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Viewpoint: Rebuilding Universities with Highly Interactive Multimedia Curricula*

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The author proposes the development of highly interactive multimedia university courses to replace the current mode of course delivery system. Courses will be provided with individualized help and paced by the student. The course effectiveness will be tested against current textbook based courses. The courses will provide an expanded market with distance learning, university and home learning environments—thereby recouping a larger share of the high development costs. The cost is divided into the categories of management, pedagogical, design and technical implementation. Course cycle is three years with two for development and one year for evaluation. Implementation of these courses will expand distance learning capabilities world Wide.

INTRODUCTION

A disturbing and dangerous mismatch exists between what American society needs of higher education and what it is receiving. Nowhere is the mismatch more dangerous than in the quality of undergraduate preparation provided on many campuses. The American imperative for the 21st century is that society must hold higher education to much higher expectations or risk national decline (*An American Imperative: Higher Expectations in Higher Education.* Report of the Wingspread Group on Higher Education, The Johnson Foundation (1993)).

Several years ago, the National Academy of Sciences held an interesting meeting in Washington DC about the US school system. The meeting was entitled 'Reinventing Schools—the Technology is Now'. Multimedia interactive technology has reached the point where we can make major improvements in schools. In this discussion schools are not the concern; it is universities that are our focus. However, the same title might be used for the endeavour proposed. So far this new approach has not even begun, at either schools or universities.

This paper suggests a far-reaching rebuilding of universities based on modern interactive technology. For universities too, the technology is now. We can rebuild, reinvent and restructure our universities with modern highly interactive multimedia computer technology, to improve learning. The Wingspread Report says that such improvement is critical. Further, significant reductions in costs are likely.

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This discussion is part of a larger approach to improving undergraduate education. Other papers expand some of the ideas developed. One deals extensively with distance learning and media choice.

The vision

This paper suggests some extensive new developments for universities. The aim is to make major improvements in undergraduate education in the whole world. It is based on recent considerations about the possibility for the university, perhaps with private companies, participating in large scale development, use and marketing of highly interactive multimedia technology-based curricula.

The following list states briefly the major aspects of this vision for universities, expanded further in this paper.

1. Provide more personalized individualized learning environments for all students. This vision suggests that many large lecture courses in universities, offering little individualized help for students, will be replaced with very high-quality, interactive, multimedia technology-based learning material, at the discretion of individual campuses and faculties. These courses must all be developed, as very few such courses exist today in US universities. Highly interactive material, almost conversational in nature, will respond to individual student problems. Learning will be an active process for all students, so that knowledge can be constructed directly by the students.
2. Verify that more students learn and learn better than today. This will be done with careful experiments with large numbers of students and many universities. A major increase in

student learning will be attained and verified by a large-scale evaluation. Thus, these new courses will be fully tested, with both summative and formative evaluations, so that the learning gains are empirically documented. The interactive courses that will continue to be used will be those that show themselves to be considerably superior, in student learning, to existing university courses. These new approaches will be used, as campuses and departments desire, to replace courses already in existence or to modify these courses.

3. Significantly reduce the costs of university education. University education is too expensive for many students. Interactive technology allows us to reduce costs.

> . . . the traditional model of one professor teaching 25 students per class, three times a week, for 15 weeks, will not scale to meet this increased demand because it is too expensive (Carol Twigg, 'The Value of Independent Study', *Educom Review*, July–August (1995)).

4. Promote research in learning in universities. We must improve the major university product, student learning. This should become a primary aim of university research.
5. Develop full new courses for many areas. This new learning material will use computers, media and the future national network infrastructure. The content of the courses will be fully revised to meet modern standards. New modes of assessment will be part of this development.
6. Market these materials. The courses will be marketed widely to other universities and to the general public. Eventually these courses should not only recoup the financial costs that have gone into them, but could become major profit sources for universities and for cooperating companies and institutions. If the markets exist, we will develop in languages other than English.
7. Use these courses as the basis for new distance learning universities. These courses will greatly aid us in setting up distance learning universities. We would thus greatly increase worldwide student access to learning. Eventually, through these distance learning efforts, we will extend the lifelong learning components of universities and work towards an educational system covering everyone from birth to death.

A university may undertake this development in partnership with other universities or commercial partners or these efforts might be entirely commercial. These full courses would replace the existing lecture-based courses. The components could augment the existing courses.

Where we are

Within almost every university in the world, the major courses of the first 2 years are delivered almost entirely by a lecture–textbook method, often with large numbers of students. Many other courses in the curriculum are also presented this way. This method, using the lecture and the textbook, has been the dominant method since the 1700s, both in schools and universities. The lecture approach is much older.

While other materials and approaches, such as video, computer material, etc., are used, such alternate approaches are typically a minor component of the total. When we consider the student learning time, textbooks and lectures dominate in almost all courses. Little has happened to change the existing lecture–textbook method, in spite of widespread criticism of the method. The use of computers thus far has had little effect on our courses.

In a few instances charismatic teachers or teachers who are able to conduct their courses in alternative fashions can make their courses a wonderful experience for the students. But for most students and most courses this does not happen.

Lack of learning.

A principal objection to the standard ways of conducting the courses is that many people do not learn or learn only partially. Not all students make the highest grades, showing incomplete learning.

Lack of individualization.

A major flaw in lecture–textbook courses is that students are mostly treated in the same way, with only minor individualization. The courses proceed in lock-step fashion, with no attempt to allow students who need more time to gain it. Seldom do students get much individual attention, given the numbers of students in the courses and the teaching strategies involved. Often large introductory courses are not taught by the tenure-track faculty, but, either partially or totally, by graduate students or by lecturers brought in specially for the courses. As universities continue to lose financial resources this situation grows worse.

Lack of interaction.

Another major problem with most of these courses is that much of the learning is passive for most of the students. Listening to a lecture or reading from a book is an active experience only for students who have either special training or aptitude. Students are not engaged. For most students learning remains passive.

The current media bore students. Many students fall asleep in lectures or while reading. Most of their lives students spend more time watching television than reading. Increasingly in the USA the students do not purchase textbooks for the courses they take.

Lack of creation of knowledge.

Students in classes today seldom create their knowledge, since discovery methods are very difficult in the lecture environment. Active learning is far more desirable, but difficult to obtain for most

students under these lecture–textbook courses, given the number of students involved.

Old content.

Many courses today have old content. Thus, beginners' physics courses have changed little in 40 years, viewed nationally.

An aspect of old content is the focus on memory. We should focus on more important intellectual skills.

Poor assessment.

Current courses assess infrequently and in modes that do not assist student learning.

It is just these problems that we can overcome with new types of courses based on modern interactive multimedia technology. This proposal discusses the possibilities.

Curriculum and technology

This proposal does not suggest adding small amounts of computer-based material to existing courses, the current direction for technology in learning. It suggests new learning material, providing an individualized learning experience for each student.

These courses should not begin with existing non-interactive courses, but should be fully designed from the beginning, using highly interactive, multimedia technology-based learning units extensively. Other learning media will be used too where appropriate. The aim is not to use technology, but to improve learning in major ways. The development we propose here is new.

Bits and pieces.

So far, development using technology in education has followed the 'bits and pieces' approach. Small amounts of technology-based material have been developed, sometimes tools, sometimes other material, to fit into existing courses. Thus, the course is only altered in minor ways. The typical standard lecture format continues, with little individualization of learning.

These bits have not improved learning. Much of such material is used only by the developers, but even widely used material has had little effect in improving learning nationally or internationally.

The bits and pieces of technology material that have been developed so far, that people continue to develop, have had little lasting effect on education. The development of these small pieces has taken place over 25 years. The evidence is clear. The 'bits and pieces' effort is often a waste of money and effort, except for a short-term effect in a small number of classes. Nationally it is a useless approach, but most development is still of this type.

Full courses.

In spite of the difficulties with the bits and pieces approach, however, few full-scale courses have been developed using highly interactive technology. If one looks at Writing to Read at the elementary level, at the University of California, Irvine, the physics course of many years ago and the logic, set theory and language courses developed at Stanford University, one has almost completed the picture. All these courses were developed many years ago.

During this period of time vast amounts of money have been spent by government and private agencies for curriculum development. Much of this funding has gone to video-based courses with a low degree of interaction at best. The situation is particularly bad in the USA where little curriculum material has been developed at the standards of the UK Open University. The notion of developing full-scale courses with interactive technology has received very little attention from funding sources.

Both at the school and university level the only way we will make major progress in improving learning with technology is through developing new *highly interactive, full-scale, technology-based curricula*, beginning immediately in the design process with the assumption that highly interactive multimedia technology is available for use with students. This proposal suggests a dramatic change in universities; the development of full, technology-based, highly interactive multimedia courses. Thus, this proposal is a genuinely new approach.

Overview

This suggestion for rebuilding universities is divided into several parts.

1. The proposal emphasizes the research activities needed.
2. The proposal discusses the new highly interactive learning units made possible by the new technology.
3. The next part, attaining the vision, concerns the details of how we reach the new university structure. It proposes two alternative beginning approaches.
4. The last part considers the full development and use of the new technology-based multimedia interactive curriculum.

This material is intended for discussion. The details may change as these notions are further explored. A shorter document contains brief recommendations. See the Bibliography at the end of this paper.

RESEARCH ON LEARNING

One of the oddities of higher education in the USA is that little research is currently being performed to improve learning at the university level, in spite of the emphasis on research in many universities. We conduct many types of research on campuses, but very little research on improving post-secondary education. However, such research is critical for future progress in improving higher education.

This lack of research in improving education is

to be contrasted with almost any major company in a competitive environment. In a company a major emphasis on research is to improve their own products. Thus, IBM maintains major research laboratories around the world, working in directions that might have some consequences for IBM. This is not to say that all this company research is applied, but it usually has the potential for affecting the future in the area in which the company works. It is realized that such research is essential if the company is to survive and prosper in a rapidly changing competitive world. However, universities do not appear to recognize this need. This situation should change.

Effectiveness of courses

Every university declares that it has a marvellous undergraduate programme, in its attempt to attract students, particularly good students. However, except for such studies as the Knapp and Goodrich considerations on the origins of American scientists, where state universities fared poorly compared to good small liberal arts colleges, little empirical information is available.

Even more important for this discussion, we perform little research into how to improve the quality of learning in our courses. Student evaluations are widely used in internal evaluations of teaching, for tenure purposes, but their value is highly questionable even for this purpose, and they tell us almost nothing about improving student learning.

Research on improving learning.

It is critical for the future of higher education and all education to study the process of learning, with and without interactive technology. This research on improving learning must be done with the same standards that we apply to high-quality research in the sciences. We need careful, well-done, multicampus studies, with large numbers of students (thousands, at least) if we are to gain reliable empirical results. All types of students should be involved.

Computers and research on learning.

The primary concern of this document is to encourage the development of large numbers of highly interactive courses using modern information technology. These courses would be of major value for extensive research on learning.

The computer allows us to monitor student learning in great detail. With highly interactive software we can gather and save moment-to-moment accounts of student progress, of what is going on in the student's mind, in a way that is impossible for lecturing and for reading. Thus, we can gather extensive detailed information about learning with our new computer courses, with large numbers of students in many institutions, increasing the possibilities of effective research.

Encouraging research on learning

We can and should actively encourage faculty to do more research in this area. This is particularly a job for presidents and chancellors in universities. We need to create a climate on all campuses that values research in this direction, which is not generally the case now.

Strong administrative support is essential to stimulate such research. The Wingspread report mentioned interesting suggestions in this direction.

Multicampus research

We may not have enough strength on any one campus to work in this direction, but we have such strength in abundance when we consider several campuses. Thus, multicampus research and doctoral programmes in this area are possibilities well worth investigating.

A multicampus activity of this type was proposed for the University of California system approximately 10 years ago, by a group including the present writer, the LARA program, after a Swedish word meaning learning and teaching. Over 100 faculty on all the University of California campuses expressed interest. However, individual chancellors did not agree to the program.

The existence of computer-based networks makes diffuse research institutes, with several geographical locations, practical. Extensive use of electronic communications allows close collaboration even though people are not at the same location. Such an arrangement for multicampus research in improving higher education could serve as a model for other areas.

THE NEW CURRICULA

Imagine a future for universities in which most learning currently delivered in large lecture environments will be replaced by full-scale, technology-based, highly interactive multimedia learning. Many such interactive courses could be offered through universities or through distance learning. Some courses would probably use the Internet and its future broadband extensions.

These courses do not exist at present, so they would *all* need to be developed. This proposal particularly involves university education, but similar considerations apply to schools. The pedagogical decisions would all be made by groups of competent and successful teachers of the areas involved.

The new courses suggested are not conventional lecture–textbook courses supplemented by technology-based learning material. The new courses are not learning experiences in which a lecture is the primary delivery system. Interactive courses must be designed from the beginning with full use of the interactive computer capabilities, probably in multimedia environments. The interactive course is new, with many features different from

courses today. The following sections consider some of the capabilities proposed.

Although the primary concern in this paper is with learning software, considerations of conversational interaction could improve all software.

> If alternative instructional technologies and credentialing systems can be devised, there will be a migration away from classic campus-based higher education (Eli Noam, Electronics and the Dim Future of the University, *Science*, **270**, 247 (1995)).

Curriculum features

Computer-based highly interactive learning has great advantages. Few examples exist now, so we emphasize some key features of interactive learning modules.

Individualization.

Individualization of learning is the key factor in making learning more effective. Every student is different, with different learning problems, different interests and different learning styles.

> Another broadly relevant outcome is a growing recognition of, and respect for, the inherent individuality in the structure of human intellect (Roger Sperry, Noble Prize Speech, December 8 (1981)).

The creation of highly interactive learning material makes it possible to respond to the individual needs of each student, impossible in the lecture or video environment where only very limited individualization is possible. The computer can, with appropriate software, analyse student inputs and maintain a dynamically changing model of each student. Both student input and this model can be used to decide what will happen next for the student, at each moment of learning. We can identify student confusions and offer aid tailored to the individual. Each student can have an individualized learning experience.

Individualization makes it possible for students to learn in the Socratic tradition; the computer asks questions or provides experimental facilities. Student discoveries of important results are possible.

Several factors make it practical to create such individualized learning material. Individualization is possible through the creation of highly interactive material. The next section discusses such interaction.

With individualization, all students can learn, not just a few. Mastery learning is discussed later.

Interaction.

The word interaction is used frequently today, particularly with computers. But some of this use does not refer to tactics useful in learning. Many existing materials might be described as 'very slightly interactive'. This is to be contrasted with highly interactive software. Interaction is not a single entity, but a spectrum of possibilities.

We need a model for highly interactive learning for the computer. Our model for interaction is interaction between a teacher and a small group of students, perhaps as many as four. A good tutor, with a few students, can provide an excellent interactive learning environment. We need to consider both the amount (frequency) of interaction and the quality of the interaction.

Socrates, as described by Plato, is one excellent example of a highly interactive student–teacher interaction. However, as we have had to educate more and more people, it has been less and less possible to provide active learning to all students. We have retreated to educational modes, lectures and books, that provide spectator education for most students. Interactive technology offers new possibilities, even with many students.

The type of interaction proposed for the new courses might be called 'conversational interaction'. It resembles, as seen in our model, the learning conversation between one or a small number of students and a skilled teacher. We also refer to software using this model as 'highly interactive'. Technology can create an engaging interactive environment for *all* students.

Such an interaction is not attained through pointing and multiple choice. Much current computer material is less interactive than older material, because of this reliance on pointing as an interaction mode.

With the computer and associated technology students can, with well-prepared materials, make meaningful responses every few seconds. The computer can consider these responses carefully, also considering the stored student model. Thus, the student experience can be highly interactive, almost conversational.

Students actively involved in learning do better than passive students. The learning environments to be created in these new courses will actively stress involved students. We want students to be participants not spectators in the learning process.

One major advantage of active learning is that it allows all students to create their own knowledge. Thus, instead of being told the laws of genetics, students can discover them in a way similar to how a scientist might discover them. This happens in the Families Module in our Scientific Reasoning Series, for example. All students can make the discovery.

Experts in learning agree that such constructed knowledge is better than memorized knowledge told to the student. However, we have few materials today that allow and encourage individual discovery.

Interaction through natural languages.

An important aspect of human interaction for learning, as in our student–teacher model, is the use of our most powerful human communication tool, our natural languages. These rich systems have evolved over thousands of years. As indicated, pointing and multiple choice are not suitable

for highly interactive material. They are of very limited use in learning.

See the Bibliography for a further discussion of interaction. We emphasize that this word has many meanings in the literature.

Interactive software can put the student in an environment similar to apprentice learning, where the learner is not 'told' things, but learns by carrying out the suggested tasks.

Cooperative learning groups.

Research shows that groups of two to four are best in increasing learning and human interaction. Such cooperative learning can be aided by the computer. Students engage in intense peer learning, assisting each other, stimulated by the computer questions. These may be local groupings or may be established through computer networks. The computer can even address individual students in such a cooperative learning group.

With a full course, we expect these groups to change frequently. The computer program is building a model for each student and so can assist in the regrouping of students.

Thus, students have the experience of working closely with many people, giving them practice in working cooperatively with others. This experience will be valuable in work experiences later in life.

Mastery learning.

With individualization and interaction we can assure that all the students learn everything, to the 'A' level, mastery learning. If we determine, online, that a student has not learned something, the computer can immediately try a learning approach more suitable to that student's learning style. We can verify at frequent intervals in the computer units that mastery occurs, for all students. So with these new courses all students will learn everything, to the mastery level.

In such interactive material, learning and testing are intimately combined, fundamentally the same activity. This is a major difference from current educational practice. A paper describes this combination of learning and assessment further (see the Bibliography for details).

Another new aspect of such learning is that the programs should have access to detailed information about each student, perhaps lifelong information. Thus, decisions can be made both on the immediate responses of the student and on information about what the student has learned before. These student models have already been mentioned with individualization and interaction.

The organization of courses for mastery learning will be discussed further when we consider new structures possible with technology.

Multimedia.

These courses will use the full range of learning media. The computer programs will present sound, pictures and video, as part of the learning material under computer control. The media output will be stored on CD ROM or be available through networks, thus using learning materials from the worldwide digital library.

We expect that voice input will soon also be practical for learning programs. So students will literally talk to the computer, rather than type.

Student and teacher choices.

The new courses will allow decisions about the content and sequence to be made both by the teachers and by individual students. Thus, they will also be individualized in this sense.

Student motivation.

Keeping students interested in the learning process is essential, so all the materials developed will give careful consideration to motivation. Not all learning is easy or entertaining, so motivational issues must be considered.

An important consequence of multimedia interactive learning is that we can keep students involved in difficult learning tasks. Our studies show that interactive material is self-motivating, if the interaction is of high quality. Interaction needs to be frequent; the student should be replying to meaningful questions at an approximately 15 sec interview, if interest is to be maintained.

Variable pacing.

Students do not learn at the same pace. If we are to achieve mastery for all, we must allow for different learning times. This is practical with technology-based learning material. A computer-based student management system is essential for variable pacing and for assuring mastery learning and so will be part of this project.

Self-esteem.

We want to increase students' self-esteem. This is possible in a mastery environment, where all students will succeed. Positive ways of addressing the student are important in this regard.

We want students to like to learn, encouraging lifelong learning. These effective components will be given careful consideration in the new development.

Other learning media.

We do not intend to imply that all learning in these new courses will depend on the computer. The question of how to best assist learning will be determined by the faculty on the design groups for each course. Thus, the balance might differ from course to course and from student to student. However, generally the interactive component would be the major component of the student learning time. All media would be used, as appropriate.

COURSE STRUCTURES

It should be emphasized that technology-based courses would often be structured differently than

our current courses. The typical, linear, fixed-paced, lecture–textbook learning approach is no longer required or desirable. With new modes of learning, new ways of conducting courses are available. See the paper on course structures in the references.

Promising types of course structure practical with the extensive use of technology may not be practical without this technology. However, only experience in developing and evaluating many such courses will reveal the full details, showing which strategies for organizing courses are best for which students.

Here I mention two possible structures, mastery courses and hypercourses. Others are possible.

Mastery courses.

It is probable that these interactive courses would be done in the mastery mode, where it is insisted that each student fully master all the material. The goal, unlike the present courses, is that everyone should learn.

The basis for this approach is frequent internal assessment, within the interactive computer material. Learning and assessment are together, not separate, on a moment to moment basis.

If assessment shows that mastery has not been attained, additional learning material would be supplied until mastery is attained. Alternate learning approaches based on highly interactive computer-based technology would make this much more likely. The new mastery-based courses would be student oriented, not teacher oriented. The programs could advise teachers when human involvement is essential to assist students in learning. However, some learning might not involve teachers.

Hypercourses.

Another possible organizational structure for non-linear courses is to base courses on hypermedia documents. The course could be considered as a collection of pieces, where a piece might be a bit of text, a picture, some sound or a video sequence. Students move between such pieces, with considerable student control.

Mastery could also be stressed. Within such hypercourses, at many spots, we would check to see if the student needs additional help and, if so, offer a different learning sequence, that is we could go beyond the mere presentation of information and assure that learning is taking place for each student.

COURSE CONTENT

Many beginners' courses in universities are old and so do not reflect the needs and knowledge of today. Hence, these courses badly need new versions. Thus, new development will often need new content. Further, our needs change as we move into the new century.

> The world our children inhabit is different, radically so, than the one we inherited. An increasingly open global economy requires that all people be better educated, more skilled, more adaptable, and more capable of working collaboratively (The Wingspread Report, The Johnson Foundation (1993)).

The development of new interactive multimedia courses will give us a chance to reconsider the content of courses. There is already national pressure for new types of courses, but with little creation of these new courses.

For example, several years ago the National Academy of Sciences held an extended session about the calculus course. Almost every speaker in that session found the calculus course inadequate at the present time. Yet that session has had little effect, in spite of an explicit National Science Foundation programme to rebuild calculus. Funding is at too small a level! The courses that are being constructed are still lecture–textbook courses, with only small components of technology in them. There have been few changes in content.

The ability to reconsider content for all courses, considering students who will live in the twenty-first century, is a valuable aspect of this proposed project. Faculty members strong in research are essential for the development groups.

Initial courses

What courses do we start with? That is, what initial course development efforts should we undertake?

Background courses.

One important area to consider are the large remedial courses, such as those in English and mathematics, with large numbers of students in almost all universities. The word 'remedial' is unpopular, but clear. This is material that 'should' have been learned in schools, but was not. Or perhaps the time interval since the school courses were taken is too great. Or perhaps the material has not been used in other courses and so has been forgotten.

The cost in a typical university for running these courses is considerable and the desire for teaching them among research-oriented faculty is almost nil. To give some idea of the size of the market, one might survey these courses at many campuses, with particular attention to the costs for development and delivery.

Often students are put into these courses via an examination. For example, at the University of California, Irvine, we set an entrance examination for the calculus course. Many students cannot pass almost simplistic entrance exams, primarily high school mathematics, and are put in remedial courses. Universities have oscillated in offering remedial courses, but the need for students to learn the type of material within them is indisputable.

The experience of offering these courses for university students at community colleges, to

satisfy university requirements, has been mixed. Many students who take these courses do not graduate, so nationally these courses have a poor reputation. For many students the existing courses do not provide an adequate learning environment.

Student needs in such courses vary greatly from student to student, so an interactive course, reacting individually to each student, could be much more efficient in student time and more effective in student learning, as compared with the traditional courses in the area.

Hence, these courses would be excellent for the trial experiment. They would also furnish us with excellent marketing experience.

Large beginners' courses in science and mathematics.

Another similar educational problem and market exists for the large beginners' courses in science and mathematics. These courses are remarkably similar from university to university, because only a few textbooks dominate the market. They are also similar in other countries.

These courses are almost inevitably given today as lecture–textbook courses, with a fixed pace and with no adjustment possible for individual students. The amount of attention that individual students receive, often from teaching assistants, is not sufficient for many students in these courses. Far more students fail these courses or do poorly in them than should be the case.

A multimedia, technology-based course, highly interactive and adapting to the individual student needs, could establish important markets for any of the large beginners' science and mathematics courses. Our experience in developing the introductory physics course at Irvine furnishes useful information for such development.

Other large courses.

The computer could play a similarly important role in any course normally taught with more that 100 students. The type of activities in these interactive courses could be far superior to that in the current courses of this size. Students could receive far more individualized attention.

In developmental efforts, in the immediate future, we should avoid small courses or courses taught primarily with non-lecture approaches. However, most university courses are lecture based.

CURRICULUM PRODUCTION

A full production system is needed for effective course development. One possibility is to study the systems used in major distance learning universities. Several approaches are possible and more empirical study of different production systems is desirable.

The new interactive multimedia courses might be developed following the strategies used at the Educational Technology Center at the University of California, Irvine, which have been developed over the past 25 years. Recently we have been joined in this work by the computer science group at the University of Geneva.

We expect that some of the material developed will use the Internet and its successors. This decision, in each case, will be a pedagogical decision, made by the design groups of faculty to be described. In many cases, either CD ROMs or networks will be possible.

Pedagogical design.

University faculty would specify the pedagogical design of these new courses. This is the most critical stage in development and the stage where experience with the students is most critical.

We would involve designers from higher education, individuals who have been particularly successful in helping students, working with them on an individual basis. Approximately three or four faculty work together in a pedagogical design group, for a week or two at a time. Designers may come from everywhere.

We have established policies for introducing faculty to the necessary procedures. The key issue is to provide an environment for the designers that stresses highly interactive material and individualized attention.

Discussion and debate characterizes such groups. Thus, some advanced discussion on conflict resolution is important.

These designs can be either on paper or with the script editor mentioned in the next section. If the designs are on paper, they are then entered onto the computer by others.

Programming.

Again, the emphasis is on highly interactive, almost conversational, modules. Most of the programming can be done automatically, by the computer.

An extensive set of tools has been developed at the University of California, Irvine and the University of Geneva, to ease the production of high-quality, extensive material. These tools include an on-line script editor and associated programs, such as code writing programs that will write approximately half of the programs at present. Later developments are expected to increase the percentage of computer-written code substantially.

Developers can choose the language for automatic programming. Facilities assist the coders to fit handwritten code into the computer-written material. Other facilities ease the problem of developing in other natural languages.

Media production and screen design.

Experienced media designers are responsible for the further design and development of each of the media involved.

Integration and beta testing.

At this stage the various components, programs and media, are put together to form the initial running program. Then it can be tested with a few students, to find programming difficulties.

Formative evaluation.

An important aspect of the development process is formative evaluation and improvement. The modules are used with typical students, with the data gathered, often by the computer, used to revise the material. Several such cycles of evaluation and revision are desirable. Much of the necessary information is gathered by the computer; professional evaluators are also important. This activity is to be distinguished from the later summative evaluation and is described in the next section. The designers review the evidence and plan the changes to be made.

A paper describing the production strategies in much more detail was given at the *IFIP World Conference on Computers,* in Madrid, in September 1992. Complete details are in the Bibliography. Further information, including documentation of the extensive tools, is available.

Summative evaluation

After new interactive learning material is developed, it is important to study carefully how effective this material is, as compared to the existing material for learning the same topic. These studies should be designed and executed by professional evaluators, working with large numbers of students. These evaluations will be important in marketing the new courses.

ATTAINING THE VISION

The previous sections present a vision of where we might go in making major improvements in learning at the undergraduate level. This vision suggests the development of full curricula based on highly interactive multimedia technology.

A vision needs practical details, a series of steps with the possibility of stopping or changing directions if those steps are not successful. In this and later sections we look at the details of creating the new technology-based courses and the distance learning universities that are essential for attaining the vision.

Starting

The first question is how to begin. Several approaches are possible.

1. In the first approach we start with an experiment, looking to obtain additional information before beginning large-scale development. Approximately 20 courses appear to provide an adequate empirical investigation. This would be ideal in that it would enable us to perform development in a variety of areas and to gain empirical information about how these courses compare with the existing courses. We could experiment with different development approaches and explore marketing possibilities. An experiment of this kind requires initial funding of approximately 80 million dollars.
2. The second possibility is to begin immediately with individual courses, learning as we go. The development of each course would depend on available funding. Here the initial funding that will be necessary will be less, but less will be learned in a reduced experiment. The long-range profits would be further delayed, because not much material would be quickly available.

The choice of an approach for initial development may depend on the amount of funding secured for this effort.

The next section discusses the proposed experiment.

The experiment

For this approach a two-stage process based on an initial experiment is suggested.

1. The experiment. First we would produce, market and evaluate approximately 20 full highly interactive multimedia courses. These courses would be the basis for a major educational experiment to determine the costs involved and the quality attainable.
2. Full development. If this experiment is successful, we would proceed to full scale development.

The experiment would establish an empirical basis for the new curriculum effort. Thus, it is an important beginning stage. However, an alternate approach is suggested later.

Experimental details.

A group needs to be established to conduct the experiment and a different group to evaluate the experiment. Only an outline of the steps is included here. Further details are available from the author.

1. Secure adequate funding.
2. Decide whether the choice of courses is to be made by the control group or through a solicitation for course proposals.
3. A variety of development procedures should be followed, with careful gathering of information in all cases.
4. No single group should be allowed to develop more than two courses, so a variety of learning styles should be represented.
5. Begin at once to plan for full-scale summative evaluation.

Evaluation of the experiment.

To determine whether this experimental project is a success or not and to decide if we should start the larger development, studies need to be made in addition to the development of the courses. Several types of evaluation are needed.

1. In course development we need to keep careful information about how the courses are developed, both in terms of what people do and the costs of the different activities. This is to give us a better financial basis for the larger development that may follow.
2. Formative evaluations will be conducted as part of the course developments themselves as in all well-done curriculum developments, as already described.
3. In addition, we will conduct, independent of the development of these materials, summative evaluations that compare these courses with those taught in traditional ways. We want to have strong evidence that students do learn more from these courses, as compared to the traditional courses and that they enjoy the new courses as compared to the lecture-based courses. We are not looking at small differences; we hope that the new courses will be much more effective than the old courses. We also need to determine whether the technology-based courses can be run efficiently, for less money than lecture courses, on many types of campuses. This data will be essential for widespread marketing. The student time for learning will also be examined carefully. Professional evaluators, independent of the other details of the project, should make these studies, so that they will be reputable from a scholarly point of view. That is, we do not want the developers themselves simply announcing that everything worked wonderfully, which is often found in education. Large numbers of students, from many campuses, need to be involved, both using the new course and the existing courses.
4. Another aspect of the experimental studies in this first phase will be to study the questions of marketing. We hope that given a variety of courses we can compare alternative marketing tactics and see which tactics are likely to be the most successful. There is little experience of full-scale, technology-based courses, so there is much to be learned in this area.

The final decision at this stage of the project will be that of deciding whether to continue to the larger project or not to continue. Procedures will need to be established, early in the experimental phase, for reaching this decision. Success in both improving student learning on the courses developed and in marketing these courses elsewhere will be important.

We will, however, probably not be able to experiment with the possibility of distance learning at this stage, because too few courses of this type will be available. However, some work in this direction might be possible. At least we can verify that the experimental courses will be usable in a distance learning environment.

As indicated, it may not be practical to conduct the experiment described, perhaps because of the expense of such an experiment. In this case an alternate approach is possible. We begin developing individual courses, one or several, as funds permit.

All the previous comments about the courses still apply in this case. We would eventually accumulate the knowledge that we would gain from the experiment, but at a slower rate.

FULL DEVELOPMENT

If we begin full development, we should already have a good basis of experience from earlier development, both for the effectiveness of the courses and their marketability.

The strategies for full development will not be described here in detail. They will be similar to those already described. Some of the material will use international networks, as in the experimental work.

The production of many new courses, as would be required, is an extensive process, so we need to rethink strategies. I have suggested the development of curriculum development factories for this purpose. For full development we would expand the developmental tools already available. A discussion of these future tools is available from the author.

Campus use

We are aiming at both campus and distance learning use of the new courses.

As courses are developed and tested, they will be offered to campuses for implementation. They will be flexible, allowing a variety of strategies for use. All will be subject to full formative and summative evaluation and this information will be made available to campuses and others to help them in their choice.

Distance learning

Universities could also use these courses to establish themselves as major distance or open learning institutions. By distance learning we mean that the students would not be physically present at a campus, but would be working in their own home, work environments or informal learning environments. Another important goal for distance learning is that the learning could take place at any time. Students could begin and end a study programme at any time. Students who prefer to work at 3 a.m. could do so.

Liberating courses from space and time considerations is an important step in making learning more available to all potential students. A key feature in the notion of open university is that all students could learn any subject also. Interactive learning units, well constructed, can adjust to the level of the student.

University credit may or may not be involved. Thus, access to courses would be greatly increased; we would gain many remote students.

A paper available from the author discusses in

much more detail the issues of distance learning. The key factors considered are the quality of learning, scalability and the costs (both development and delivery). Various technologies are reviewed.

Several possibilities exist for the delivery of these new courses for distance learning, depending on the development of the technology in the next few years. The most likely possibility now is through CD-ROM, although network-based delivery procedures are also possible. A combination of these (and possible new) technologies is likely for the future, as networks improve in speed and availability.

The possibilities for creating new distance learning institutions based on computer technology are very interesting. The full use of highly interactive, multimedia learning modules is a new direction for distance learning institutions, which is very promising for the future. One possibility is that most undergraduate learning will take place this way.

Areas of development

I have, in the discussions about the experiment, suggested some areas for developing full university level interaction courses using modern multimedia computers. All the lecture courses would be obvious possibilities for the early stages of full development.

Three factors are important in making choices, as stressed before.

1. Improving student learning. Good courses of this type, stressing individualized student learning, could be of major help to all students.
2. Opportunities for marketing. Good marketing possibilities for technology-based courses at the university level.
3. Distance learning. We wish to look towards the formation of major distance learning institutions, based on highly interactive, multimedia learning units.

I emphasize that I am particularly concerned with materials that might well realize a profit in a few years, in spite of the sizeable development costs that would be involved. There would be a major market for such courses.

FACULTY

The developments suggested in this document will have major implications for university faculty and on the structure of our universities. This section reviews faculty implications.

Numbers

The new technology-based courses suggested in this document will require less human time than the existing lecture–textbook courses, both for lecturers and tenured faculty. The interactive courses at Stanford University, in logic and set theory, give us information in this direction.

Patrick Suppes is nominally the instructor on these courses. However, he spends none of this time 'teaching' the courses. No lectures are offered. A few teaching assistants are still employed to work directly with the students, but most of the individualized student help comes directly from the computer.

The courses in the Open University and other distance learning institutes worldwide, give us further information in this direction. The courses developed in this project will be highly individualized. Less faculty time will be needed for curriculum delivery.

The consequences of reduced faculty time

Fewer faculty will be needed for course delivery, allowing some interesting new possibilities for universities. These possibilities interact with each other but not all are simultaneously possible.

1. Universities should realize savings of money in the early courses.
2. We could accept more students, with the same size faculty.
3. Faculty could devote more time to advanced undergraduate students, to graduate students or to research. Again, not all could happen at the same time.
4. Faculty could teach more experimental courses, not part of the standard curriculum. For example, more small discussion-based courses for freshmen or sophomore students, could be offered on some campuses.

Universities could weigh these possibilities and make choices consistent with their missions.

ALL COURSES?

There may be areas for which it would be difficult to develop courses that could compete well with traditional courses. However, we believe that anything currently taught in a large lecture environment can probably be taught in a much superior fashion with interactive computer material. In other areas, more experience is needed.

On the other hand, we would expect in our vision that the courses given directly by professors in universities would be the smaller courses, with no more than approximately ten students, taught on a discussion basis or by other methods that go far beyond a lecture–textbook strategy. These courses would not be easy to replace with technology-based courses, given our present experience.

The marketing of technology-based courses

There will be a heavy demand for technology-based courses at universities if it has been established for each course, through careful research, that that course is far better for student learning than the courses currently being taught. Such research is suggested in this proposal.

Furthermore, there would be a considerable market for informal use, outside institutions, for

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There will be a heavy demand for technology-based courses at universities if it has been established for each course, through careful research, that that course is far better for student learning than the courses currently being taught. Such research is suggested in this proposal.

Furthermore, there would be a considerable market for informal use, outside institutions, for

segments or entire courses. Many of these might also be sold to schools in this country and elsewhere in the world. Versions in other languages would be developed, as appropriate.

At present there is little experience in marketing the types of courses considered. Hence, the marketing issues would need to be considered carefully, working with experts in marketing to the school and university markets. Considerations of this type should start right at the beginning of the project, before there are any materials available to market.

FUNDING

A major, initial problem is to obtain funding, first for the experiment and then for the following extensive development.

To develop high quality interactive multimedia curriculum material of any type demands significant funding, of approximately 4 million dollars per course. This includes the full-scale evaluation essential for the experiment. Later development could be less, because we will learn from our early efforts.

This figure comes from major high-quality course development efforts, such as that at the UK Open University. It seems unlikely that we would be able to obtain this funding for this project within one university, given the current financial problems. Thus, outside funding will probably be required.

For the experiment, funding might come directly from Congress or from organizations such as the National Science Foundation or other federal or state sources or commercial funding might be possible.

Government funding

It is conceivable that we could persuade Congress, federal agencies or the State Legislatures to fund some material of this kind, since it would probably save money in the long run and even be a profitable venture. All components of the higher education system in a state could make use of these new courses. Thus, the financial savings might be great.

The experiment might be funded this way, with the prospect that, if successful, further funding might come from other sources.

Cooperating universities

Another possibility is that several universities might be interested in working together, each providing some of the funding. Perhaps this could be done through an organization such as EDUCOM.

Foundations

Private foundations interested in major improvements in higher education would be another possible source.

Commercial funding

The most likely directions to pursue would be, I would think, to find venture capital or to join forces with an existing company or companies. Several possibilities exist. In the USA we have many technology-rich companies that depended heavily on the defence budget, now interested in new areas to explore. The educational market is large, but so far technology is a minor component.

A major course development would furnish an exciting new area for companies to explore, a market that no-one is involved with to the extent suggested and one that has considerable promise.

Just what kinds of financial arrangements could be worked out between these companies and the universities is unknown. We do not have, I believe, much experience in joint ventures with commercial companies, but there may be views on how to do this.

We should prepare a prospectus for venture capital groups and commercial companies, outlining the likely markets and the possibilities for working together in this direction. Readers who have more experience with this might have more suggestions. Perhaps this document would serve partially for that purpose.

CONCLUSIONS

I summarize briefly in this final section some relevant information.

1. This document proposes the development of many highly interactive multimedia university courses. These courses would replace the current university courses.
2. A full experiment might further large-scale development. Approximately 20 courses would be developed and extensively tested against the existing lecture–textbook courses. Approximately 80 million dollars would be required for this experiment. If the experiment is not successful, not leading to greatly improved student learning, work will stop. The alternative to the experiment would be to begin with individual courses, as funds are available.
3. The courses under discussion would be full courses in each subject area, making extensive use of modern informatics technology. Traditional media would be used as appropriate.
4. The courses would be highly interactive, thus providing individualized help and keeping students interested.
5. The courses would be individualized to the needs of each student.
6. The courses could be used in universities to replace existing courses, in distance learning environments and in informal learning environments such as homes. Thus, there are three markets to pursue.

7. To develop a full-scale, technology-based course of the type mentioned above, using modern production capabilities would cost approximately 4 million dollars. This cost is similar to that for the UK Open University for a course with or without technology.
8. This cost is divided approximately equally into four areas: management, pedagogical design, technical implementation and formative evaluation and improvement.
9. Typically a 3 year cycle is needed for a course; 2 years for development and 1 year for formative evaluation and improvement.
10. Careful evaluation is important in producing courses that could be successfully marketed.
11. The strategies that could be followed in the development are well described in many papers from the Educational Technology Center at the University of California, Irvine.
12. The universities could use these courses to establish distance learning institutions. At the moment there are no major distance learning institutions in the USA, in spite of their increasing presence in the rest of the world.

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