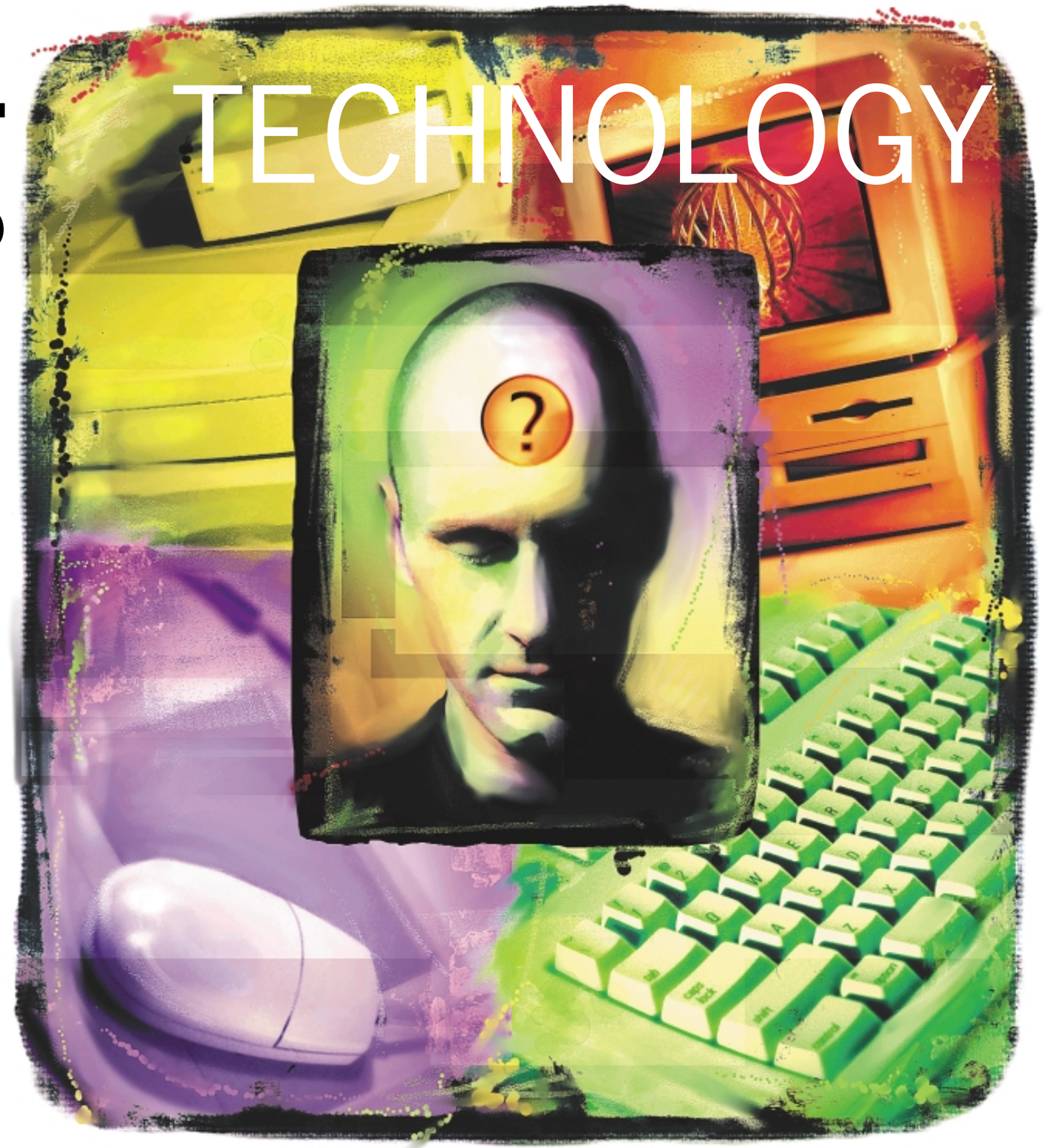
Learning TECHNOLOGY



By Alfred Bork

TEACHING AND LEARNING ARE OFTEN MENTIONED TOGETHER. But they are very different. Teaching is done by teachers, and learning by students. Our focus should be on learning. Teaching is interesting only if it leads to learning, and learning often occurs without teachers. Although my primary interest here is learning beyond secondary school, much of this discussion applies to learning at all levels.

Goals for Learning:Visions

Visions are important human tools for guiding future behavior. We start here with worldwide visions of learning, summarized with two statements: we need much better learning for all; we need learning to be affordable for the individual and the world. Current and past learning has seldom met these visions. Any new approach to learning should be evaluated in terms of such visions.

Much Better Learning for All

Better learning for all emphasizes learning, not teaching or educating. Learning can be much more effective, both cognitively and affectively, than it has been in the past and is now. It can occur everywhere and at any time. Pace can depend on the individual learner. Everyone can learn everything well. Learning can be an enjoyable, lifelong experience. In 1968 George Leonard expressed this idea beautifully: "The purpose, the goal of education [is] *the achievement of moments of ecstasy.*"[1]

The next focus is *all.* All six billion people—regardless of location, gender, race, wealth, or other factor—should have learning available.

Learning should enable us to solve problems, including major world problems, to increase our creativity, and to live peacefully with all others on earth. Humanistic aspects of learning should be stressed. Through learning, we can achieve the World Bank goal of "a world free of poverty."

Affordable Learning

Learning must be offered at reasonable cost. The poorest individual should have access to learning, in all subject areas. Learning should be sustainable after special funds vanish.

The critical factor is cost per student, including development and delivery of learning. More students can lead to lower cost per student. Learning efforts should be scalable to large numbers, to everyone on earth.

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This article is dedicated to Michael Hooper.

Illustration by Derek Lea

PARADIGMS

In *The Structure of Scientific Revolutions*, Thomas Kuhn introduces the concept of the *paradigm*.[2] The paradigm guides thinking, often unconsciously. It is a useful way to organize this discussion of the past, present, and future of learning technology.

Several paradigms are relevant to our discussion:

- **LEARNING PARADIGMS. These paradigms are thought of as theories of learning, but so far none have the empirical basis of theories in physics. They determine many actions of schools and other organizations, as well as individuals.**
- **COMMUNICATION PARADIGMS. Several types of communication are important in learning. First is communication, face-to-face or remote, between people—between students, teachers, professors, parents, friends, and others. Second is communication between people and computers, and third is communication between computers.**

Learning Technology in the Past and Present

Learning Paradigm: Information Transfer

The dominant learning paradigm of the past and today is *information transfer*. It conceives of learning as the acquisition of information, sometimes also considered knowledge or wisdom. Colleges and universities, secondary schools, training activities, and much informal learning have been based on this paradigm for centuries. It developed with far fewer people on earth. It could also be called the *classroom-teacher paradigm*. Paulo Freire describes it as follows: "Education becomes an act of depositing, in which the students are the depositories and the teacher is the depositor. Instead of communicating, the teacher issues communiqués and makes deposits which the students patiently receive, memorize, and repeat. This is the banking concept of education . . . it is the people themselves who are filed away through the lack of creativity. . . . For apart from inquiry . . . individuals cannot be truly human."[3]

Consider college and university courses in the students' first years. These courses are mostly large lecture sessions; information pours from the professor's mouth to the students' ears and (often not accurately) to the students' notes. The classroom is dominated by "teacher talk."

The major auxiliary learning technology is the textbook, usually determining course structure. Textbooks continue to grow larger and more expensive. Some students realize textbooks can replace lectures. Other help may be involved: office hours, discussion sections, laboratories, undergraduate tutors, and graduate tutors.

One unfriendly view is that a hole is drilled in the student's head, and knowledge is poured in.

Technology in the Information-Transfer Learning Paradigm. When learning technology has been used in the information-transfer paradigm, the course has remained fundamentally the same. Technology appears as online syllabi with assignments and corrections to text and lecture, problem solutions, e-mail with instructors, e-mail with students, class Web pages, list servers, chat rooms (text and speech), videos of lectures, marketed student notes, CD-ROMs in the textbook, computer-based learning, and other forms.

Recently course Web sites have become common. University administrators often suggest or require such a site, containing the material usually given in a printed syllabus: course outline and schedule, references to the text, other references, problems, problem solutions, links to other sites, and in a few cases, additional learning material. Tools, such as FrontPage, aid the construction of class Web sites. Universities run classes for faculty. Languages with limited interaction, such as HTML, are introduced, directly or through tools. Web "courses" sometimes convince university administrators that the computer material might constitute a "course" on its own. They see this as an easy way to offer distance learning or to allow for more students. Usually the aim, seldom achieved, is to save money.

Another use of technology is to increase communication, between students and teachers (or tutors) or between students. The oldest example of this use is electronic mail. I used e-mail in an online physics course, in a time-sharing environment, about twenty-five years ago. The number of messages increases with class size, causing problems with large classes. Graduate students may answer e-mail, and students can be encouraged to communicate with each other. E-mail is the most important technological resource for this learning paradigm.

Recent communication tactics are chat rooms, moos, and two-way video, also effective only with small numbers. My experiences with a chat room for twenty students in educational technology at Johns Hopkins University showed that one person cannot type faster than twenty! Chat rooms can now be conducted with voice, however.

Since the paradigm is information transfer, the pursuit is for faster hardware—in the form of both computers and infrastructure—to transfer information faster. This is expensive: there is always new hardware. Technology is thus an add-on for the information-transfer learning paradigm, with other costs remaining mostly unchanged.

Another aspect of this paradigm is that learning takes place largely in the institutions where the possessors of information are located. Weak attempts at distance learning use these people, working as individuals or with the support of a programmer or other technical aid.

Computer Learning in the Information-Transfer Learning Paradigm. There is occasionally a precursor to a new paradigm. For learning, this role was played by computer-based learning. These developments are better understood through the tutorial learning paradigm, to be introduced later. Three examples will be mentioned here, none recent. All involved sizable amounts of learning material.

My colleagues and I developed the computer-based quarter in calculus-based physics, a mastery course focusing on problems, at the University of California, Irvine. Each unit depended on an online quiz, from problem-generators that produce a wide variety of problems of a given type. As students worked the problems online, the program looked for students' difficulties and offered help. Much learning resulted from solving problems, individualized to the needs of each student.

The second example is the logic and set theory course designed by Patrick Suppes at Stanford University. The focus was theorem proving. The heart of these activities was the marvelous proof-checkers. Students were asked to prove many theorems, differing from student to student. The program offered help with proofs and checked the activities of the students, in a highly individualized fashion. Students could prove many results typically shown in the textbook or lecture.

The third example is the set of literature and biology courses developed at Brown University by Andries van Dam and others. These courses, presenting a rich collection of information, were based on hypertext, before it was used on the Internet.

Why did these successful examples not lead to similar projects? The answer is that because these courses violated the dominant paradigm of information transfer, others were not encouraged to develop similar courses. In addition, all three projects preceded the personal computer, so distribution beyond the developing campus was a problem. Also, compared with traditional courses, which required no funds, these three projects were expensive to develop.

Communication Paradigms: Three Types

The dominant communication paradigm for learning in the past and present—people-people communication—is "one-much," the basis of large courses delivered by lectures. Even discussion sections may have twenty or thirty students. One-on-one time with the instructor is limited in large classes.

People-computer communication was initially based on the keyboard, which came from the typewriter and still shows peculiar aspects like the "qwerty" layout. Now pointing devices such as the mouse are important.

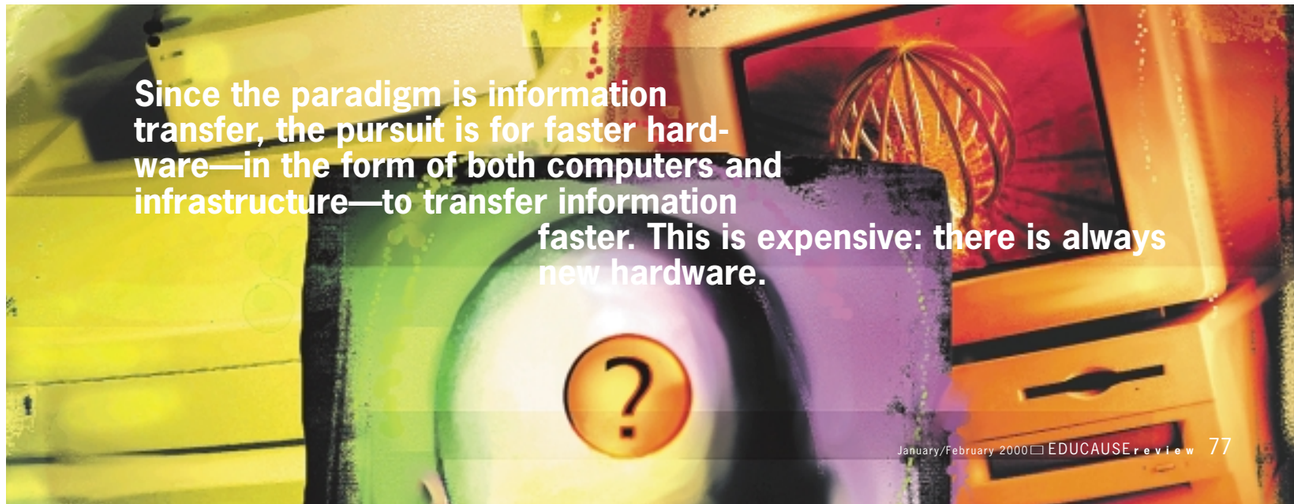
The paradigm for computer-computer communication is the network, particularly the Internet. Universities invest vast sums in "infrastructure," often without any view of how it is to be used in learning.

Learning Technology in the Future

Predicting the Future

Predicting the future is risky. About twenty years ago I incorrectly predicted that by now the computer would be the dominant form for learning.

A paradigm shift is always difficult, as Michael Hooper suggested: "Perhaps all of the stakeholders of higher education are caught in a paradigm paralysis. We have difficulty



changing the way we think and the way we behave. . . . To break this paradigm paralysis we should consider asking some new questions."[4]

But we can see signs of change in the paradigms.

Learning Paradigm: Tutorial Learning

The most important new paradigm change concerns learning. This change will be difficult for schools and universities, immersed for centuries in the information-transfer paradigm. The new approach sees learning as fully active, focusing on the student as learner rather than on authority figures. Like most other "new" paradigms, it is not completely new.

Tutorial learning involves a highly skilled tutor and a student or a small group of students. Examples are tutors for children of the wealthy, tutors at Cambridge and Oxford, and Socrates. Tutoring is effective with very good tutors, focusing on individual students. Tutorial learning with people as tutors cannot be the primary form of learning, however, because there are few good tutors and it is very expensive.

But technology makes all the difference! With the existing computer technology, we can provide tutorial learning for everyone on earth. In a television series years ago, a test pilot crashes. The doctors say that they can rebuild him because they have the technology. Now we have the technology to rebuild learning!

Computer-based tutorial learning will never approach the excellent human tutor. But it can constitute a giant step forward from the information-transfer learning paradigm. The following are important factors in this new learning paradigm.

Highly Interactive. The word *interactive* is commonly used with computers. However, since interaction ranges from low to high, the emphasis should be on the word *highly*. Highly interactive learning has frequent interactions, as in a conversation between people. A gap of more than fifteen seconds between high-quality interactions begins to lose students' attention.

The quality of each interaction is important as well. Interaction guided by pointing is of low quality. Most high-quality human interactions depend on powerful natural languages. They are important for learning, with and without computers, and are a critical ingredient of computer-based tutorial learning. Students view such learning as a conversation with the computer. Voice input, now practical and inexpensive, aids in the experience. No techniques from artificial intelligence are needed, although they may eventually prove useful.

Individualized. Each student has unique difficulties, demanding individualized attention. Learning using the tutorial paradigm looks frequently for student problems, offering individualized assistance and verifying that the assistance was effective. This activity is continuous during learning.

Adaptive. Highly interactive learning material adapts to the needs of each student. Both recent student inputs and long-term records for each student can contribute. The records are written and read by the learning programs, and skilled teachers in the design process ensure adaptivity.

Each learning experience is directed to a student's current needs. L. S. Vygotsky described the student learning space at a particular moment as the "zone of proximal development." Tutorial learning units can be in this zone for all students.

Variable learning time is likely in tutorial learning. The notion of a fixed time to learn will vanish, along with the standard twelve years required to graduate from high school and the four or more years of university-level work. Tutorial learning will be a much more efficient use of the student's time, a continuous process from birth to death. Courses will not exist.

Mastery. With the tutorial learning paradigm, every student can learn everything in each subject. Thus a calculus student learns to the "A" grade level. The key is individualization. Assessment and learning are intimately combined, with assessment determining what learning material is presented next to the student. Assessment also reviews previous knowledge.

Grades and explicit tests will vanish. So will the negative learning attitudes generated by testing and associated threats from parents and teachers. Mastery will encourage lifelong learning because it does not depend on these threats.

Creative Learning. In the tutorial learning paradigm, students can construct, or discover, their own knowledge. In one program in the Scientific Reasoning Series developed at Irvine fifteen years ago, middle-school students, following procedures similar to those used by scientists, discovered the laws of genetics. A current proposal from the Educational Technology Center at the University of California, Irvine, suggests units in which *all* students will discover the Newtonian laws of motion, rather than being told the laws.

Students learn by creating. The key is not a naked simulation that offers no help or checking to see if something is discovered, but a clothed simulation that constantly watches students' progress and offers appropriate assistance.

Learning Content. This new paradigm will bring changes in what is learned. Memory is no longer important. Solving problems, encouraging creativity, adapting to change, and building intuition take priority. Major world problems, such as violence, are addressed by all students from an early age.

Distance Learning. Today, *distance learning* generally means having thirty students at a remote location and using information-transfer approaches such as lectures, video, and two-way video. This does not match the new learning paradigm.

Given vast numbers of students of all ages, we need distance learning in each subject to be effective for thousands, and eventually millions, of students. The natural way to deliver tutorial learning to such large numbers is through highly interactive distance learning. Students can be anywhere at any time. For example, the United Kingdom's Open University has "courses" of ten thousand students; interactive technology makes much larger enrollments possible.

Motivation is important for distance learning. This does not imply the need for gimmicks like loud music, puppets, anthropomorphic animals, or cute animation. Highly interactive learning units are intrinsically motivating; the program responds frequently to the student, keeping learning active.

Peer Learning. Peer learning in small groups can be encouraged in the tutorial learning paradigm. Both local and electronic learning circles, arranged by the computer, are possible. The computer can determine, from stored student records, which students are at the same location in the learning process and can bring these students together.

Students, parents, or others might be involved. Groups of four are best for these learning circles.

New Production Techniques. Producing tutorial learning sequences is not like producing information-transfer units. A production process focusing on highly interactive adaptive units is necessary. Starting with existing units based on information transfer, such as lecture- or video-based courses, is not likely to produce excellent tutorial material. Unfortunately, this is a common approach.

At the University of California, Irvine, we developed a tutorial learning system over thirty years ago. About fifteen years ago we began working with the University of Geneva, in Switzerland. Our focus is on pedagogical design by experienced teachers, working in groups of about four, and on professional evaluation. The emphasis is on locating students' problems and helping with the problems identified.

After the system was designed, we supported it with software, developed at Irvine and Geneva. Design documents, or "scripts," are entered directly into the computer, and the computer writes much of the code from these scripts. Facilities are available for developing and maintaining programs in multiple natural languages.

Experimental Studies. Examples of extensive computer-based tutorial units are few. Our first step should be to gather needed data about developing such examples and about their effectiveness with a wide range of students. Then new learning units in the tutorial learning paradigm can be developed. Next, these units can be used with large numbers of students in both formative and summative evaluations. Skilled evaluators not associated with the development should do these evaluations. Students who might be eventual users should be involved. Studies should be conducted in several cultures and regions of the world.

Learning Appliance. In the developed countries, the general-purpose computer may still be widespread for learning. But a computer for learning, a *learning appliance,* could be cheaper and simpler than today's personal computer. Solar panels, as in a model from Siemens, allow computing without power. Today's computers have more powerful proces-

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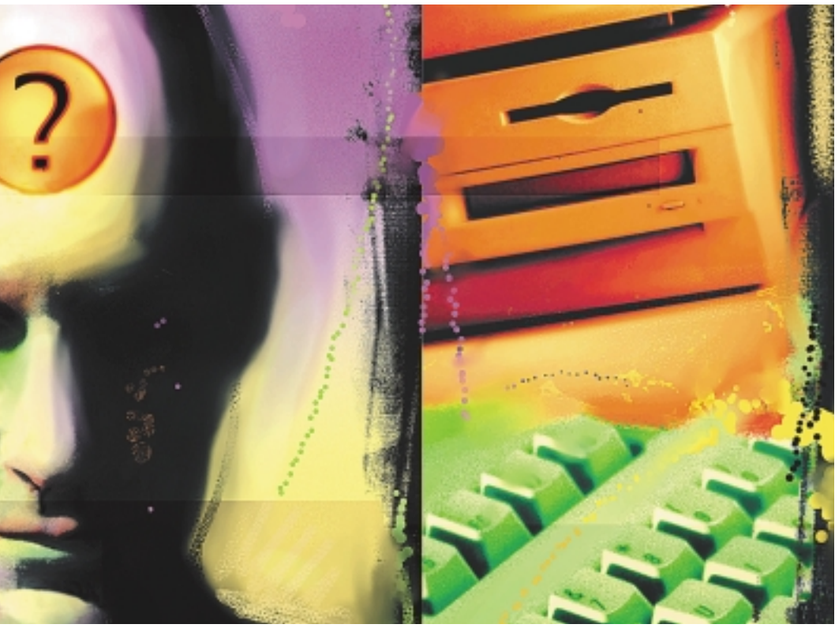

Learning can be available everywhere, at reasonable costs, with large numbers of students. Interactions will take place mostly at local computers.

sors than are needed for highly interactive learning units, except possibly for voice input.

Communication Paradigms: Changes in the Three Types

With people-people communication, learning—mostly asynchronous—in small peer groups, local and electronic, will be stressed.

With people-computer communication, speech will be important. Science fiction has long realized that voice is the natural way to communicate with computers, though this does not require full natural-language recognition.

With computer-computer communication, learning units need to be distributed worldwide, using the least-expensive delivery method. Current distribution methods such as CD-ROM and DVD-ROM will be useful. The Internet will be of increasing use also as we become skillful in designing and implementing units using local interaction. But few of the poor, especially in the developing countries and even in the United States, have access to the Internet.

Wireless communication is likely, either through an individual location reaching a nearby server, the approach used recently by an organization called NETSCHOOLS, or through satellites. Eventually satellites may be the major distribution mechanism. Learning can be available everywhere, at reasonable costs, with large numbers of students. Interactions will take place mostly at local computers.

Moving from Information Transfer to Tutorial Learning

The transition from past to future—from the information-transfer to the tutorial learning paradigm—will not be easy or smooth. It will be opposed by some political, social, and economic agendas. But superior learning and eventual profits from the new educational products will overcome these problems. We see promising forerunners, such as the examples of computer-based learning mentioned earlier.

Colleges and Universities

We might assume that the new learning paradigm will be realized first in colleges and universities, but this does not seem likely. Universities are vulnerable to outside competition. They are conservative and do not understand the pressures of society. They often idealize themselves. They pursue directions not related to learning, such as semiprofessional sports like football, wasting energy that could be devoted to education. Professors mostly know no learning paradigm except information transfer. This paradigm succeeded for them personally, so they believe it should work for all. University administrators have the same background.

When facing possible competition, universities put faith in the accreditation or certification process. As a member of several accreditation committees, I believe this faith is misplaced. Employers want competence, not accreditation.

Almost half the student hours in universities are spent in the twenty-five large beginning courses in the first and second years. Often graduate students or lecturers teach these courses. If these courses are successfully challenged by effective, well-tested, tutorial, computer-based distance learning courses, the economic basis of many universities will be threatened.

The best hope of universities would be to engage in serious high-quality distance learning. My attempts to persuade several universities, however, have been unsuccessful. Although university administrators talk much about distance learning, such learning is intended for small groups and remains in the information-transfer paradigm. University officials are mostly not aware of the major efforts outside this county, such as the United Kingdom's Open University.

If many universities do not survive because of outside competition, we will have major problems, including where research will be conducted. These issues require serious attention now, before the battle erupts between universities and new, competing institutions.

Companies

New learning institutions are forming, many for profit. It seems unlikely that universities will be successful in this competition. This appears to be the source of Peter Drucker's business-based prediction that universities will die within thirty years.[5] So far, Drucker's prediction seems reasonable. Yet even though universities may not compete successfully with these new forces, they may work with other groups, at the level of individual professors or at the level of institutions.

Existing companies are mostly offering information-transfer learning. Some have already failed, such as the California Virtual University. Some of these organizations are nonprofit, such as Western Governors University, now associated with the United Kingdom's Open University. So far, they have few students. Commercial organizations include the University of Phoenix and Jones International University. I see no sign that these institutions appreciate the paradigm shift. Newer organizations, such as UNEXT Learning Systems (see <http://www.unext.com>), may be successful. In some cases, universities are partnering with these organizations; for example, Columbia University, Stanford University, and Carnegie-Mellon University are partnering with UNEXT in the business area.

The production of extensive computer-based tutorial learning units is not simple. Many organizations do not have a clear idea of how to produce materials and are not spending enough money to develop highly effective units. These institutions will succeed or fail based on the quality of their learning and on their marketing effectiveness. Many are more skilled with marketing than with development. Some may combine post-college learning development, or other areas of learning, with college learning development.

Governments and Foundations

Governments concerned about colleges and universities could be funding the curriculum development of tutorial learning materials. This is rare in the United States but is common elsewhere, with the support of high-quality, large-scale distance learning institutions. Another important role of governments and foundations could be to support the experimental efforts that are important for careful future planning.

International Organizations

The problems of learning are worldwide and are unlikely to be solved in one country or one group of countries. Organizations such as the World Bank, UNESCO, the United Nations, and USAID invest large sums each year in education. If they would spend money on tutorial learning, they could play an integral role in improving learning, particularly in early experiments. Universities and commercial organizations would likely take on large-scale development if convinced that tutorial learning was practical.

Conclusions

We began with visions for learning. The new paradigms offer us a good chance of realizing these visions.

We can start with the experimental efforts, gathering data. We might also want to conduct experiments proposed by others, reaching for the same visions. Given the results of this extensive effort, we can then proceed to large-scale development. Learning could be the largest of all software markets.

We have an exciting period ahead for world education. Great opportunities exist for improved and affordable learning for all. We can indeed have a world free of poverty and a world without violence.

Notes

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