, hardware, network, CD-ROM, videodisk, and satellite dishes for instructional purposes in US schools:

Figure 5

Technology Infrastructure of US Schools:
Patterns of growth, rising trends in networking and multimedia

- Number of computers for precollege instruction growing at least 10% a year (QED, 1992)
- Amount of software purchased for precollege instruction growing 20% a year (QED, 1992)
- Computer networks in 14% of US schools, up 64% from 1992-1993 (QED, 1993)
- CD-ROM applications found in 13% of US schools, up 48% from 1992-1993 (QED, 1993)
- Videodisk applications found in 14% of US schools and 50% of districts, up 45% from 1992-1993 (QED, 1993)
- One third of all school districts, serving one half of all public school students, now use satellite dishes for instruction, up 87% between 1992-1993 (QED, 1993).

Figure 6 shows that while ahead of Japan and the Netherlands, US schools are still not engaging in very substantial external network use.

Figure 6: Percent of computer-using schools that reported school use of an external network during 1992 by frequency of use and country within school level

	Frequency of Use			
Country	None	Less than Weekly	Daily or Weekly	Number of Schools (N)
Elementary				
Japan	83	16	2	80
Netherlands	100	0	0	179
USA	77	6	17	165
Lower Secondary				
Austria	94	6	1	264
Germany	96	3	1	144
Japan	89	10	0	113
Netherlands	70	26	3	297
USA	78	10	12	144
Upper Secondary				
Austria	76	20	3	161
Japan	93	7	1	131
USA	66	18	16	136

Source: International IEA Computers in Education Study (Pelgrum & Plomp 1993)

In these uses, e-mail services and database access predominate. Figure 7 shows that even basic instruction in use of electronic mail is pretty rare in US schools.

Figure 7: Percent of US students ever taught to "send messages to another computer" by gender, race, and region within grade level, 1992

	Grade 5	Grade 8	Grade 11
gender			
female	12	20	15
male	19	28	24
race			
white	14	20	17
African American or black	18	35	27
other	27	30	24
region			
northeast	11	23	22
southeast	17	20	18
midwest	16	21	19
west	18	29	20
percent of all students	16	24	19
(total number students)	(3947)	(3491)	(2951)

Source: IEA Computers in Education Study, USA (1992). (In Anderson, 1993b)

Now that we can see what's in the classroom, to what uses are such computer technologies being put? Recent international studies including the United States document that a predominant use of computers in education is to teach *about* computers rather than *with* computers (Anderson, 1993b; Becker, 1993). Figure 8 makes this point clearly, where up to half of the computer use in upper secondary schools is computer education rather than computer use for academic subjects. And for subjects where computers are fundamental to adult works, such as mathematics, science, and writing, only small proportions of computer access time are devoted in US schools.

Figure 8: Mean percent of overall school computer use in US schools during 1992 (as estimated by school computer coordinators[a]) by subject within school level

Subject[b]	Elementary	Lower Secondary	Upper Secondary
Learning about Computers			
computer education			
learn word processing	12	16	17
learn keyboarding	13	15	14
learn tools, databases, spreadsheets	4	8	12
learn programming	3	7	8
subtotal	2	46	51
Learning with Computers			
academic subjects			
use for math	18	12	7
use for english	17	10	7
use for science	8	7	6
use for social studies	9	6	3
use for foreign languages	0	1	2
use for fine arts	2	2	2
subtotal	54	38	27
vocational education			
use for business education	3	3	10
use for industrial arts	1	3	6
subtotal	4	6	16
Other			
recreational use	10	10	6
other	1	1	0
subtotal	11	11	6
grand total	101	101	100

Source: IEA Computers in Education Study, USA (1992)

[a] Computer coordinators were asked to make summary estimates of all the student computer use in their schools during the year (across all subjects and grades) by rating the total amount of time devoted to each activity.

[b] The items were not subdivided and labelled by subgroups in the original question.

[c] Totals greater than 100 are due to rounding.

Figure 9 illustrates this same pattern from the perspective of reports from computer-using students.

Figure 9: Percent of computer-using students[a] who report considerable computer use[b] during 1992 by school subject and country within grade level

	School Subject[c]				
Country	Computer Education	Math	Science	Social Studies	Native Language
Grade 5					
Japan	17	5	1	3	1
Netherlands	18	21	8	22	24
USA	51	28	5	10	10
Grade 8					
Austria	71	7	2	1	5
Germany	81	15	–[d]	–	9
Japan	10	2	2	1	1
Netherlands	86	7	–	12	7
USA	67	7	2	3	9
Grade 11					
Austria	84	2	1	0	1
Japan	73	2	5	1	5
USA	83	6	4	2	4

Source: International IEA Computers in Education Study (Pelgrum & Plomp 1993)

[a] Percentage calculated only on students who reported computer use in school.
[b] Considerable use is defined ten or more computer uses in the subject during the year.
[c] Only students who report taking such courses are included in the analysis.
[d] Number of valid cases too small (<250) or too many missing cases (20 %).
(In Anderson, 1993).

Current Roles of Media in Education

Today's classrooms are media-rich places. Media within individual classrooms commonly include commercial media (such as print, filmstrip, video and software publishing), repurposed media (such as cut out or photocopied articles or graphics), and local media (such as locally produced dittoed or photocopied documents, audio, or video). They also contain all sorts of media-display devices, such as blackboards, overhead projectors, film projectors, VCRs, and computers. Each device gives teachers and students particular expressive qualities. Today each device is a separate communication palette, not electronically connected to the others. In essence, there is no underlying theory or well- understood set of experiences that detail the particular expressive value that each device, and the media that may be created or displayed with it, brings to learning or how the media can be combined for particular communications outcomes.

Why, for example, does a teacher at a given moment in an instructional conversation choose a blackboard as the means to support teaching-learning communication, and choose an overhead projector at another time? Or, what defines those occasions where a still image works best as conversational support in comparison to motion video? We currently lack the principles or the appropriate lenses on the decades of experience with communication media to answer these questions. Yet answers to these questions become very pressing in a new media future where communication bandwidth, software, and hardware will combine to give teachers and students orders of magnitude more raw media access and expressive potential than that available today, and where choices along these dimensions have service and pricing implications, as Schramm (1977) years ago argued for non-computer media in education.

The expressive potential of media, however, will be diminished unless we understand how to engineer classrooms, other learning environments, and the tools they contain so people can use them. In today's classrooms, for example, teachers use tools whose design and expressive potential are not well suited to the tasks to which they are put. Films and videos offer a case in point. Teachers often acquire and show a thirty to sixty minute video when only a two to five minute segment buried in the middle contains the material which is crucial to their educational topic, and even this segment needs special elaboration and annotation. This demonstrates where the film or video media is useful, but its representation as a sequence of analog images is ill-suited to the two-way communication intensity of the classroom. In such situations, teachers are often forced to retrospectively point out to students the salient aspects of the just-presented film or video. Relatedly, it is easy to find examples from classroom observations where a teacher or a student wants a specific graphic or picture but it is not readily available from any classroom book (Cruz, Gomez, & Wilner, 1991). If time is taken to attempt to get the needed example from elsewhere, the instructional immediacy of the moment for the creation of a learning conversation is lost.

In addition to resolving the mismatch between expressive potential and expressive need in classrooms and other learning environments, interactive multimedia computing and communications technologies can make data available in the classroom available at home. Children spend a significant amount of time using media for entertainment as well as instruction – two thirds of US homes contain videogame machines. For the most part, media used for these purposes are separate from any school-based or other learning activity. For example, video games that kids use at home are wholly separate from the computers and other data they use in the classroom. It's also the case that people who work together in classrooms (e.g., with computers) cannot continue to easily reestablish those collaborations and their computational context outside the classroom. Properly networked new media technologies could encourage a merging of entertainment and educational technologies and make it possible for all students to continue in-class collaborations outside classroom boundaries.

This framework provides a point of contrast for the emerging paradigms of integrated multimedia computing and communications, and their prospective use in creating distributed multimedia learning environments. The integration of media which uses computing and communications technologies promises to transform educational practices in radical ways. Such integrations radically transform the relationships between media, shift locations and times where learning supported by new media may take place, learning environments. The integration of media which uses computing and communications technologies promises to transform educational practices in radical ways. Such integrations radically transform the relationships between media, shift locations and times where learning supported by new media may take place, potentially change the traditional asymmetric roles of media producer and consumer in education, and will redefine the markets and the costs for production, delivery, and both primary and derivative uses of media. Global markets·for integrated multimedia products and services in education should emerge in a vast, internetworked planet over the decades ahead.

Toward Teacher Innovations Using New Media Technologies to Support Reform

With all the buzz about the National Information Infrastructure, there is extensive congressional interest in these issues of information technology in education. The US Congress's Office of Technology Assessment has a major policy study underway right now to determine what teachers need to enhance their work with technologies, and what the proper Federal roles to support them might be (Fulton, 1994). Senators Edward Kennedy and Thad Cochran requested that OTA assess how the uses of technology are affecting teaching, and how teachers can best be prepared and supported in pre-service and in-service programs for using technology effectively. They note particular concerns with the availability and quality of such programs for teachers, and equity issues. This request to OTA was also endorsed by the House Committee on Education and Labor.

It is widely recognized that teachers need far more support and training than they receive today, experience with models of the ways that technology can be integrated with curriculum and enhance their teaching, and the time and administrative support for their innovations in using such tools (e.g., Anderson, 1993; Sheingold & Hadley, 1990). The OTA Project Proposal notes that support can come in the form of *resources*, including a personal computer with modem and phone line in the classroom for each teacher, in *release time* for planning and creating applications of computer-based tools (such as databases for history or science explorations, multimedia lessons in English and fine arts, or spreadsheet applications in mathematics), or in *professional opportunities* – for identifying cross-curricular applications and team-teaching with their colleagues, or networking with peers from other schools to share experiences and best practices.

The properties of support needed for teachers are unclear as yet, in part because some non-traditional educational goals become more important with NII access. Since students will have broad access to digital catalogs and materials over networks, new research skills in this medium are needed. Since millions of files in databases on computer servers throughout the world can be tapped by students in their work, specifying problems and resources needed to investigate or address them is an increasingly important skill for students and teachers. Teachers' access to colleagues through network communication forums such as electronic conferences and newsgroups opens up opportunities for sharing and professional development, but makes new time and task demands on them as well as others seek their guidance.

Today pre-service teacher education rarely provides experiences in either coursework or internship placement with computer or communications technologies. The OTA study seeks to document how leading schools of education and states are offering exemplary programs and approaches which highlight technology as a resource for teaching rather than an object of "computer literacy", the common orientation today (Becker, 1993). As a resource for teaching, technologies may help teachers do their work in more effective or satisfying ways, enable them to establish different arrangements of learning environments, or provide information access crucial in exciting new ways.

In a 1993 study by Barbara Means and colleagues funded by the US Department of Education, on "Using Technology to Support School Reform", a variety of charts illustrate how shifts in classroom philosophy toward more active learning, common in reform approaches to instruction, are enhanced by specific uses of educational technologies. Active learning emphasizes what I earlier called transformative communications.

US education reform efforts are both general, as in the Educate America Act recently expanding and legislating Goals 2000, which was adopted by the National Governors' Association, and specific to curriculum areas, as in the influential standards developed by the National Council of Teachers of Mathematics and others underway in science and other disciplines. What these efforts share, as the OTA Project Proposal notes, is "a view of active learning/adventurous teaching", based on a model of students actively constructing knowledge and understanding through interaction with and support from other learners, teachers, information, and technologies.

In this model (Figure 10), the roles change for both students and teachers, shifting from lecturing and 'chalk and talk' presentations to large groups of students, to more time spent supporting, facilitating, and coaching individual students or small clusters of students collaborating on activities.

Figure 10: Changes in classroom philosophy from traditional didactic classroom to non-traditional intentional learning environment

	TRADITIONAL DIDACTIC CLASSROOM	NON-TRADITIONAL INTENTIONAL LEARNING ENVIRONMENT
Students	Passive recipients of information provided by teachers.	Students as researchers and teachers.
Teachers	Provider of knowledge. Classroom manager.	Model learner and thinker. Guide and facilitator.
Curriculum	Basic skills distinct from higher order.	Learning to learn and thinking as basic skills.
Content	Broad coverage of content. Fragmented curriculum.	Depth rather than breadth. Integration of basic skills (reading, writing, etc.) in service of learning coherent curriculum.
Computers	Drill and practice. Programming.	Tool for intentional reflection and creation of extended community.
Assessment	Fact retention. Traditional testing of content.	Performance/projects/portfolio. Knowledge discovery and utilization processes.

Source: Hellerer & Gordon, 1994

In the terms of my discussions of communications earlier, teachers are shifting in their roles from transmissional to transformative communications. Curriculum, content, computer uses, and assessment all change in what Ann Brown and Joe Campione call "intentional learning environments" (Heller & Gordon, 1994).

Conventional and reform-oriented approaches to instruction may be compared in terms of Figure 11's seven dimensions: classroom "look and feel"; instructional mode; duration and nature of instruction; social structure of student work; role of teacher; student groupings; and assessment mode.

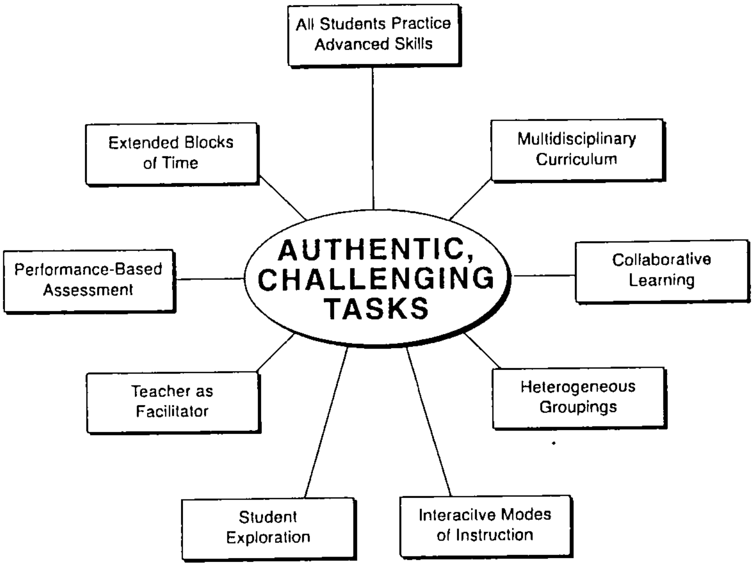
Figure 11: Comparisons of conventional and reform approaches to instruction

Conventional Instruction	Reform Instruction
teacher-directed	student exploration
didactic teaching	interactive modes of instruction
short blocks of instruction on single subjects	extended blocks of authentic and multidisciplinary work
individual work	collaborative work
teacher as knowledge dispenser	teacher as facilitator
ability groupings	heterogeneous groupings
assessment of fact knowledge and discrete skills	perfomance-based assessment

Source: Means et al., 1993

At the heart of education reform in terms of these dimensions is the use of authentic, challenging tasks (Figure 12).

Figure 12: Authentic, Challenging Tasks as the Core of Education Reform



(Source: Means et al., 1993)

Barbara Means and colleagues have provided a reasonable classification of educational technologies which we can then use to relate to reform-oriented approaches to instruction. They distinguish tutorial, exploratory, application, and communication technologies, with the examples you see listed in Figure 13.

Finally, in Figure 14, we can see how specific types of computer technologies can potentially support specific features of education reform. I refer you to their report for a comprehensive review of exemplary uses of specific educational technologies for education reform.

Figure 13: Classification of educational technologies

Category	Definition	Examples
Tutorial	Systems designed to teach by providing information, demonstrations, or simulations in a sequence determined by the system. Tutorial systems may provide for expository learning (the system displays a phenomenon or procedure) and practice (the systems requires the student to answer questions or solve problems).	– computer-assisted instruction (CAI) – intelligent CAI – instructional television – some videodisc/multimedia systems
Exploratory	Systems designed to facilitate student learning by providing information, demonstrations, or simulations when requested to do so by the student. Under student control, the system provides the context for discovery (or guided discovery) of facts, concepts, or procedures.	– microcomputer-based laboratories – microworlds/simulations – some videodisc/multimedia systems
Application	General-purpose tools for accomplishing tasks such as composition, data storage, or data analysis.	– word processing software – spreadsheet software – database software – desktop publishing systems – video recording and editing equipment
Communication	Systems that allow groups of teachers and students to send information and data to each other through networks or other technologies.	– local area networks – wide area networks – interactive distance learning

Source: Means et al., 1993

Figure 14: Features of education reform and supportive technologies (in: Mens et al., 1993)

Features of Education Reform							**Potentially Supportive Technology**
heterogenous groupings	performance-based assessment	authentic and multidisciplinary tasks	collaborative work	interactive modes of instruction	student exploration	teacher as facilitator	*Given a supportive instructional setting, the following technologies can support various features of reform, as indicated in this chart. It is possible to use the technologies in ways that promote other aspects of reform and many other exemplary products are currently available, but only uses and applications cited in the text are listed here.*
	•	•			•	•	**Electronic Databases** general discussion (pp. 19-20)
		•			•		**Electronic Reference Tools** Data Discman (p. 19) Encyclopedia Britannica (p. 19) The World Almanac and Book of Facts (p. 19)
•	•	•	•	•	•	•	**Hypermedia** Computer Supported Intentional Learning Environments (p. 26) Discover Rochester (p. 27) HyperCard (pp. 26-27)
				•		•	**Intelligent Computer-Assisted Instruction (ICAI)** general discussion (p. 15) Geometry Tutor (p. 15)
				•	•	•	**Intelligent Tools** Geometric Supposer (pp. 51-52)
		•	•		•	•	**Microcomputer-Based Labs** general discussion (pp. 15-20, 52-53)
	•	•	•	•	•	•	**Microworlds and Simulations** LOGO (pp. 20-21) LOGOWriter (p. 21) LegoLOGO (p. 21) Catlab (pp. 58, 67) Immigrant 1850 (pp. 44-45, 61) Palenque (p. 23) SimCity (p. 21) SimEarth (p. 21) Voyage of Mimi (pp. 17, 44) Where in the World is Carmen Sandiego? (pp. 21. 87)

Figure 14 (continued): Features of education reform and supportive technologies (in: Mens et al., 1993)

Features of Education Reform							Potentially Supportive Technology
heterogenous groupings	performance-based assessment	authentic and multidisciplinary tasks	collaborative work	interactive modes of instruction	student exploration	teacher as facilitator	
•	•	•	•		•	•	**Multimedia Tools and Approaches** Multimedia Works (pp. 27-28) Point of View (pp. 47, 53)
•	•	•	•	•	•	•	**Networks and Related Applications** Discourse System (p. 60) Earth Lab (pp. 50-51, 70, 83) FrEdMail (p. 29) Kids Network (pp. 29, 34, 49-50) Learning Circles (pp. 30, 48-49, 63-65) Learning Network (pp. 30, 48, 63-65) Network 2 (p. 32) SpaceLink (pp. 30, 34)
•				•		•	**Two-way Video/Two-way Audio Distance Learning** general discussion (pp. 29, 31-37) EDNET (pp. 32, 34) TENET (p. 34) WHETS (p. 34)
•	•	•	•		•	•	**Videocameras, VCRs, Editors** MicroMacro Lab (p. 60) VideoPals (p. 31)
		•	•	•	•	•	**Videodisc and CD-ROM** The Adventures of Jasper Woodbury (pp. 22-23) Animal Pathfinders (p. 23) Civil War Interactive (p. 23) The War in the Persian Gulf (p. 47) GTV (pp. 23, 86)
	•	•	•		•	•	**Word Processors/Intelligent Writing Tools** general discussion (pp. 25-26) Writing Partner (p. 79) TextBrowser (pp. 61-62, 69)

The CoVis Project as Example of a Distributed Multimedia Learning Environment

These emphases on reform-oriented uses of educational technologies and the National Information Infrastructure are brought together in the CoVis Project, on Learning through Collaborative Visualization, which I direct at Northwestern University (Pea, 1993).

The CoVis Project was designed on the premise that without careful research conducted in a well-designed high performance computing and communications context, the information superhighway will prove to be an empty promise for education. The CoVis Project is one of four NSF-funded National Networking Testbeds for Education that is providing an important articulation of the promise of the National Information Infrastructure (Office of Science Technology and Policy, 1993). CoVis provides an example of a distributed multimedia learning environment. Schools and scientists are linked through an advanced computer network for students' project inquiries that enables them to use tools for creating scientific visualizations from weather, climate, and environmental data and to communicate with email, rich data sharing, and desktop videoconferencing in collaborative and tele-apprenticing relationships.

Our central goal in the CoVis Project is to exploit advanced technologies and approaches to pedagogy to help make the teaching and learning of science in classrooms involve authentic, challenging tasks, which better resemble the practice of science by professionals (Pea, 1994). Today's classroom study of science largely lacks the originality, open-endedness, and community nature that are hallmarks of the practice of science (e.g., Linn, Songer & Eylon, in press; Ruopp et al., 1993). The CoVis Project is developing a broad suite of software, hardware, and networking technologies to support the teaching and learning of science through open-ended inquiry in an extended scientific community. This community extends beyond the boundaries of a classroom and includes, in addition to teachers and students, research scientists, museum-based informal science educators, and science education researchers. The CoVis Project studies and reports on the design and implementation of these network-based and media-rich learning environments for an audience of learning scientists, educators, educational telecommunications policy analysts, and corporations defining "new media" industries and services. In the CoVis Project we are asking questions such as: How should next-generation information networking be implemented to spur science educational reform? What are proper educational support roles for networked multimedia technology and desktop video conferencing? How can today's teachers transform their work-roles in new learning environments? What new curriculum materials, tools and assessments will be needed to support revitalized science curriculum that keeps pace with developments in the sciences?

[A 6:45 minute video on *The CoVis Project was played.*]

Challenges for Establishing NII Distributed Multimedia Learning Environments

Where are schools now in the path toward distributed multimedia learning environments on the NII? I will briefly sketch eight challenges on the way, in terms of emerging trends and issues of importance for media educators and media developers:

Missing phone lines and internetworking
Today's classrooms and schools are islands of instruction, not electronically part of greater intellectual communities. Therefore, first and foremost, classrooms need telephones and simple network terminations for integrating communication and computation. There may be over 3.5 million computers in US K-12 schools, but there is very little "education without walls" today – neither the teacher's desk or the classroom wall typically has a

basic phone line now (Honey & Henriquez, 1993). Even the common school paradigm of wide-area network telecommunications is a single computer with a modem attached to a phone line, with student computers unconnected to a local-area network or LAN. Even when schools have LANs, they are rarely connected to wide-area networks, although the establishment of distributed multimedia learning environments would require such internetworking (Newman, Bernstein & Reese, 1992). One recent article notes that: "Retrofitting schools to provide classroom-level access [to NII] will require a huge public works project easily comparable to the national effort to make aging schools safe from asbestos contamination" (West, 1994).

Changing roles for educators and students als contributors and not only as consumers of media in distributed communities of learners

One by-product of a transformative orientation to media communications in education is the creation by teachers and students of new media documents which can be used in other settings, not only in the classroom where they were created. For example, in the CoVis Project, students are creating multimedia research reports on issues in atmospheric sciences which can, with suitable quality control, contribute new resources to the learning environment of many other schools through internetworking. In Toronto, Scardamalia and colleagues have established a local-area network-based hypermedia environment for students' use in community "knowledge building" (Scardamalia & Bereiter, 1991; Scardamalia et al., 1989). In another example, TERC's LabNet Project (Ruopp et al., 1993) has established a network of hundreds of physics educators in the United States who are sharing techniques and resources which they have found effective in establishing project-enhanced science learning in their classrooms.

Additionally, as large numbers of educators, students, and other instructional resources come "on-line", the need for directory services and powerful search mechanisms for people, not only information, will become apparent.

Changing places for media in education and coordination problems of school and home computing

The major rush by new media companies to develop educational or edutainment products for home markets will confront schools with big headaches not only in terms of equity issues, but also in terms of coordination/integration issues between what is being learned at home and what is being learned at school. Schools are ill-adapted to deal with these coordination problems. In recent media coverage of Microsoft's entry into educational tools and titles, it is noted that Bill Gates plans to bypass the schools and go directly for the home market which is far larger and does not involve the complexities of state adoption procedures that many print publishers have found cumbersome. From all indications, there are likely to be different values for home-based interactive products and services, including a heavy entertainment focus and embedded advertising (as in Whittle's Channel One program, Satellite Week, 1990) to reduce product costs. And "In the worst case, we could wind up with networks that have the principle effect of fostering addiction to a new generation of electronic narcotics (glitzy, interactive multimedia successors to Nintendo and MTV); their principal themes revolving around instant gratification through sex, violence, or sexual violence; their uses and content determined by mega-corporations pushing mindless consumption of things we don't need and aren't good for us." (Kapor, 1993, p. 54).

Changing roles for publishers in networked environments predominated by dynamic multimedia documents

Technologies and commercial services providing for on-demand publishing have been developed by McGraw-Hill and Xerox in the past several years to allow localized customization of printing of text and other instructional materials. This trend toward custom compilations of media resources for instruction is evolving in the development of transaction-based fee structures for networked information services for interactive media documents. It is well-recognized by publishers that these new architectures for information distribution are posing widespread challenges to the scope of intellectual property rights.

Systemic school technology planning
It is increasingly recognized that effective integration of educational computing and communications in the service of reform requires much more than hardware and modest software investment, the primary 1980's emphasis for school computing in the United States. School systems must engage in careful technology planning as it relates to reform, and long-term budgeting for renewal.

Serious levels of teacher education and support
Teacher education efforts in support of using the new interactive multimedia technologies for education, and appropriate professional development opportunities and incentives must be much more serious in extent to make the differences needed for reform (Fulton, 1994; Honey & Henriquez, 1993). Neither in-service or pre-service programs are well developed for teacher education that highlight critical pedagogy involving transformative communications with new media technologies.

Equity problems are very troubling
Beyond long-documented inequities of access to computing in rural and inner city schools as compared to suburban schools, a diverse and important set of findings also documents gender, socioeconomic level and racial differences in non-school computer access.

Figure 15 illustrates that at Grades 5, 8, and 11, males have more access to computers in the home and are spending more time with computers in the home.

Figure 16 shows that SES differences in both home computer access and time used are particularly dramatic, at grades 5, 8, and 11.

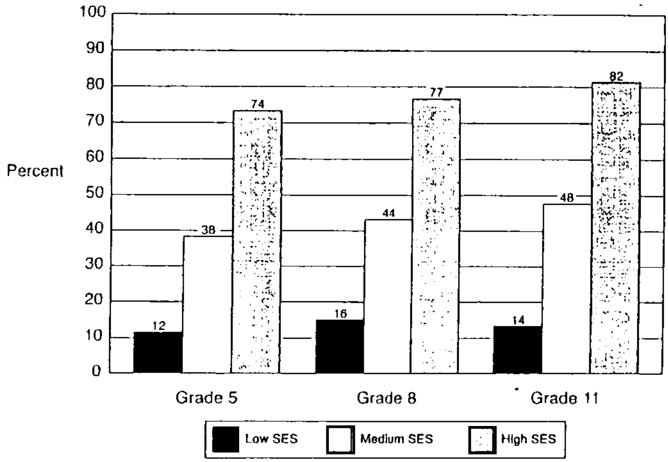
Figure 15: Percent of US students who report out-of-school computer access, a computer in the home, and mean hours of non-school computer use during 1992 by sex and socioeconomic status within grade level

student characteristic	any computer access outside school (this year)	computer in the home	hours per week using non-school computer: mean	hours per week using non-school computer: SD
		grade 5		
sex				
male	83	40	2.9	6.2
female	82	37	2.2	4.3
SES				
low	70	12	2.0	5.6
medium	85	38	2.2	4.7
high	96	74	3.6	6.0
all	83	38	2.5	5.3
		grade 8		
sex				
male	83	51	2.7	4.8
female	82	45	1.7	3.1
SES				
low	66	15	1.2	2.5
medium	82	44	1.9	3.9
high	94	77	2.9	4.7
all	82	48	2.2	4.0
		grade 11		
sex				
male	81	57	3.0	5.7
female	79	46	1.7	3.1
SES				
low	59	14	1.5	2.7
medium	81	48	2.0	3.8
high	92	82	3.1	5.8
all	80	51	2.0	4.6

Source: IEA Computers in Education Study, USA (1992)

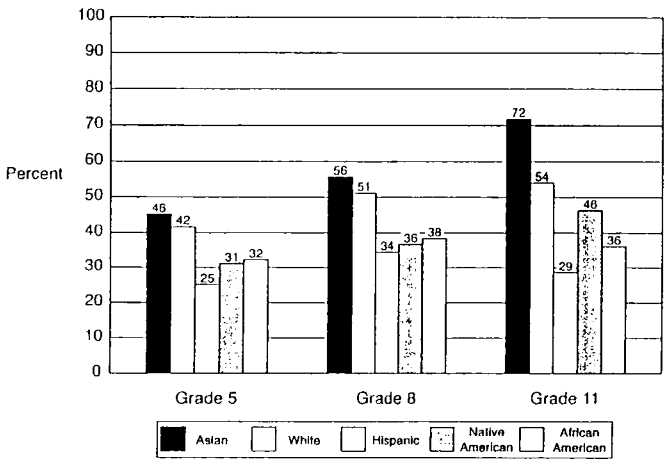
Figure 17 shows for all grades, blacks and Hispanics are less likely to have a home computer than whites. These race differences are apparent even when SES is controlled for (Anderson, 1993b).

Figure 16: Percent of all U.S. students who report a computer in the home by socioeconomic status within school level, 1992



Source: IEA Computers in Education Study, United States. (In Anderson, 1993b)

Figure 17: Percent of all U.S. students who report a computer in the home by race within school level, 1992



Source: IEA Computers in Education Study, United States (1992).

These findings raise policy issues of immediate concern for the federal government, the states, and for local communities. Dramatic differences in computer access appearing in homes for SES especially, but also for race and gender, are potentially contributing to troubling inequities in the US student population. Yet the 1993 NII Agenda for Action document from this administration is clear on this issue, noting that we must:

"Extend the 'universal service' concept [for telephones] to ensure that information resources are available to all at affordable prices. Because information means empowerment – and employment – the government has a duty to ensure that all Americans have access to the resources and job creation potential of the Information Age."

Another equity issue is also of concern: There is very little in the way of non-English software available in support of ESL populations which are becoming an increasingly large proportion of students in US K-12 schools.

Empirical evaluations of effectiveness

Empirical research has for some time documented that computers in education can provide cost-effective teaching resources. But most of this research has been directed at computer-assisted instruction paradigms that are not consonant with the emphases on active learning, authentic and challenging learning tasks, and performance-based assessment in reform-oriented uses of computing technologies (Means et al., 1993). Needless to say, the same is true for emerging paradigms of distributed multimedia learning environments. The action-oriented nature in much educational computing research today takes place in the complexities of real educational settings rather than in carefully controlled laboratory studies, and poses new challenges for research on the benefits of technology use in education. Among important topics for study we may highlight the need for empirical study of the cognitive and social demands of particular media technologies for specific tasks and domains of inquiry in education, such as scientific visualization, simulation building, and multimedia composition. One can only urge, however, that taking an overly cautious approach to school technology planning and implementation by awaiting "the definitive research study" will lead you to miss crucial opportunities to learn how to improve the educational experiences in your schools through ongoing testing, monitoring, and refinement within your own situation. We should be mindful of the fact that we often place double standards on research on learning with educational computing – insisting on research results to warrant investments which are rarely insisted upon for other teaching and learning resources in education.

Conclusions

What contributions can media make to school reform? In my judgement, the integrated multimedia computing and communications technologies now becoming available will not by any means make their contributions sheerly through their use. This is because some uses of such media, perhaps even the ones we may most expect from the present teacher-centered classrooms which emphasize communication-as-transmission, are not congruent with reform orientations which stress students' active learning and engagement in authentic, challenging tasks. To serve such ends, new media technologies should not serve as machines for "delivering" knowledge, but as resources and tools for augmenting human interactions and communications required for learning. The new media paradigms congruent with such reform orientations will be symmetric, not largely asymmetric as in the video-on-demand use that many view as the "killer application" for new media information services for the home.

Asymmetric architectures will perpetuate broadcast mentalities for education, unlike highly interactive ones which emphasize transformative communications. So when we see the current spate of projects around audio-visual telephones at a distance using satellites or fiber optics cable installations to replicate the well-crafted lecture, with minimal question asking and real learner interactivity, or absent joint inquiry across communication sites, we are as concerned about the prospects for learning offered as many critics rightfully were in the times of educational TV. The technology *per se* is not the central issue. It is specific kinds of activities involving the technology that will be likely to pay off in educational outcomes. New media should seek to foster learner expressiveness and augment teachers' tasks of interpreting and then guiding student understanding toward higher standards.

The wonders of learning through transformative communications when education is at its best will continue to lie in the hands of individual teachers. They will not be replaced by new media technologies, and the role for educational leadership is to ensure conditions so that their best work as teachers can be augmented with new media tools in ways that enhance the learning of all of our students. Teachers need a supportive administrative context and regular opportunities for development. They need the time and tools to support their participation and development as professionals in a community of learning for reform. Every school needs to develop lead teachers as agents of change for integrating and innovating in education with new media technologies. States, businesses, and universities can play major supportive roles in empowering teachers in their work of fostering learning with these new tools. Lighthouse schools for innovation can be established in every state to provide model programs that illustrate what is possible and which provide professional development opportunities for teachers. New collaboratives with school systems, universities, and corporations have the potential to bring together the resources of the workplace, communities, and higher education to systemically reform education, including uses of new media technologies that foster national reform aims toward higher standards. These are extraordinarily exciting times, but even free and ubiquitous computing and communications will not improve education in and of itself. For that requires your visions, your passions, your commitments, and your hard work as teachers, educational leaders, and action-oriented media researchers.

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