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Tutorial Learning for the New Century

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This paper begins with visions of the future of learning. It then considered current and new paradigms concerning technology and learning. It gives particular emphasis to highly interactive tutorial learning, for very large numbers of students in distance learning situations. Then it considers schools and universities in terms of the new paradigms. It ends with a brief plan for attaining this new learning system.

KEY WORDS: Learning, tutorial; distance learning; global, mastery; adaptive.

GOALS FOR LEARNING: VISIONS

> We need to educate more people,
> educate then to far higher standards,
> And do it as effectively and as efficiently as possible.
>
> —*An American Imperative*
> *Report of the Wingspread Group*

One of the most important tools that humans have discovered for guiding future behavior is that of visions. So we start with worldwide visions of learning.

My visions, and I hope those of others, can be summarized with two statements. First, we need much better learning for all. Second, we need this learning to be affordable for the individual and the world. Any new approach to learning should be evaluated in terms of such visions. These visions are expanded in the next sections.

Much Better Learning for All

Better learning for all has a number of aspects. First, it emphasizes that our focus is learning, not teaching or educating, as already suggested. Better learning implies that learning can be much more effective than it is now, both cognitively and affectivity. Learning can take less time. Everyone can learn to the mastery level. Learning can be available lifelong. Learning should be available everywhere and at any time. Each learner should have an individualized learning path. Pace can depend on the individual learner. Learning should be enjoyable. It should be a passion for everyone on earth.

The next focus is *all*. All 6 billion people on our planet should have learning available, regardless of location, gender, race, wealth, or any other such factor. Further, they should love to learn, seeing this as a critical continuing ingredient of life. We need a global learning society.

> Learning is . . . a necessity of life, It's a consummation, like eating or making love . . . people are still half-starved for learning.
>
> —James Cooke Brown
> *The Troika Incident*, Doubleday, 1970

Learning should include all areas, including problem solving, creativity, and living with all others on earth. It should address major world problems. Humanistic aspects of learning should receive prominent attention. People must be able to live with others on earth, close and far away.

Affordable Learning

All learning must be at reasonable cost. Even the poorest individual, at any level of learning, should have affordable access to learning, in all subject areas. Learning must be economically scalable to very large numbers, everyone on earth.

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The critical cost factor is the cost per student for an hour of instruction, including both development of learning materials and delivery of these materials. Because development costs are fixed, more students can lead to lower costs per student, if inexpensive delivery systems are available.

This paper argues that these visions can be attained with current interactive technology, hardware, and software. It proposes one such approach. Other approaches leading to these visions may also be possible.

PARADIGMS

In a well-known book, *The Structure of Scientific Reasoning*, Thomas Kuhn (1998) introduces the concept of the paradigm. The basic idea is not new, and the use of the terminology often leaves something to be desired. But it is a useful way to organize this discussion of the past and future of learning. The paradigm guides thinking in the area, often unconsciously. Sometimes the word model is used for paradigm, but these terms are also used differently.

Four types of paradigms are relevant to this discussion: learning paradigms, interface paradigms, hardware paradigms, and communication paradigms. These paradigms are not independent of each other. The first, the learning paradigms, are the most important in this paper; the focus is on learning

- *Learning Paradigms.* These paradigms concern the view of learning widely held in a society. They are sometimes thought of as theories of learning, but so far none has the empirical basis of major theories in the physical sciences. They determine many of the actions of schools, universities, and other organizations, as well as individuals, with respect to learning.
- *Interface Paradigms.* Any user of the computer "sees" the computer through some interface, rather than seeing the hardware directly. The learning user is like any other user with regard to the interface. Learners could have unique interfaces, but this seldom happens so far, except for minor differences.
- *Hardware Paradigms.* In addition to the user–computer interface, the student also has a view of the computer.
- *Communication Paradigms.* Several types of communication are important in learning. First, there is the communication, face to face or remote, between students, teachers, professors, parents, friends, and other people. When technology is used in learning we also have communication between students and computers, and communication between computers, including use of networks.

LEARNING PAST AND PRESENT—PARADIGMS

Learning Paradigm: Information Transfer

The dominant learning paradigm in the world might be called information transfer. It evisions the primary aim of learning as the acquisition of information. Sometimes this is also considered knowledge or wisdom. Universities, schools, training activities, and much informal learning have been based on this paradigm for centuries. This learning paradigm developed at a time when there were far fewer people on earth, so we can wonder if it is still effective. It could also be called the classroom–teacher paradigm, as the student environment is the class. Here is a portrait of this paradigm.

> 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, transformation, and knowledge in this (at best) misguided system. For apart from inquiry . . . individuals cannot be truly human. (Friere, 1993)

Consider, for example, most university courses, particularly in the first years of students' experiences. These courses are mostly offered in large lecture sessions, where information pours from the professor's mouth to the students' ears, and (often not too accurately) to the students' notes. The classroom is dominated by teacher talk.

The major auxiliary learning technology is the textbook. The textbook usually determines the structure of the course. Textbooks have grown larger and more expensive. Some students realize that the textbook can replace the lecture. Various other help for students may be involved: Office hours, discussion sections, laboratories, undergraduate tutors, and graduate tutors. Technological aids are also possible, and are discussed in more detail in the next section.

There may be periodic assignments, sometimes graded and returned to the student. Examinations will occur at several points, particularly at the end. For large courses, many such exams are multiple choice, called multiple guess by many students. One unfriendly view of this information transfer process is that a hole in drilled in the student head, and knowledge is poured in.

Technology with the Information Transfer Paradigm

When learning technology is used in courses based on information transfer, it is not surprising to see that the same paradigm is in use. The course is fundamentally the same. Technology appears as on-line syllabi, on-line assignments, corrections to the text and lecture, problem solutions, e-mail with instructors, e-mail with other students, class web pages, list servers, chat rooms, videos of lectures, CD-ROMs in the textbook, computer-based learning, and other similar forms. Information transfer is still dominant. The popular terminology for this use is that the computer is a tool.

Recently the use of a course web site has been a common occurrence. Administrators often strongly suggest, or even require, such a site, in the past several years. This site will typically contain the material in a printed syllabus: The course outline, the class schedule, references to the text and other books, other references, problems, problem solutions, links to other sites, and in a few cases additional learning material.

Various tools, such as MicroSoft FrontPage, have been developed to aid in the construction of class web sites. Universities often run classes for faculty to show them how to develop such sites. Languages with very limited forms of interaction, such at HTML, are introduced, either directly or through tools. Sometimes pictures and animation unrelated to the course are in the site.

When I suggested 10 years or so ago on my campus and for all of the University of California that all syllabi should be on-line and so publicly available, many faculty members considered this to be a violation of their privacy. The view was that what went on in the course was the private business of the instructor. On-line syllabi have partially changed that belief.

Another valuable use of technology with information transfer is to increase communication, either between students and teachers or tutors, or between students. The oldest form is electronic mail. I used it in an on-line physics course, in a timesharing environment, about 25 years ago. Each night I would answer about 30 messages, in a class of 300 students. Now the messages are over local networks, or the Internet. The number of messages increases with the size of the class, so this approach has problems with very large student numbers. Graduate students may answer the e-mail. This is perhaps the most important technological resource for the traditional learning paradigm, as it increases the level of feedback in learning that offers little feedback.

More recent communication tactics depending on networks are chat rooms, moos, and two-way video. These are also most effective with a small number of students. My recent experiences with running a chat room for about 20 students in educational technology at Johns Hopkins University, with a moderator trying to organize the students, showed that one person cannot type faster than 20! Two-way video is expensive and does not improve the situation.

Courses with material on the World Wide Web sometimes persuade university administrators that the computer material might constitute a "course" on its own. They see this as an easy way to claim that they offer distance learning, or perhaps to allow for more students. The aim is usually to save money. This is seldom satisfactory, although some students can learn with little of the paraphernalia, both early technology and modern technology. These students often do not need the lecture either.

Because information transfer dominates, it is not surprising that the pursuit is for faster hardware, both computers and infrastructure. Information is delivered faster. This is a continuing expensive game, as there is always new hardware and new network capabilities. The vendors naturally encourage the purchase of the latest models. Administrators offer only weak resistance. Seldom is the new hardware justified for learning.

Another aspect of this paradigm is that leaning should take place in schools and universities. This is where the possessors of information are located. Weak attempts at distance learning, increasingly common in the last several years, still use these people, working as individuals or with support of a programmer or other technical aid. The results are not impressive.

Finally, technology used in the information transfer paradigm mostly leads to increased costs. Technology is an add-on for this paradigm, with other costs mostly unchanged. Universities spend large sums on computers and infrastructure, almost as if it is magical. They find that it is not.

Computer Learning with the Information Transfer Learning Paradigm

It sometimes happens that there is a precursor to a new paradigm. For the learning paradigm this role was likely played with early attempts to use computer-based learning. Although these developments took place when the information transfer learning paradigm was dominant, they are better understood through the tutorial learning paradigm, to be introduced later.

Four examples of computer-based learning will be mentioned, although others also existed. They are presented chronologically, I believe. None is recent. All were sizable amounts of learning material. All moved beyond the information transfer paradigm. Three are at university level, and one at school level.

Colleagues and I developed the computer-based quarter in calculus-based physics at the University of California, Irvine. This was a problem-based course, in the mastery tradition. Each unit depended on an on-line quiz, from problem generators to give a wide variety of problems. As each student worked problems on-line, the program looked for common student problems, and offered help. Thus much of the learning of the course was within solving problems, individualized to the needs of each student.

The second example is the logic and set theory courses developed by Patrick Suppes at Stanford University. The focus is 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 programs offered help with proofs and checked the activities of the student in a highly individualized fashion. Students could prove many results typically shown to them in the textbook or lecture.

The third examples are the literature and biology courses developed at Brown University by Andries van Dam and others. These courses were based on hypertext, before it was used on the Internet. A rich collection of information was present.

The final example is the Writing to Read Project, developed for IBM by John Henry Martin. It was an introduction to reading for children of 5 or 6 years old. It derived from the phonics approach of the Initial Teaching Alphabet in England, but avoided some of the problems of that project, including the use of unfamiliar symbols from the international phonic alphabet. Since the typewriter was to be used by these young students, all the symbols needed for the phonic representation of English had to be on standard typewriter keyboards. Interaction was weak, but humor was well used. Educational Testing Service conducted a full evaluation. Perhaps the most interesting feature is that it used a new learning environment, not the standard classroom.

Why did not these examples lead to many more similar projects? This is the effect, I believe, of the dominant learning paradigm of information transfer. Other factors also were important. The first three preceded the personal computer, so distribution beyond the developing campus was a problem. Cost of development may also have frightened people from further activities. Except for Writing to Read, large-scale marketing was not possible.

Interface Paradigm: Graphical Interface

The next type of paradigm is the interface between the student and the computer, how the student "sees" the computer. This applies to the operating system and to applications, including learning applications. We have seen recently two interface paradigms, the command-driven interface and the newer graphical interface.

Command-Driven Interface

In the command interface, each action is specified by a command. The best known of such interfaces were the Apple II interface and the DOS interface developed by Microsoft and IBM, respectively. This interface paradigm has been of less prominence recently, but has a current resurgence in the form of UNIX, particularly in LINUX. It has always played a major role with workstations, such as those from Sun.

Graphical Interface

The WIMP (windows, icons, mouse, and pull-down menus) interface came from the Xerox Palo Alto Research Laboratories and others. It has existed in many forms: the Xerox Star, the Lisa, the Macintosh, OS/2, and the various Windows from Microsoft. Today it is almost the dominant interface for operating systems and applications, even learning applications. Current versions of UNIX show some WIMP characteristics.

The screen is organized in windows. With the desk top (operating system interface) icons start some frequently used programs, and menus give access to

others and to files. One clicks sometimes once, sometimes twice, with one button or another on the pointing device.

Within applications, there is a somewhat different form. A bar at the top of each window tells the application and the name, and contains icons for changing the size or closing the window. The next line has names (file, etc.), which lead to pull-down menus. Then a variable series of lines (toolbars) has little pointable icons. Several lines may appear at the bottom on the window.

It is remarkable how this approach is followed, even if it is completely irrelevant. I recently attended an international meeting on technology in education. Speaker after speaker showed such windows even though the various items, such as menu and tool bars had no connection with the learning process. Screens had much visual garbage unrelated to the task at hand.

Hardware Paradigm: General Purpose Computer

For many years the paradigm for hardware has been that the computer should be able to do anything, given the software. This drive for universality assumes that the computer will be identical for all applications. It thus does not allow for specialization of hardware. But this paradigm does not account for the increasing embedding of computers into other devices, a common occurrence today. Nor does it account for the rise of subcomputers such as palm tops, which are more limited in their capabilities.

Communication Paradigms

The communication paradigms concern human–human communication, human–computer communication, and computer–computer communication. The paradigm for people communication has been the one-much strategy, the basis of large courses delivered by lectures. Even discussion sections are likely to be for 20 or 30 students. One-on-one time with the instructor is very limited in large classes.

The paradigm for human–computer communication was initially based on the keyboard, but now pointing devices such as the mouse are also important. The keyboard came from an older technology, the typewriter, and still shows many peculiar aspects of this venerable age, such as the odd QWERTY keyboard. Douglas Englebart at Stanford developed the mouse for an editing system not in use today. Xerox PARC used it for the WIMP interface; modern use derives from that project.

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

LEARNING IN THE FUTURE—PARADIGMS

Predicting the Future

Predicting the future is always risky. About 20 years ago I predicted that by now the computer would be the dominant form for learning. I was wrong; I underestimated the time required, among other factors. A paradigm shift is always a difficult time, as Michael Hooper suggested with regard to universities.

> 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. (Hooper, 1997)

But we can already see signs of change in all the paradigms discussed. The new paradigms are very promising with regard to attaining our visions. They will appear in the next few sections, and then we will consider their applications to the components of our learning system. Much future work will be essential to create new educational systems based on these paradigms.

Learning Paradigm: Tutorial Learning

The most important of the new paradigms is that concerning the new form of learning. This is the aspect of the future that will be most difficult for those immersed in the older paradigm to accept. Schools and universities have been based for centuries on the information transfer paradigm, so change will not be easy, but change is essential if we are to reach the visions presented earlier.

This new approach has a different view of the learning process. It sees learning as fully active, focusing on the student as learner rather than on authority figures giving information. Like most "new" paradigms it is not completely new.

Tutorial learning refers to the type of learning that takes place between a highly skilled tutor and the student, or a small group of students. The classic

examples were the tutors for the children of the wealthy in Europe, the tutors at Cambridge and Oxford, and Socrates. This always been an effective way to learn when very good tutors were involved. The focus was on the individual students. The interaction was conversational. But classical tutorial learning could never be the primary form of learning, because there were few good tutors, and because it was (and is) a very expensive way of learning.

However, digital technology makes all the difference! We can now provide computer-based tutorial learning for everyone on earth, with existing technology. I am reminded of a television series of many years ago in which a test pilot crashes. The doctors examining him say that they can rebuild him, because they have the technology. Now we have the technology to rebuild learning! However, more than the technology is needed.

Computer-based tutorial learning will never approach that available from the very best human tutor. But it can be a giant step forward from the information transfer systems of today. It is now practical for all learning. The important factors in this paradigm of tutorial learning are the following.

Highly Interactive

The word interactive is much used with computers, often in specialized ways. So the emphasis here needs to be on *highly*. The learning process is the antithesis of what happens in the lecture. Both frequency and quality of interaction are important. Highly interactive learning has frequent interactions, just as in a conversation between two people. We find that a gap of more than 15 seconds between high-quality interactions begins to lose students in learning units.

Further, with highly interactive learning, the quality of each interaction is very important. Our experiences with interactions between people are important in judging the quality of an interaction with the computer. Interaction with pointing is of low quality. The major tool humans have developed for interactions are our powerful natural languages, spoken or written. Most high-level human interactions depend on our languages. Languages are also a critical part of our thinking process. They are vital for learning, with and without computers. Natural languages are an important ingredient of computer-based tutorial learning.

Several modes of interaction are possible with languages. One is where the computer is a Socratic tutor. We expect natural language questions, in English in this country, and free-form student answers. No techniques from artificial intelligence are needed, although they may eventually prove useful. The designers of the learning material, good teachers in the area involved, provide the basis for this interaction. In another mode the computer responds to student questions. This is now possible in limited domains.

Voice input will aid in this process of quality interaction. Speech recognition is now practical and inexpensive for tutorial learning with computers. In the tutorial environment, with limited vocabulary needed at each point, no training of the voice engines will be needed. More experience is needed in this area.

Individualized

A major problem in learning, perhaps the central problem is that each student has unique problems, demanding individualized attention for the most efficient learning. The learning units using the tutorial paradigm can look very frequently for student problems, offer individualized assistance, and verify that the assistance, was effective. This activity should be continuous during the learning activity.

Several different learning approaches may be needed, as students have different capabilities. As we learn more about learning styles, it may be possible to predict the approach that is best for each student.

Adaptive

Highly interactive individualized learning material can adapt to the needs of each student. Both the recent student inputs, and long-term records for each student, can contribute toward this adaptation. The records are written and read by the learning programs to assist in individualizing the learning experiences, as instructed by the designers. Individualization and adaptivity are both a function of the design process, done by skilled teachers as already mentioned.

Each learning experience must be carefully directed to the student's current needs. L. S. Vygotsky described the student learning space at a particular moment as the zone of proximal development. The student is prepared to learn the material in this learning space. The zone changes from moment to moment. Tutorial learning units should be in this zone for all students, possible with highly interactive learning.

Variable learning time is likely in the tutorial learning paradigm. The notion of a fixed time to learn will vanish, along with the notion of 12 years of school

and 4 or more years of university. Tutorial learning will be much more efficient of the student's time. It will be a continuous process from birth to death. We can expect most students to progress faster than they do now. Learning will be more efficient.

Mastery

With this paradigm of learning we can assure that every student learns everything in each subject. Thus a student learning calculus learns it to the "A" level. Benjamin Bloom (1984) showed many years ago that mastery is possible for all students, given the right learning environment. Good tutorial computer units now make this economically possible.

The key is individualization. Assessment and learning will be intimately combined, with the purpose of assessment primarily to determine what learning material should be presented next to the student. Assessment will also review previous knowledge; what the student could do at one point in time may not be possible later. Students will take different amounts of time in learning, whatever is necessary to ensure mastery; some will move much faster than current students, as already suggested.

Grades and explicit tests will vanish in the new environment. So will the negative learning attitudes generated by testing and the associated threats from parents and teachers. Mastery will encourage lifelong learning, because learning is enjoyable, it does not depend on these threats, and because learning success happens for all.

Creative Learning

Students can construct their own knowledge, in the tutorial learning paradigm, as contrasted to being told things. Thus, in a program we developed 15 years ago middle school students discovered the laws of genetics, in a way similar to procedures used by scientists. All students succeeded. In a current proposal we suggest units where *all* students will discover the Newtonian Laws of Motion. The unit for Newton's first law already has been designed, but funds have not been available for implementation.

Students learn better by creating their own knowledge, rather than by being told things. Simulations may be available on the computer. The key is not a naked simulation, which says "discover," but offers no help or even checking to see if something is discovered, but a clothed simulation that constantly checks on the student's progress and offers relevant assistance as is appropriate. Equipment may be used in such a way also for science education. We designed such a module based on the whirleybird unit from the Berkeley elementary science program directed by Robert Karplus.

Learning Content

Along with this new learning paradigm, we also expect changes in what is learned. Developing the new curriculum material will give us a chance to rethink what content is now needed. Much current material is old, not reflecting the best standards of today.

Memory should no longer receive primary emphasis. Problem solving, creativity, and intuition building should take priority. We need people to want a nonviolent world, one in which they are happy with themselves and others, who enjoy life. Major world problems such as violence and water should be addressed in tutorial learning material for all students from an early age.

Distance Learning

The natural way to deliver tutorial learning is through distance learning. Students can be anywhere and can learn at anytime. Motivation is important in materials for distance learning. The units must be designed to keep students working at difficult learning tasks. Part of evaluation during the development process is to make certain that this happens. This does not imply the use of gimmicks such as loud music, puppets, anthropomorphic animals, cute animation, and similar approaches. Highly interactive learning units are intrinsically motivating because the program responds frequently to the student, keeping the learning process active. The 15-second rule as the time between points where the student does something significant, has already been mentioned. Distance learning has many different meanings, some not adequate for the new learning paradigm. This is discussed further later in this paper.

Peer Learning

Peer learning in small groups will be encouraged in these future distance learning activities. Both local and electronic learning circles, arranged by the computer, are possible. The computer can determine,

from the stored student records, which students are at the same location in the learning process, and bring these students together. As more and more students are using the material, this will become a very important feature. Students learn well when other students are working with them. Students, parents, or others might be involved. Groups of about four are best for these learning circles, I believe.

Producing Computer-Based Tutorial Units

Production of tutorial learning sequences is not like producing information transfer units. A different 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 succeed in producing excellent tutorial material. Unfortunately this is a common approach today in developing learning material.

Many systems for producing tutorial leaning modules are possible. At the University of California, Irvine, we began to develop such a system over 30 years ago, described briefly here. The focus is on pedagogical design by very experienced teachers, working together in groups of about four. Full evaluation by professional evaluators is also a key feature. The emphasis is on locating the problems the student is having, and helping with the problems when identified. About 15 years ago we began working with the University of Geneva, in Switzerland.

The design is recorded in a script, a graphical representation of the full student interaction, with all details shown. The designers look for student problems, offer assistance, and verify that the assistance was effective. The aim is mastery for each student. Designers also decide what information about the student to store, and how the program is to use that information.

After the system was well developed, we supported it with software, developed initially at the University of California, Irvine, and recently at the University of Geneva. Design documents, scripts, can be entered directly in the computer, and the computer can write much of the code from these scripts. Facilities are available for developing and maintaining programs in multiple natural languages.

The system and the software are described and documented in papers in the references (Bork, 1992), and in other available material. The system is fully capable of developing high-quality tutorial learning units. Further refinements are possible.

Experimental Studies

We have as yet very few examples of extensive computer-based tutorial learning units. More empirical data are needed as to the problems of developing such examples and the effectiveness of such programs with a very wide range of students. Several segments should be carefully developed and professionally evaluated. This work would form the basis for future development. This critical step is discussed again at the end of this paper.

Interface Paradigm: The Invisible Interface

We only sketch the new interface paradigm for learning programs. Because the focus of this paper is on learning, we want nothing to distract the student from this task. Nothing should be on the screen that is not directly relevant for learning the material at hand. Many years ago we made the operating system invisible for such use. That seems to be a desirable direction for the future. Learning does not need the complexities of today's interfaces.

Another factor for a new interface paradigm is voice input. As we move from typewriter input to voice input, we need to reconsider the computer interface. Another aspect, at least for the immediate future, is to worry about how text should be arranged on the screen. Suggestions from readability research, such as the use of short lines and natural phrase breaks at the end of each line, are currently ignored.

Hardware Paradigm: Learning Appliance

In the developed countries the general-purpose computer will still be widespread for learning, but for many situations a computer build just for learning, a learning appliance, will furnish a new paradigm, much cheaper and simpler than today's personal computer. For remote areas solar panels, as in the recent model from Siemens, will allow computing without availability of power. Today's computers have more powerful processors than needed for supporting highly interactive learning units. Embedded computers and palmtops already point in this direction.

Communication Paradigms: Changes in the Three Types

With human–human communication, the importance of learning in small peer groups will be

increasingly stressed. Both local and electronic groups, synchronous and asynchronous, will be used, with increasing importance on asynchronous as more and more students are included.

With human–computer communication, speech will be of increasing importance. Science fiction has long realized that voice is the natural way to communicate with computers. This does not require full natural language recognition.

Computer–computer communication involves distribution of learning units worldwide. Current methods such as CD-ROM and DVD-ROM will be useful for distribution of tutorial learning materials. The Internet will be of increasing use, as we become more skillful in designing and implementing units that use local interaction. But few of the poor, even in wealthy countries, have access to the Internet. So it increases the gap between rich and poor. In the developing countries it will be a long time before the Internet is adequate for large-scale learning. High-speed networks are a likely possibility, again in the developed countries.

Wireless communication is likely to be the new mode, either in an individual location reaching a nearby server, or through satellites. Eventually satellites may be the major distribution mechanism for learning. They can make learning available everywhere, at reasonable costs where large numbers of students are involved. Again, the interactions will be mostly at the local computers.

MOVING FROM INFORMATION TRANSFER LEARNING TO TUTORIAL LEARNING

The transition in learning paradigms will be a major change, given the long history of the information transfer paradigm. It will not be an easy or smooth change. It will be opposed by some political, social, and economic agendas, but our needs for improved education and the eventual profits from the new educational products may help to overcome these problems. We can see forerunners of this new approach, such as the three examples of computer-based learning mentioned earlier. Several types of players may be involved. Several types of institutions may be involved, including schools and universities.

Distance Learning

The importance of distance learning for the new paradigms has already been mentioned. The term *distance learning*, like interaction, is used in various incompatible ways. The typical situation for distance learning in the United States today will not lead to our visions. Having 30 students at a remote location, with information transfer approaches such as lectures, video, and two-way video, do not meet the needs of 6 billion people in the new century or of the new learning paradigm. We need less labor-intensive directions. We spend too much money on "experiments" in this limited direction, using ever more expensive technology.

Given the vast numbers of students of all ages who need to learn, we need distance learning that is effective for thousands, and eventually millions, of students. This is the possibility we should pursue: Computer-based tutorial distance learning via the computer for very large numbers of students. At least we should try it, because the promise is great.

The United Kingdom Open University has already demonstrated that well-designed distance learning "courses" can involve 10,000 students, using primarily print material. They furnish a clue as to what is possible. They show us that the important factor is not the cost of development, but the cost per hour of student material. Open University courses can cost millions to develop, but costs for each student are low.

Interactive technology makes delivery to many more students possible, at reasonable cost. The computer-based tutorial learning paradigm demands this new form of distance learning. One consequence is that the concept of teacher no longer exists: with such large numbers of learners it does not make sense.

Universities

It is natural to assume that the new learning paradigm will be first realized in universities and schools, but this does not seem likely to me. This section considers universities. Universities are far more vulnerable to outside commercial competition than is commonly understood. First, they are very conservative, not understanding the pressures of society. They often idealize themselves. They pursue many directions not related to learning, or even opposed to learning, such as semiprofessional sports like football, wasting energy that could be devoted to education.

Further, the professors mostly know no learning paradigm except that of information transfer. This paradigm succeeded for them personally in their learning days, so they believe it should work for all. If students do not learn, and many do not in our current

systems, they consider it the fault of the students. University professors have always conducted courses in the information transfer tradition. They have little experiences with large-scale development of learning material, and often even less interest.

> We have to develop new conceptions of the production and marketing of software. There is no more sense in having each university prepare all its own instructional programs than there would have been in having each one publish its own textbooks.
>
> —Herbert Simon, *EDUCOM Bulletin*, Spring 1987

University administrators mostly have the same background. While my experience is mostly in the United States, as reflected in this paper, I believe these comments appear to various degrees around the world.

Universities put much faith in the accreditation or certification process when they look at the possible competition. As a member of several accreditation committees, I believe this faith is misplaced. Employers want competence, not accreditation. Accreditation is a minimal procedure. Already one distance learning university has been accredited, and others will be.

Close to half the student hours in universities are in the 25 large beginning courses that dominate the first and second years. Often these courses are not taught by tenure-track faculty, but by graduate students or lecturers. Large lecture sections are the norm, with little interaction. If these courses are successfully challenged by effective well-tested tutorial distance learning computer-based courses, the economic basis of many universities, particularly state universities in the United States, will be threatened. If many universities fail, this will lead to major problems, such as where research is to take place. Those problems should be addressed now, before we are in the crisis.

The major battle may come between existing organizations, such as universities, and new institutions such as companies. The best hope of universities would be to engage in extensive, high-quality tutorial distance learning for very large numbers of students. This would demand serious production of interactive learning material that does not exist at present. The period of formation of a new university is a particularly important time for such developments. There is no sign that this is happening.

My attempts to persuade United States' universities to follow such directions have not been successful. They continue with the unfortunate assumption that their faculty can develop distance learning materials in their spare time.

Companies and Universities

Companies may be the major players of the future in learning. Initially this may be with universities, and eventually I believe for schools also, unless both types of organizations make major changes in their current directions, so far unlikely. This section considers university-level distance learning available outside traditional universities. Many such organizations exist or are forming, many for profit. It seems unlikely to me that universities will be successful in this competition, although well-done, large-scale tutorial distance learning could help as I have already suggested.

This appears to be the source of the business-based prediction of Peter Drucker in 1997 that universities will die in 30 years. Universities will not compete successfully with these new forces, but they may work with other groups, at the level of individual professors or at the level of institutions. So far this prediction seems reasonable. Drucker is often right.

It is early in the process, so future details are fuzzy. The existing companies mostly are still thinking with the older information transfer learning possibilities, it would appear. We have already had some spectacular expensive failures, such as the California Virtual University.

Some of these organizations are nonprofit, such as the Western Governors University, now associated with the United Kingdom Open University. So far they have few students. I do not know the quality of their courses.

Commercial organizations include The University of Phoenix and Jones International University. I see no sign that these organizations appreciate the paradigm shift to tutorial learning. Newer organizations, such as UNEXT Learning Systems (UNext.com), may be more successful players. In some cases, universities are partnering with these organizations, such as Columbia University, Stanford University, and Carnegie-Mellon University with UNEXT.

The production of very large amounts of computer-based tutorial learning units will not be a simple process. Some of these organizations are still developing learning material in the old information transfer learning paradigm. Many do not have a clear idea of how to produce such materials. They are not spending enough money to develop highly effective learning units. The strategy for many is to hire a faculty member and provide support. This is not likely to work. Money alone is not sufficient, although it is

necessary, as the experiences of the United Kingdom Open University demonstrate.

These institutions will succeed or fail based on the quality of their courses and on marketing effectiveness. Many are more skilled with marketing than with development. Some may combine postcollege learning development, or other areas of learning, with college learning development.

Schools

Educating young children involves at present far more students than does higher education and lifelong education, although this will change. So this is currently the largest market. Much of the costs for schools are currently people costs, for teachers and administrators. It is now a labor-intensive process, based primarily on information transfer as the learning paradigm.

Unlike universities, schools in the United States and elsewhere have long been subject to extensive criticism. Perhaps the most famous report on this topic, not the first or the last, is *A Nation at Risk: An Imperative for Educational Reform*, published in 1983. The title expresses the negative view of our schools and the possible unfortunate future impact of this on the country. Many other such studies exist. Further, parents are often unhappy with the schools available for their children. Nolan Estes once described our schools as "a cage for every age."

In many parts of the world, schools do not exist and have little prospect of meeting the demands for learning. Hundreds of millions attend no schools, and many have only a minimal education. About 1 billion adults are illiterate, the majority girls. Later in this section, we will return to this important issue of international education for children.

These reports on school problems and the literature that followed have suggested a wide range of cures, mostly for developed countries: National goals, curriculum frameworks, higher standards for students, model schools, television programs, television publicity for "good" programs, more state and national examinations, more teacher training, longer school days and years, smaller classes, more computers in schools, more internet connections, elimination of social promotions, standards and examinations for secondary school graduation, praying in schools, charter schools, vouchers, state control of public schools, private management of public schools, systemic reform, and destruction of public schools. Many of these have been tried. None of these cures seem to make any large difference in student learning, nationally or internationally, although very large amounts of money have been spent in the United States, both by states and the federal government, on some of these approaches. Political philosophies rather than educational visions motivate some of these ideas. The reader will note that these ideas usually assume the information transfer paradigm for learning. Often they lead to additional costs to sustain them.

The 1997 *Report to the President on the Use of Technology to Strengthen K–12 Education in the United States* devotes a major section to software content and pedagogy. It recommends a constructivist approach, although this term is used in a wide variety of ways. Little software of this type has been developed for mass use. "There is widespread agreement that one of the principle factors now limiting the extensive and effective use of technology within American schools is the relative dearth of high quality computer software. . . . " But still, several years later, little such software is being developed.

With universities, as we have seen, companies are already beginning to compete with them. But this has happened less in the school market, perhaps because of the complexity of that market. Schools play many roles other than learning, often not well because of the mixture. One example is baby sitting, useful in a society where increasingly often both parents work.

An exception to commercial investment in children's learning is the Edison Project, from Christopher Whittle. The original idea was to introduce a large number of private schools, heavily based on technology. I do not know the nature of the new learning material intended. He hired some well-known people, including Benno Schmidt, President of Yale University, but I believe he could not raise the funds for developing the technology-based learning units necessary. Then the plan changed, with more emphasis on the schools, even public schools, and less on the new, technology-based curriculum. Efficient management of the schools, with professional management is stressed. Recently he has changed the name to Edison Schools and received sizable funding. There seems to be little current production of learning units, so the tutorial model is not the driving vision.

Another interesting development is home schooling, legal in many locations. So far the numbers involved are small; often there are private agendas outside of learning. With skilled parents who can devote much time to this (mostly well-educated mothers

who do not work outside the home) the situation is tutorial, and so often effective. The curriculum units available are mostly those available in the schools, so information transfer is still stressed. Standardized tests increase the problem. But if tutorial distance learning computer-based units were available, this might become a much larger market.

Another aspect of the home market may be even more important in moving us toward distance learning for school learning. Many parents are unhappy with their children's schools. They try to supplement school learning with home learning. There is already a market for computers in this activity. Preschool learning is one such large home market for highly effective, carefully evaluated learning units.

So far this discussion about schools and the tutorial learning problems has referred mostly to the United States and other developed countries. Schools are an even more drastic problem in poorer areas, as already mentioned; often they are minimal, or do not exist. Western attempts to help have been ineffectual, based on trying to duplicate our poor efforts in parts of the world that will never be able to afford it at a sufficient level. Tutorial distance learning, in the students' native languages using inexpensive learning appliances, could be a very important direction for improving learning in developing areas.

The school market is much larger potentially than the university market. It is likely that we will soon see more private competition. Initially highly interactive tutorial units might be marketed for use in traditional school settings and for home use. Gradually, as more effective material is produced, we will begin to see more commercial competition. But the strong forces existing in the school establishment will not be easy to change. The only way to move to the tutorial approach will involve major changes.

One intriguing possibility is that development of learning material for this market in wealthy areas could support the conversion to other languages and the distribution in the poorer areas. As in other areas, we need more experimental efforts, with careful evaluation, before these activities are widespread. Many languages would be necessary in this strategy.

Informal Learning

Although schools and universities come to mind when we talk about learning, even today most learning takes place elsewhere. People learn almost everywhere, sometimes as part of daily activity. Apprentice learning is still common in some professions. Libraries are a common learning place, for example. People learn much in their homes. Informal learning is common in our society. An important component is lifelong learning.

So the market for tutorial informal learning already exists. Unlike the situation with schools and universities, the informal market has no strongly vested interests to fight for the market. It will be a natural and easy way to introduce the new material. We can begin with kiosks in libraries, museums, shopping centers, and other public places. These locations can even be used for evaluation. Later small computers with wireless connections can supply learning anywhere—even, with the solar panels already mentioned, in places where no electricity is available. Students who use tutorial material in such environments will soon demand it for all learning, if the learning material is effective and desirable.

One particularly important component of informal learning might be early learning. Babies are marvelous learners, learning a language, vocabulary and grammar, and a theory of the universe around them. The concept of object is learned at this time. Young children are highly inquisitive, exploring the universe around them. But soon these excellent learning skills are lost in our present education systems.

We need to design and evaluate computer-based tutorial learning units that pick up just after language is learned, so that the spoken language quickly leads to reading and writing. Just as almost everyone learns to speak, almost everyone should learn to read and write. There is no reason for illiteracy in today's world! I expect voice input to pay an important role in this very early learning.

Another important aspect of this very early informal tutorial learning will be to prepare people to get along with others. Nonviolent ways of viewing the world should be learned at an early age, well before 5 years old. We want happy individuals who respect the rights of all others. The only possibility for this to happen is with tutorial computer-based learning units. There are too many people for other approaches.

As schools and universities decline, as I think they will, informal learning will become more and more important. Every place is a spot where tutorial distance learning can take place. In a strong sense, all learning will become informal learning.

Governments and Foundations

Governments concerned about the learning of their citizens, in their schools and universities and elsewhere, could be funding curriculum development

of tutorial learning materials. This is rare in the United States, but more common elsewhere with the support of high-quality, large-scale distance learning institutions such as the United Kingdom Open University and the other mega-universities.

The United States story here is worth telling. The Soviet Sputnik was a traumatic event for education in this country, leading to the belief that our educational systems, particularly in science and mathematics, needed improvement. Many large and well-supported curriculum efforts were funded, mostly in the schools. I worked on the Harvard Project Physics course for secondary schools, one of these efforts.

Just when we were getting good at developing such material (this was all before computers were widely used in learning) one course destroyed the entire curriculum movement, *Man, a Course of Study*, a fifth grade sociology course. The proceedings of the extensive congressional investigation into this course are still interesting reading. The problems were entirely political, having nothing to do with students and learning, I believe. We have developed few large courses in the United States since then. The federal government never has recovered.

But even these new courses completed soon became minor players in the market. Often they were impractical for the typical learning situation. The material developed for elementary science was particularly interesting, with three major projects at the University of California, Berkeley, the Massachusetts Institute of Technology, and the American Association for the Advancement of Science. This material depended on discovery modules, not the memorization that dominated and still dominates the field. Students worked in groups of four or so. But these elementary science products were not widely used. Very few teachers, even with training, could manage such groups in typical school settings, although large sums of money were spent on training teachers.

At Irvine, about 15 years ago we moved some of these elementary science modules to computer, in the tutorial mode suggested in this paper, and IBM successfully marketed some of the units, about 20 student-hours, as the *Scientific Reasoning Series*, but we could not find funds to continue this project, or to support other similar projects. They are still good examples of the interaction possible with computer-based learning, but the graphics show the age of the product.

An important role of governments could be to support early experimental efforts for highly interactive tutorial computer based units. These are critical for careful future planning. So far this has not happened, in spite of the large amounts of money spent trying to improve learning. Foundations could also play this role. They, too, spend large sums on learning materials.

International Organizations

The problems of learning are not restricted to a single country; they are worldwide. It appears increasingly unlikely that they can be solved in one country, or by one group of countries. This is particularly the case when we consider how learning can help our major global problems. If we are to have "a world free of poverty," as the World Bank suggests, we must work to raise the level of learning in all countries.

Organizations such as UNESCO, the United Nations, the World Bank, and USAID are heavily involved in education in the poorer parts of the world. Most of these organizations are still working and thinking in the information transfer paradigm. They spend large sums of money each year, often imitating what is happening in the developed countries. If they would try major developments in computer-based tutorial learning, they could be very important in improving education worldwide, again particularly in the early experimental efforts. Commercial organizations, schools, or universities might be more willing to take on large-scale development if they were convinced that tutorial learning was practical.

We have little experience with international curriculum development. Different languages and cultures would need careful consideration. Development systems should assume that eventually material will be moved to other languages. In some areas, international development, with teachers from several countries participating in the design groups, is likely to be practical. Perhaps the easiest place to start is with science and mathematics; to many of us they seem quite similar all over the world. Material that takes into account several different cultures could be superior, in assisting learning, to our present one-culture material, as it would involve a wider range of insights of how students learn. Experimental efforts in developing material for several countries could be very rewarding.

NEXT STEPS

As I have been suggesting, a plan for the immediate future is necessary. I summarize my suggestions

here. Our first step is to gain more information about the production of highly interactive tutorial units, through careful development of several extensive sets of material, as I have mentioned several times. All ages and subjects should be considered for these experimental efforts. Several different techniques for development might be tried. Financial data are important for future planning.

The next step is the most critical. These experimental units should then be tested with large numbers of students in both formative and summative evaluation. Skilled evaluators not associated with the developmental activities should conduct these evaluations. Students of all types who might be eventual users should be involved in these evaluations. Several languages, cultures, and regions of the world are desirable. Adequate funds should allow careful evaluation.

Given the results of this extensive empirical effort, we can then proceed to large-scale development, if the experimental data indicate that this direction will be productive. This development will be a major effort, comparable to putting a man on the moon, but with less uncertainty because of the first step just suggested. Learning material must be prepared in many areas, spanning birth to death, over a period of many years. As we have emphasized, professional evaluation of these units is also critical. These efforts would be best if they were worldwide, with sales in developed countries supporting development and distribution for developing countries. Experiences with the first materials will give valuable advice for later material.

It is unlikely that current schools, universities, and other learning institutions of today will be adequate to lead us into the future. We need to plan for new structures to distribute, market, and maintain these new learning units, forming new organizational structures for the future. These organizations, or others, must also be concerned with future production, maintenance, and revision of the learning units. We will have a better chance for planning these organizations after some of the learning units exist. Some of this effort may be commercial.

Both in content and in learning methods we still have much to learn for future learning material. An activity paralleling those just mentioned should be research in learning. This might be supported by governments, foundations, or by profits from marketing the materials in the developed countries. The learning materials themselves, with their built-in capabilities to store information about the student, will assist with this research. The extensive stored material will give us far more evidence about human learning than we have been able to gather so far! We may even conduct experiments with different ways to learn something, with the programs gathering the information about effectiveness. Eventually this work might lead to adequate theories of learning.

FINAL COMMENTS

We began with visions for learning. The new paradigms offer us the chance of realizing the visions at all levels of learning. Much work is ahead of us.

We are at a wonderful moment in human history. For the first time we have the possibility of educating everyone on earth to each person's full potential. We have an exciting period ahead of us for world education, at all levels. Great opportunities exist for greatly improved and affordable learning based on the tutorial learning paradigm. We must be bold!

> And indeed there will be time
> To wonder, Do I dare? And
> Do I dare?
> Time to turn back and descend the stair
> With a bald spot in the middle of my hair.
> Do I dare
> Disturb the Universe?
>
> —T. S. Eliot, "The Love Song of J. Alfred Prufrock"

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