Where is the Knowledge?
Knowledge Management, Research and Pedagogy in the Electronic Age

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Presentation to The Special Libraries Association 83rd Annual Conference, San Francisco, CA June 10 1992

Abstract

Paper presented to the Special Libraries Association, 83rd Annual Conference,San Francisco, Ca., on June 10 1992. Defines, discusses and lauds new technology for research and pedagogy in the electronic age in the near future both nationally and internationally. Gives examples of usage ranging from reconstruction of Dead Sea Scrolls to planning baseball strategy to answering medical questions in Africa.

Alerts both teachers and librarians to expect change and maintains that librarians will not be passive consultants but knowledge managers. Discusses the concept that lecturing is an unnatural act and predicts that within next two years automated instructional systems will be implemented. Says that delay is caused not by lack of machinery but lack of courseware. Discusses limits of present software such as CD-ROM. Advocates networked, digital video for future educational technology, i.e. Computer-Mediated Learning Systems, although concedes that technology cannot meet all instructional needs.

I would like to speak to you this afternoon about knowledge and knowledge management. I want to share some of my thoughts about the role that knowledge managers — and that means most of you — will play in coming years, as you assume new roles and forge new alliances in the fields of research and pedagogy. And finally, I want to describe my vision of the next generation of learning systems, and the role that knowledge managers might play in the development of these systems.

As many of you know, if you have read any of my columns in the *Chronicle of Higher Education,* I am a baseball fan. In fact, I have often taken the position that fife is a metaphor for baseball. When I attend baseball games, I witness, in essence, a reshuffling of statistics. For as the wonderful sports writer Roger Angell has said, every time a big league umpire shouts play ball, a host of statistics "swarm and hover above the head of every pitcher, every fielder, every batter, every team, recording every play with an accompanying silent shift of digits."[1]

Virtually every observer of the American pastime has commented its preoccupation with statistics. Recently, a cultural anthropologist noted that this obsession characterizes "a nation preoccupied with enforcing a vision of community upon a vastly heterogeneous population. What statistics do for baseball, polls and elections do for society at large."[2]

An article in last Saturday's *New York Times* drove home his point, persuading me that in this political season, America's infatuation with statistics is indeed spilling out of the ballparks. Perhaps you saw the page-one article headlined: "Bush, Asking for Continuity,Sounds Like a Revolutionary." In the article, political analyst Andrew Rosenthal documents the President's "sudden fondness for the oratory of revolution," offering the following data:

> In seven public appearances this month alone, Mr. Bush used the word "change" or "reform" 188 times. He spoke of "revolution" 17 times, including 10 times in one speech at a high school in Allentown, Pa., a personal record for Mr. Bush in a single address. Mr. Bush has talked about change before, but generally in other countries. In all of 1991 he spoke of "change" 57 times, all but seven times in reference to places like the Soviet Union, Ethiopia, Argentina and Peru.[3]

Now, all of us here share a fascination with information, and the ways it is collected, interpreted, and used. And so I hope you agree with me that this front page story reflects a revolution in textual analysis that has been brought about by the proliferation of personal computers over the last decade.

Not that the statistical analysis of texts is entirely new: we've always had literary bean counters, who have commented on the frequency of particular terms in a Shakespearean text, or in the Bible. Concordances existed long before the age of the personal computer.

But today, we can subject a vast range of texts to statistical analysis with the push of a button or the click of a mouse. You can be sure that journalist Rosenthal didn't sit with a stack of speeches and a yellow highlighter, marking every occurrence of the word "revolution." He used a computer to search *Presidential Documents,* an electronic compilation of official White House records.

Machine-Readable Text

One of the things that computers can do better and more efficiently than we humans is count. Let me say that as an educator, I rarely stress the computer's computational capacity; I'm much more excited about the computer as a communication and knowledge-building tool. And by nature, I'm more inclined to networking than nitpicking.

But when it comes to analyzing source materials, computation can yield new insight, detecting patterns that would otherwise remain beneath the surface. As Avra Michelson of the

National Research and Education Network noted in a recent speech, computers can count not only words, but also brushstrokes in a Rembrandt painting.[4]

"Increasingly," she adds, "they can perform pattern recognition, do semantic analysis, analyze text, and model concepts. And computers can perform these processes faster with a large number of sources in greater precision than scholars who must rely on manual interpretation of data."[5]

In these ways, computers have radically changed research methods not only in the sciences, but also in the humanities and social sciences – in such diverse fields as religious studies, renaissance music, medieval medicine, and lyric poetry – and efforts are underway to convert paper-based materials in virtually every field to machine-readable form. The Thesaurus Linguae Graecae (TLG),a project for converting the extant ancient texts of classical Greece, is but one example. About 8,000 series of source texts in the humanities have already been converted to machine-readable form.[6]

Two recent efforts are facilitating the conversion process. First, a project called the Text Encoding Initiative (TEI) is developing guidelines for encoding text. This should allow scholars around the world, working on widely different research projects and using different methodologies — not to mention different hardware and software – to share electronic texts. The second effort is the creation of a new institution, the National Center for Machine-Readable Text in the Humanities.

Increasingly, we're seeing non-textual sources converted to electronic formats as well. The American Memory Project at the Library of Congress has begun

a five-year pilot project to convert sources in a variety of media (including not only text, but also sound recordings, still pictures, and early film footage) to machine-readable form. Initially, these sources will be available on CD-ROM, but ultimately they will be digitized, so that they can be distributed over networks and manipulated by users.[7]

Let me give you an example of a multimedia archival project that is closer to home. Here in Ohio, at Wayne State University, instructional technology specialist Bob Smith is in the early stages of assembling a very important multimedia archive, documenting the history of African-American education in America. Smith plans to travel all over the country, gathering materials for this project – not only texts, but also photographs, recordings of oral histories, and video footage. All of these sources will be accessible electronically.

New Technologies, New Questions

Technology is changing not only our research methods, but also the kinds of questions we are posing.

In the physics lab, investigators now routinely tackle problems that require massive computation and would have been considered unthinkable budget-busters only a few years ago.

In the Indians' dugout, manager Mike Hargrove can now get answers to questions like: how well does Albert Bell bat against left-handed pitchers with two men on base? Or what are the odds that Steve Olden will walk Ricky Henderson in the ninth inning?

In the realm of archeology, two Ohio-based scholars who until recently had been denied access to the Dead Sea Scrolls, have been able to reconstruct the historic document, using a desktop computer. Professor Ben Zion Wacholder of Hebrew Union College in Cincinnati and his graduate student Martin G. Abegg Jr. used a recently published Concordance, which gives information about the location and context of individual words in the Dead Sea Scrolls, to piece together the entire text, phrase by phrase and sentence by sentence.[8] Without today's technology, I doubt that they would have undertaken the effort. It would be like cutting and pasting Andrew Rosenthal's notes to patch together President Bush's stump speech!

And while I'm on the subject, my last example of how the computer is changing scholarship is the Bush scrolls: It's a safe bet that to conduct his research, Rosenthal needed nothing more than a laptop and a modem – or perhaps a CD ROM player. It probably took him relatively little time to access the database of presidential documents and carry out a series of word counts.

It's easy to forget that ten years ago, Rosenthal would have had to go about this task differently. He could have counted the words by hand. Or, he might have brought data on a magnetic tape to the campus information center for processing by a professional programmer using a mainframe computer.

But it's far more likely that he wouldn't have written the article at all. I'm not suggesting that the mainframe approach would have struck him as unwieldy. I'm saying that the word-count approach probably wouldn't have occurred to him in the first place.

As Avra Michelson notes, today's researchers are less likely to rely on programmers to perform their computations. And that changes their approach. She writes:

> Being directly involved in computing changes one's perspective on the nature of research itself: the kinds of questions that can be posed, the analytical methodologies that can be used, the types and amount of sources appropriate for analysis, and the form of presentation of the findings.[9]

The Library —A Work in Progress

Now, clearly, all of these developments are changing the nature of the library and the role of librarians and archivists. Today's library is very much a work in progress. Despite rapid change, it will be years before most libraries are fully electronic.

Although electronic materials play an increasing role at the Library of Congress, the vast majority of items – nearly 87 percent – are still on paper. The Library now has nearly 100 million items in its total inventory; it reports about 12.5 million records on computer databases.[10]

But change will come. In time, the Library of Congress will be a virtual library – a vast electronic network that will give users access to multiple information sources in all possible media, ideally by means of multifunctional workstations located inside or outside the library's physical plant.

I was fascinated to learn, by the way, that the Library of Congress is taking steps to turn itself not only into a virtual library, but also into a "**virtual reality li**brary." *The Chronicle of Higher Education* reported earlier this month that the National Demonstration Lab for Interactive Information Technologies

(the new computer center set up last month at the Library of Congress), is consulting with the Council on Library Resources about simulating itself in "virtual reality" – the interactive technology that lets you "enter" a computer environment. That would be quite an experience for us die-hard browsers. We could virtually "walk" through the stacks, taking books off shelves to peruse their contents or leafing through journals — without ever leaving our offices.[11]

I said a moment ago that today's library is a work in progress. I might add that today's librarians and archivists are works in progress as well. For one thing, the distinction between the two professions is beginning to blur. Traditionally, a key difference has been that archivists work with unique material, and librarians with materials that are available in multiple forms. But as more and more texts are converted to electronic formats for storage and dissemination, that distinction loses meaning.[12]

The archivist's role is changing in another sense as well. Archivists have generally been concerned with materials that no longer have a useful life within the organization in which they were created. Usually, materials are at least 30 years old by the time they are excreted from an organization and entrusted to archivists. But as we store increasing numbers of materials in digital formats, there is growing need for archivists to move from custodianship of records to direct involvement in system design, so that as new materials are acquired, they are preserved in a format that safeguards the integrity of the record while allowing access to it.

Access and Equity

I have read and heard many different views of how tomorrow's libraries and archives will evolve, but everyone seems to agree on one point: access to information, rather than ownership of information, will be the measure of a research facility.

Equal access to information resources is becoming a major issue on campuses across the nation, and in political bodies as well. After all, information is power in today's world, and the impulse to limit access to information has been very strong in Academia, as in other parts of our society. The struggle over the text of the Dead Sea Scrolls is a great example.

The research library cannot continue to be an institution that caters exclusively to the well informed. Too often, today's library is seen as an information warehouse open only to those who are already familiar with its culture and its rituals. If this persists, our libraries will serve a smaller and smaller segment of the American people. Our libraries must also meet the needs of the uninformed and the misinformed.

Knowledge managers have an important role to play in providing access to information to those who need it most, including potential users in the developing world. We cannot be content to provide information at an ever faster rate to those who already have access to vast stores of data. It is not enough to use technology to enrich lives. Whenever possible, we must use it to save lives as well.

In the last year, I've begun to speak of a challenge facing those of us who specialize in knowledge management: we must make the world "safe for intelligence."

By that, I mean that we must create a world where our tremendous intellectual, informational, and technological resources can make a difference – improving the quality of life for all of us who share this planet.

Thanks to electronic networks, health workers in industrialized countries, have rapid access to the most recent research findings. They can use personal computers in their offices and clinics to get detailed, specific information about diagnosis, treatment and drug trials. For example, AIDS doctors can pinpoint the information they need using CD ROM discs that hold a library of virtually all of the most up-to-date AIDS literature in one compact source.

Just imagine what these tools could mean to the beleaguered medical workers– both urban caregivers and bush doctors – in Africa and elsewhere in the developing world. With recent advances in wireless communication, these connections will be more feasible. Motorola is talking about sending up satellites to serve as revolving antennas for parts of the world that have poor telecommunications infrastructures. Imagine a world where satellites can beam answers to urgent questions posed by a parasitologist in Zaire, a teacher in Somalia, or a farmer in Uruguay!

Pointers and Retrievers

Of course, day to day most of us are more involved in issues of local access than global dissemination. Providing local access means not only creating electronic resources and networks, but also giving a broad range of people the know-how they need to access those resources and those networks. Both efforts are critical; but they compete for scarce dollars. As a result, we're hearing a great deal of debate about priorities.

Some argue that until more patrons are computer-literate, libraries need to invest heavily in instruction and assistance. At James Madison University, for example, technical services staff have been shifted to public services to meet patrons' growing need for help negotiating electronic databases.

Others, like Kenneth Dowlin, City Librarian for San Francisco, stress the need for librarians "to move from pointers and retrievers to facilitators and organizers," shifting human resources from "the end of the stream, which helps the patrons find books, to the front line, which will organize information so that they can find it themselves."[13]

Of course, librarians need to do both: first they have to confuse users by converting materials to electronic form, and then they have to help them access those materials. Dowlin speaks of pointers and retrievers; to the computerphobic, today's librarians might seem to be a new breed– something like a cross between a pit bull and a St. Bernard. First you scare the daylights out of the patron, and then you offer first-aid and comfort.

But seriously, Dowlin makes an important point, and he is not alone.

As we move toward the virtual library, librarians will not be passive consultants. They will assume the very active role of knowledge manager. Richard Lucier of the University of California at San Francisco, draws the distinction in this way: "What is remarkably different about the knowledge management role is that it insinuates the library at the beginning of the information

transfer cycle rather than at the end and focuses on information capture rather than access and use.[14]

Lucier's own work exemplifies the changing role of the librarian. As you may know, before going to UCSF, Lucier worked at Johns Hopkins, where he directed a multidisciplinary team of librarians and information specialists, software engineers, content specialists, and social scientists – including an anthropologist. This team collaborated with scientists and scholars on the Human Genome Project, creating specialized databases and electronic tools for the project, and assuring that the construction of this complex knowledge base, and the documentation of that process, would go hand in hand. This project is an important example of how knowledge management is revolutionizing the relationship between researchers and librarians.

The Heart of the Library

Before going any further, I want to acknowledge that one of our most thoughtful writers on knowledge management is right here at Case Western Reserve. Kaye Gapen, Director of the University Libraries, defines knowledge management as:

> [the] means by which librarians can help scholars and universities retain control of the intellectually-generated property that is their most precious and valuable commodity. It is a way of structuring new works as they are created, so that they are maximally accessible and a way of accessing existing resources to enable the highest level of integration with the scholar's work, helping to create new knowledge.[15]

Gapen urges us to look at tomorrow's library from a different perspective. As we envision the virtual library, she argues, our first step is usually to try to understand the technologies that we hope to bring together; then, from our standpoint inside the technology, we take a look at the people who will use it. She calls this the "view from the outside in."

It is the wrong view, Gapen argues, because the "heart of the library, the pulsing purpose which has comprised the library's mission, has been something else altogether..." She identifies that "something else" by quoting Jesse Shera, who wrote 20 years ago that the mission of the library is to "bring together human beings and recorded knowledge in as fruitful a relationship" as is humanly possible.[16] Gapen says that as we move toward the virtual library, it is not enough to build a technological infrastructure. We must lay an intellectual foundation as well, rethinking what it takes to bring together human beings and recorded knowledge.

As Jesse Shera wrote, the basic problem in librarianship is to "match two patterns – the pattern of human thought to the pattern of organization of the library."

As we apply new technologies to the creation, preservation, and dissemination of knowledge, Gapen challenges us to do nothing less than to reconsider what it means to learn – as an individual process and a social process. In this sense, I have found a kindred spirit in your university's library director, because I have been delivering a very similar message as I've traveled to campuses across the nation.

The Learning Society

For the last several years, I have been encouraging people to envision our society as a total learning environment – what I call the Learning Society. The idea is to recognize learning as a normal, necessary part of being alive rather than a specialized activity tied to the classroom.

In the Learning Society, modern technologies are harnessed to free up the way we learn, so that learning can go on at any time, at any place, on any topic, and in any sequence.

Today, human knowledge roughly doubles each year, and the shelf life of expertise grows shorter each day. We hear a great deal about the *information explosion* – the astonishing increase in our ability to collect and process data, and the resulting bombardment of people and institutions by massive quantities of information.

I have urged a shift in emphasis away from the information explosion, to a *learning explosion*, in which we burst the normal confines of how we think about learning as bound to fixed places, times, subjects and sequencing.

To ignite the learning explosion, we need to rework not only our libraries, but virtually all of our institutions, so that they promote rather than discourage continuous, collaborative learning.

In the terms outlined by Gapen and Shera, we must create organizations whose structures and communication patterns are aligned with the thought processes and learning styles of the people they bring together. Because until we do, advances in information technology – no matter how swift–will not bring about equally dramatic increases in productivity.

Information and Knowledge

Gapen draws an important distinction between information and knowledge. Citing Shera, she says that information becomes knowledge only when you have "processed through your own value system, related it to your own image and perhaps changed your image of the world, as a consequence of it.[17]

The kind of learning that is most important to us in higher education is, in fact, this process of transforming information into knowledge. It is the process of meaning-construction. And in view of the information explosion, no challenge is as urgent today as helping students find meaning in the flood of data that threatens to overwhelm them. Unless we meet this challenge, we shall be forced to ask, as T.S. Eliot did decades ago:

> *Where is the wisdom we have lost in knowledge?*
> *Where is the knowledge we have lost in information?*[18]

I believe that the knowledge we have lost in information can be reclaimed at a very particular location – the juncture where librarianship meets pedagogy.

Knowledge Management and Pedagogy

In discussing the changing role of the librarian, I spoke earlier about the need for greater collaboration, throughout the life of a project, between librarians and researchers.

Let me now add that we need more collaboration between librarians and teachers — and not only in making course materials available. As knowledge managers, librarians need to be involved in the design and development of curricula, particularly interdisciplinary curricula.

We are beginning to see this happen. A case in point is the Synthesis Coalition Project. Barbara von Wahlde of SUNY-Buffalo writes that like the Human Genome Project, it "involves librarians as team members in the development of a complex knowledge base," but in this case the goal is developing a "multimedia database of curricular materials, ranging from simple text to full-motion video, connected to courseware development studios and hightechnology classrooms.[19]

My message to the librarians among you is: Expect change. In coming years, as you assume the role of knowledge managers, you will be increasingly involved in instruction — the development of instructional strategies and materials, as well as active participation with students and teachers in learning activities.

But I am also saying to the teachers among you: Expect change. Pedagogy in higher education is not all it should be. The lecture format is quickly becoming obsolete. In coming years, you will be working closely with knowledge managers to help your students learn how to learn, that is, how to access information and do the meaning-construction work needed to transform information into knowledge.

As we revolutionize knowledge management in higher education, we will also need to transform teaching.

In the last few years, a number of well known scholars have published books about higher education in America. And while they've expressed markedly different views on the state of the modern university, they agree on one thing: in the realm of higher education, there is no consensus on what constitutes excellent teaching, and no systematic effort in place to improve pedagogy.

Page Smith, probably the most severe critic of higher education, argues in *Killing the Spirit* that all true education necessarily involves response, and that "the lecture system is the most inefficient way of transmitting knowledge ever devised."[20] He adds that it would be more effective, in most instances, to distribute lecture notes at the beginning of the term.

And yet, Smith tells us, "80 to 90 percent of all instruction in the typical university is by the lecture method.[21] He cites the observation of Patricia Nelson Limerick that:

> lecturing is an unnatural act, an act for which providence did not design humans. It is perfectly all right, now and then, for a human to be possessed by the urge to speak, and to speak while others remain silent. But to do this regularly, one hour and 15 minutes at a time...for one person to drone on while others sit in silence?[22]

Admittedly, Smith is a singularly harsh critic of higher education. But he is hardly alone in criticizing the quality of college teaching. In *College: The Undergraduate Experience in America*, Ernest Boyer agrees that "today, the lecture method is preferred by most professors"23 and that "....the college teaching we observed was often uninspired...."[24] With few exceptions, the teachers he and his colleagues observed functioned as talking heads, spouting information to passive recipients for 45 or 50 minutes at a time.

Boyer describes a freshman psychology lecture, where:

> ...300 students were still finding seats when the professor started talking. 'Today,' he said into the microphone, 'we will continue our discussion of learning.' He might as well have been addressing a crowd in a Greyhound bus terminal. Like commuters marking time until their next departure, students...alternately read the newspaper, flipped through a paperback novel, or... [stared] into space. Only when the professor defined a term which, he said, 'might appear on an exam' did they look up and start taking notes.[25]

Of course, Boyer's observations are not all negative. The results of his national survey were far less discouraging than the anecdotal evidence from campus visits might suggest. In fact, most students said that they were satisfied with the teaching on their campus.

But he also found that nearly a third of students at research universities have more than 100 students enrolled in most or all of their classes, and that the freshman and sophomore classes (often the general education sections) were most likely to be overloaded.

Nearly half of the students he surveyed said that "general education courses are rarely taught by the best faculty members of the departments in which they are given." In my view, the problem is most acute in the sciences, where so many of the critical introductory courses are taught by graduate students and young faculty members from abroad, who may have difficulty communicating effectively in English, and have very little feel for the culture or previous educational experiences of their students. We're losing science students early in their academic careers, and this is part of the problem. To be effective in the classroom, these knowledgeable teachers need a great deal more support than they now receive.

Even staunch defenders of the modern university express concern about the quality of teaching. In *Beyond the Ivory Tower*, Derek Bok observes that faculty are increasingly distracted by government service and/or private consulting work. He acknowledges that teaching loads have dropped significantly in scientific disciplines, like math and experimental physics, "where the interests of undergraduates have steadily given way to the demands of pure research."[26]

At this point I want to call time-out for a moment. I want to be very sure that I'm not misunderstood. Let me say clearly that my purpose is not to denigrate either the efforts of our college teachers, or their professionalism.

But let's be real. We all know that teaching the same introductory material for the tenth or fortieth time can be intolerable. We all know that we wait impatiently for students to master the basics, so we can get to the heart of the matter _ the more interesting, substantive part of the curriculum.

When I taught general physics, it took many weeks for students to master enough basic physical principles so that we

could begin to link those principles, and carry on a conversation about what happened when we did.

As Henry Rosovsky writes in *The University: An Owner's Manual,*

> How to remain interested in one's professional duties is a major problem. It is hard to see how anyone can teach, say, introductory economics for over a quarter of a century without falling asleep at the very mention of the assignment.[27]

So yes, we sometimes get bored or burned out. And yes, the competing demands of research, publication, and activities that supplement low academic incomes, can certainly drain our energies.

But I'd venture to say that most of us faculty members want very much to teach effectively, to motivate students, and to find ways to mesh own academic pursuits with our teaching responsibilities. And some succeed brilliantly.

In *The Vocation of a Teacher,* a rare and inspirational account of a career in college teaching, Wayne Booth says that after teaching some twelve thousand class hours, holding as many as fifty thousand student conferences, and writing something like eight million words of commentary on student papers, he has not yet burned out. (After reading those statistics, I found myself hoping that Booth would write a sequel called "The *Vacation* of a Teacher"!)

Booth remains enthusiastic about his classroom duties, but describes steep obstacles "that can not only turn good teachers into bad, but drive them from the profession entirely..."[28] He speaks, among other things, of impossible workloads; large classes; and poorly prepared students.

My question — and the question underlying my entire discussion of the quality of college teaching — is this: With the help of knowledge managers, can we not take advantage of today's educational technologies to scale, or at least to scale down, some of these obstacles?

I think we can.

I say this, fully aware that microcomputers have been widely available on campuses across the nation for several years now— and have not yet begun to resolve most of the problems I've mentioned.

That is because we've had the machinery, but not the courseware.

Up to now, higher education has been more resistant to adopting new courseware than elementary and secondary schools. In part, this reflects the realities of the instructional materials business. In K-12, decision-making is highly centralized at the state and district levels. In higher education, the individual instructor generally specifies the text or courseware.

It also reflects the fact that as things stand, the academic world rewards prolific researchers, but not the people who effectively link research with instruction. We all know colleagues and friends who have left the names of textbooks off their curriculum vitae, for fear that they won't be taken seriously as scholars. The same has held true for authors of academic software.

And finally, it reflects the fact that until now, we have not had a workable, cost-effective way to deliver multimedia courseware to large groups of students in a way that would let them work at their own pace.

All of that is changing. We are about to leapfrog over existing technologies to the next generation of learning systems.

I'm not talking about the year 2000 _ as technologists are wont to do. The instructional systems I'm about to describe will be available within the next two years.

The Next Generation of Learning Technologies

Picture this: a student sitting at a workstation tries to solve an equation, but gets it wrong. Within seconds, she is shown a three-minute video that explains how to approach that class of problems, and how to solve a similar equation. She tries again. If she gets it wrong again, she can review the video clip, or she can seek help in another format.

Computer-Mediated Learning Systems exploit the potential of multimedia to make interactive learning more immediate, more compelling, more closely attuned to the needs and learning styles of individual students.

You may have seen multimedia applications that take advantage of CDROM or videodisks, mixing video clips, recorded speech, music, animation, graphics, and text.

The best of today's multimedia applications let us make better use of teachers' time and energy.

Let me offer an example. Dr. C. Carl Jaffe, a professor of diagnostic radiology at Yale University's medical school was frustrated about the amount of time he was spending teaching each new resident how to interpret the video images of ailing hearts produced by an ultrasound machine.

"My time was very inefficiently used because I repeated myself every month," Dr. Jaffe complained.

So he worked with a Yale programmer to create a multimedia application for the Macintosh. Now the resident works independently at the computer, at his own convenience. He clicks the mouse to select a particular diagnosis, and sees a video clip showing how the heart of a person with that disease would appear on the ultrasound machine. Clicking the mouse on a stethoscope symbol, the resident can also hear the recorded heartbeat associated with that particular condition. After a session, a test built into the system asks the resident to make diagnoses based on unidentified video clips.

These days, when new residents arrive on his rotation, says Dr. Jaffe, "I tell them to see the computer and come back to me when they talk my language."

This is a wonderful application, but it is certainly not the last word in instructional technology. It is limited, because it relies on machines that store information mechanically, rather than electronically.

Now, don't get me wrong. The videodisk player is a wonderful invention. And CD-ROM discs function brilliantly as archival tools, compressing vast libraries of data in forms that can be easily accessed.

Using CD-ROM, a rural doctor can quickly access all of the most recent medical research, and home in on the article that most closely relates to a patient's specific symptoms.

Using a videodisk, a law student can not only review the decision in a particular case, but also view exhibits presented at the trial, or watch a videotape of actual testimony.

These are powerful research tools. And they are valuable instructional tools. But they have a critical limitation. Because they store information mechanically, it cannot be easily manipulated or updated.

Furthermore, a videodisk player is generally used by one learner at a time, or by a large group of students viewing a single screen and all working at the same pace. The images and sounds stored on the disc cannot be distributed simultaneously to numerous learners at individual workstations, allowing each student to work at his or her own pace.

That's why the next generation of educational technology must be based on **digitized** information — information that can be stored electronically, manipulated at will, and distributed to users in a form that allows them to control the learning experience.

And that is one reason why the next educational technology will leapfrog right over disc players of all kinds — to networked, digital video. That is the technology that is at the heart of Computer-Mediated Learning Systems.

Computer-Mediated Learning

I am talking about a multimedia learning system that takes advantage of digital video, distributing it over local-area networks, and offering students interactive, autonomous instruction at individual workstations.

Now admittedly, that's a mouthful. So let me "deconstruct" that sentence, commenting briefly on each of five major elements.

1. First, I am talking about a multimedia learning system...

All of us — not just our media-crazed kids and students — receive a great deal of our information and entertainment in multisensory formats. Research shows that multimedia presentation engages learners who were poorly served by traditional teaching methods. But I might add that it adds texture and richness to the learning experience for all of us — including those of us who still keep a stack of books on the nightstand, right next to the remote control for the VCR and the CD player.

The next generation of learning systems will take advantage of the most effective, appropriate combination of media for each instructional objective, integrating text, graphics, computer simulation, audio, and full-motion video as needed. In many cases, it will allow the learner to select the kinds of media through which they want to receive and express ideas. In this way, it will pay more than lip service to the idea of respecting students' learning styles.

Learners won't be passive audiences for multimedia presentations. They will be able to work with sounds and images as comfortably as most of our students now process the written word — using multimedia editing techniques to explore and test new ideas.

2. Computer-Mediated Learning Systems take advantage of a stateof-the-art technology — digital video.

We've long known that video is a powerful instructional tool. The challenge has been to integrate video with other media in ways that allow flexibility and interactivity.

Today's most powerful solution is digital video.

We now have at our disposal practical, cost-effective means for encoding analog sounds, still images, and moving images into information bits so that they can be stored efficiently in computer files.

Let me put this another way. We can now store great quantities of material — and not only text, but also videos, sound recordings, graphics, photographs, and various combinations of these media — electronically rather than mechanically. In this way, we can bypass audio tapes, video tapes, and even laser discs altogether.

The advantages of electronic storage and access are tremendous. Hardware costs shrink significantly. And the sticky problem of standardization — of knowing which disc player to buy, and which discs will play on which machines — simply goes away.

When we digitize multimedia presentations, we still can access and retrieve information at will. But now, we can also revise or update the material, based on changing realities, changing curricular goals, and the changing needs and progress of individual students.

We can produce courseware that is truly responsive to learning styles, strengths and weaknesses of our learners.

3. The next critical element is the local area network.

To make digital video practical for instructional purposes, we needed an efficient way to deliver it to many students at the same time, in a way that allows each user to control the pace, sequence, level of difficulty, and the amount of practice that they want in each area.

We now have that capability. We can now store digital video on a database, making it available to multiple users over a local area network.

It sounds simple enough — but getting to this point was anything but easy. Video images are notorious "bit guzzlers." When you convert a video clip to electronic impulses, you're actually encoding information about the rapidly changing matrices of dots, called pixels, that create video images. You also have to encode the sound, and any information in other formats that accompany the video presentation. It's a daunting process. Each minute of digital video represents a huge repository of data.

To network digital video, you have to feed vast amounts of information from one computer to another. To make this feasible, technologists have had to make great leaps in the science of compressing and transmitting data.

New compression techniques allow us to bundle video data in efficient packets that can be transmitted much more rapidly. And of course, optical fiber networks allow much faster transmission than copper wire.

These advances mean that by sending data over a fiber running at the rate of a gigabit per second — that's a billion bits per second — one hour of video can be transmitted in only five seconds.

These advances take networked video out of the realm of futurism, and into the realm of the classroom.

4. The fourth element I want to highlight is the individual workstation.

Networked digital video allows students to work on their own, doing the kind of practice that doesn't make efficient use of a teacher's time.

As high-speed networks are installed in schools and on campuses throughout the country, these workstations will be located not only in computer centers, but also in libraries and dorm rooms. You won't have to play musical chairs to fit large groups of students in the language lab.

5. The fifth key element is interactivity.

We're used to thinking of interactive computer programs as those that elicit responses from users, giving them some degree of control over the learning experience. In many cases, interactive programs allow learners to navigate their way through the many channels of a particular subject.

In this model, the computer is reactive — responding to the learner' s preferences. But with the next generation of learning systems, the computer will take the initiative as well, behaving more nearly like a tutor.

Thanks to object-oriented programming and advances in authoring systems, the courseware we develop for Computer-Mediated Learning Systems will allow the computer not only to detect recurrent patterns in an individual's work — evaluating strengths and weaknesses on an ongoing basis — but also to respond to those patterns. It will be able to anticipate the learner's needs before the learner has expressed them or even become aware of them.

This allows a whole new approach to assessment---and here I want to distinguish assessment from the kind of competitive, norm-based testing that typifies the textbook-driven model of instruction.

All students need feedback and reinforcement — especially those with little recent experience of academic success. As Ernest Boyer observes, "Good teaching also means careful evaluation of the student. And yet, it is for this important task most teachers are not well prepared." The bottom line, says Boyer: "Learning is diminished."[29]

The key to effective assessment is timing. You have to seize what I call the "teachable" moment. You have to provide support when it is needed, in a format that matches the student's learning style.

I'm talking about help that arrives just when it is needed — at exactly the moment that a student is having trouble solving a problem or carrying out a task. That's why I call it "just-in-time" coaching.

In many cases, it will take the form of a video clip that explains and illustrates the concept or skill that is giving the student trouble. The student studies the video—watches it two or three times, if necessary—and then takes another stab at the problematic task. If she still gets it wrong, she might watch another video clip that gives a fuller explanation or provides more examples.

And all of this takes place in a setting that is non-threatening, and that offers both feedback and privacy. In this context, learners may well be more comfortable about admitting mistakes, about practicing skills that they're still a long way from mastering, or about trying out new ones.

In this way, Computer-Mediated Learning Systems move us toward the goal of linking assessment with instruction on an hour-by-hour, or even a minute-by-minute basis.

All The Elements Come Together

Computer-Mediated Learning Systems allow truly individualized learning, allowing students to pursue individual interests and to address their own strengths and weaknesses.

Because it lends itself so well to independent learning, it will have the greatest impact in higher education.

Demographics play a role here. We know that two out of five students on our campuses are now age 25 or older. These adult learners will be able to make excellent use of educational technologies that let them work independently, at their own pace, and at times and places that suit their overcrowded schedules.

Let me add that Computer-Mediated Learning is a very exciting, very promising approach to remediation—a growing concern in an era when most colleges and universities must meet the challenge of working with underprepared students.

In the late 1980s, a national survey of 250 higher education institutions showed that 84 percent offered remedial courses in basic skills, and roughly 15 percent of all freshmen at those colleges attended one or more remedial class in English or math.

Even the more selective institutions must offer remediation. At UCLA, for example, half of all new freshmen are placed in non-credit remedial math and English courses, despite the fact that the university admits only the top 12 percent of graduating high school seniors.[30]

Boyer reports that nearly all colleges now have a remedial program of some sort. But participants' academic gains have been modest, at best.[31]

Generally speaking, we lack an effective approach to remediation.

Now is the time to recognize that the traditional talking-head approach to instruction that failed these students in their previous schooling won't work now. There's no point serving up more of the same.

Now is the time to take seriously the notion that not everyone learns in the same way, at the same pace, in the same order. When we read newspapers, all of us start in different places. It's the

same way with learning. So why don't we free our students from the standardized sequence?

Now is the time to consider new approaches to serving non-traditional students — older, part-time students who could make good use of autonomous learning opportunities, but are now less likely than their classmates to make use of campus computers.

Now is the time to consider new learning technologies in subjects where students are accustomed to working independently, like language classes and possibly science labs.

And finally, with budgets subject to deep cuts, with class size growing, and with teachers facing what Wayne Booth called "spirit-crushing workloads," now is the time to explore the use of new learning systems to make the very best use of teachers' time and energies.

In light of the challenges we face today, can we afford to overlook innovative, state-of-the-art instructional strategies?

Let me repeat: The kind of learning system that I have described will be available within two years. Higher education is the next frontier of educational technology. And I expect many of you to be at the forefront of this movement.

The approach I have described represents a departure from academic business as usual. It questions the current educational order. It casts doubt on the viability of lecturing as the major form of instruction. It suggests that computers may be the most effective medium of instruction in certain subject areas — particularly those that require learners to develop automaticity, practicing critical skills until they become second nature.

But I am not arguing that technology is the best means of delivering instruction across all subjects. In some areas, learning requires conversation, and teaching means encouraging meaning-construction through Socratic dialogue.

We need to create instructional strategies that match students' patterns of thinking and learning with the kinds of knowledge we find in the various disciplines. This is not only a great technical challenge; it is an imposing intellectual challenge. To meet it, teachers need the help of knowledge managers.

I have only one more observation to make. In this presentation alone, I have used the word "revolution" seven times and the word change eleven times — not to mention three "transformations" thrown in for good measure. That is a personal record for me in a single address. I wonder if it qualifies me for a place on the ballot.

Notes

1 Cited in Bradd Shore, "Loading the Bases: How Our Tribe Projects Its Own Image into the National Pastime," in *The Sciences*, May/June 1990, p. 16.
2 Shore (1990), p. 16
3 Andrew Rosenthal, "Bush, Asking for Continuity, Sounds Like a Revolutionary," *The New York Times*, April 25, 1992, p. 1.
4 Avra Michelson, "Forecasting the Use of NREN by Humanities Scholars," remarks presented at the panel at National Net '92 on "New Constituencies for the NREN," March 27, 1992. The presentation resulted from Michelson's collaboration with Jeff Rothenberg of the Rand Corporation.
5 Michelson (1992), p. 5.
6 Michelson (1992), p. 6.
7 Michelson (1992), p. 7.
8 See "The Computer Keys' Scrolls: Closely held ancient documents are revealed through modern software," in *Time*, September 16, 1991, p. 64. The scholarly battle over the Dead Sea Scrolls appears to be coming to an end. A microfiche edition of the Scrolls will be published in fall 1992 in the Netherlands, with the agreement of the Israel Antiquities Authority. It will contain photographs of the scroll fragments that have not yet been officially published.
9 Michelson (1992), p. 9.
10 *The Chronicle of Higher Education*, March 4, 1992, p. A22.
11 See "Libraries," *The Chronicle of Higher Education,* April 8, 1992, p. A23.
12 My comments on the changing role of the archivist rely, in part, on an interview conducted with Avra Michelson of NREN, April 27, 1992.
13 Cited in Barbara von Wahlde and Nancy Schiller, "Administrative Issues in Creating the Virtual Library," unpublished paper, March 1992.
14 von Wahlde & Schiller (1992), p. 18.
15 Kaye Gapen, "The Virtual Library: Knowledge, Society, and the Librarian," unpublished paper, April 1992.
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26 Derek Bok, *Beyond the Ivory Tower: Social Responsibilities of the Modern Unviersity*. Cambridge, MA: Harvard University Press, 1982, p. 74.
27 Henry Rosovsky, *The University: An Owner's Manual.* New York: W.W. Norton & Co., 1990, p. 90.
28 Wayne Booth, *The Vocation of a Teacher.* Chicago and London: The University of Chicago Press, 1988, p. 235.
29 Boyer, p.154.
30 Boyer, p. 76.
31 Boyer, p. 77.

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