DOCUMENT RESUME

ED 285 444 HE 020 520

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TITLE Technology: Serving a Grand Idea.
INSTITUTION Western Interstate Commission for Higher Education, Boulder, Colo.
PUB DATE Feb 87
NOTE 17p.; Paper presented at the "Higher Education and the New Technologies: A Focus on State Policy" conference sponsored by the Western Interstate Commission for Higher Education and the State Higher Education Executive Officers (Denver, CO, September 24-26, 1986).
PUB TYPE Viewpoints (120) -- Speeches/Conference Papers (150)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS College Instruction; College Libraries; *College Role; *Computer Oriented Programs; Cooperative Programs; Educational Objectives; Education Work Relationship; Financial Support; Higher Education; *Information Technology; Labor Force Development; *Problem Solving; *Productivity; Program Costs; Shared Resources and Services; State Aid

ABSTRACT

The question of whether information technology can increase intellectual productivity is addressed. If concern for the intellectual productivity of professionals increases, universities are likely to become more important in society. Access to the knowledge base affects intellectual productivity. The way that people use the contents of the knowledge and skill base to solve problems also affects productivity. Information technology brings better access to the knowledge base, and it can also improve problem-solving because of the interactive nature of computers and the future potential of access to expert guidance for problem-solving. College instruction on the use of technology should focus on solving problems in the student's discipline or profession, as opposed to teaching students to write computer programs. Students' intellectual productivity should increase if they are provided a more unstructured environment and more independent activity. The college library might contain general purpose problem-solving programs that could be used in many different courses. Costs of information technologies and the advantages of resource sharing among universities are discussed, along with considerations for state governments. (SW)

Technology
Serving a Grand Idea

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This paper is the text of President Van Horn's address at the conference, "Higher Education and the New Technologies: A Focus on State Policy." The conference was sponsored by the Western Interstate Commission for Higher Education (WICHE) and the State Higher Education Executive Officers (SHEEO) in Denver, Colorado, on September 24-26, 1986. A summary of the complete conference is available from WICHE, P.O. Drawer P, Boulder, CO 80301-9752. Please cite order number 2A159 with your request.

Published February 1987 by the
Western Interstate Commission for Higher Education
(WICHE)
P.O. Drawer P
Boulder, Colorado 80301-9752
Telephone: (303) 497-0200
Printed in the United States of America
Publication Number 2A165

The Western Interstate Commission for Higher Education (WICHE), an interstate compact organization, helps western states to provide high-quality, cost-effective programs to meet the education and manpower needs of the region.

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Many of us love information technology, but one always should ask the question "what is the central or critical issue?" The goal in higher education, a simple goal that often is overlooked, is to graduate people who will perform well in society. Most things that educators talk about are secondary issues: for example, better teaching, large or small classes, or the effectiveness of video instruction.

A related point is that most significant social changes build upon at least one grand idea. One question that each of us might ask is what forms the grand idea behind the use of information technology in higher education. And if there is a grand idea, does it make the whole process worthwhile and sensible? The rationale that most educators exposit is that computers are important; and, therefore, students should learn about them, hardly a grand idea.

I believe that a grand idea does exist. The grand idea stems out of the process by which civilization developed. The world has witnessed a small set of long enduring trends that allowed the development of civilization. One is the concept of physical productivity. Anthropologists argue that human beings learned to use tools, and thus triggered a beginning of civilization. Physical productivity, as reflected for example in the industrial revolution, automation, mass production and robotics, clearly played a key role in building the prosperity and cultures that exist today. Only several hundred years ago in pre-modern societies, few people lived well. Kings and nobles may have lived better than everyone else, but by modern standards even they did not live a very good life. Only with the increase in physical productivity did society as a whole experience reasonable prosperity.

A seccnd long-term phenomena is biological productivity. History has witnessed great improvements in people as biological organisms, first with the development of public health measures and more recently with advances in modern biology. In the next century our society may succeed in ending or controlling many of the afflictions that people have suffered for centuries, for example, cancer and heart disease. Biological productivity bring another major thread in the development of civilization.

The long term experience that should hold the most impcrtance for educators never seems to be discussed. I call that concept intellectual productivity. Civilization, more than from anything else, evolved from increases in the intellectual productivity of people, -- i.e., problem-solving, innovation, learning, creation, evaluation and reflection. Education is an old and a major way of increasing intellectual productivity. Education strives to create people who are intellectually more productive, an exact but seldom mentioned analogue to physical productivity. Of course, there are many ways to increase intellectual productivity. The question today is "Does information technology offer for intellectual productivity the same potential impacts that were offered by technology in physical productivity". In short does information technology promise or is it already bringing an intellectual revolution. I wish to address this question with the caveat that a definitive answer is probably many years away.

Several significant current trends will shape our lives and will shape our universities in the future. Numerous articles refer to the "information economy" in the United States. That term may mislead The economy is not so much an information economy as it is a "knowledge-intensive" economy. The U.S. economy depends on highly skilled, well-educated professionals to make it run. It is no accident that farmers today have personal computers. To be successful in almost any area of the economy, a professional--manager, accountant, scientist, physician, engineer, etc.--requires good access to the knowledge-base and to problem-solving tools.

The United States is primarily an urban economy and most of the wealth is generated in urban areas. In these urban areas, wealth is generated by professionals. Land is important, natural resources are important, capital is important, and labor is important. But the multiplier on top of all these activities is knowledge and the knowledge-base. Professionals are the critical source of national wealth. Increasingly in the future, the skill of professionals or the ability of professionals to do their jobs will determine the health of the U.S. economy and society. Our labor force does not want to work for the wages paid in Korea or China. Our comparative advantage must be professionals who are intellectually productive plus an infrastructure that provides opportunity and incentives.

Intellectual productivity is the key. If over the next 10, 20 or 30 years the U.S. can turn out professionals who are more productive, then we will have a strong economy. If our professionals are not highly productive, then our quality of life relative to the rest of the world will decline.

Over the past thirty years, there have been tremendous advances in technologies that relate to knowledge transfer--mainly television, computers, and telecommunications. These technologies often are perceived as mathematical, technical or computational, but in truth they are related more closely to libraries than to adding machines. They are technologies for information storage and transfer, first cousins to a book. The cost performance of these knowledge transfer technologies holds particular interest as one of the few areas in the economy where costs per unit of performance are steadily going down and where there is no end in sight.

The future of our universities receives and deserves much thought and speculation these days. If our future society will be dominated by concerns for the intellectual productivity of professionals, then universities will become far more important than they are now. Universities are the traditional source of professionals. If our society can succeed in turning out professionals who are highly productive, then universities most likely are the institutions that will bring about this change.

INTELLECTUAL PRODUCTIVITY

Intellectual productivity is the reciprocal of the time required by a professional to perform appropriately a set of unstructured or creative professional tasks. It has long been apparent that the available skill and knowledge base is very important to the productivity of a professional. An engineer who graduates today from a university is much more productive than engineers who graduated thirty years ago. Today's engineer probably is not on the average any more intelligent, but the knowledge-base that a new engineering graduate commands is immensely better than the knowledge-base that existed twenty or thirty years ago. By the above definition the new engineer is more productive than his counterpart of thirty years ago and that productivity can be attributed to improvements in the skill and knowledge-base.

Both content of and ease of access to the knowledge-base affect productivity. Most of the problem-solving activity that goes on in business or government involves people searching for solutions to problems that have been solved. The solutions already are in the literature, but there is an access problem. With the great increase in the size of the knowledge-base in recent years, a professional might spend his life looking through the knowledge- and skill-base and still not find the relevant part. Without easy ways to get access to the relevant items, it often is easier and cheaper to rediscover them.

Intellectual productivity also is affected by problem-solving: how effectively people use the contents of the knowledge- and skill-base to find a satisfactory solution to a problem. Most education focuses on knowledge transfer and deals less effectively with problem-solving. In the university, problems are mostly structured. A faculty member assigns a problem and expects to receive a unique answer. The student finds "the answer" and the exercise is over. The significant problems once a professional graduates from a university are unstructured: there is no obvious answer, there is no formula, and much of the time there is argument about what the correct answer is by leading professionals in a field. One of the great arguments for studying the humanities is that humanities education suffers less from an obsession with a predetermined correct answer.

Most problem-solving activity at the university is directed as well as structured. A faculty member tells you which problem to solve and what to read for guidance. Once you get out of the university, you have to select for yourself the problems you are going to solve and find by yourself the relevant parts of the knowledge-base. Universities clearly perform well a number of valuable functions, but their explicit commitment to increasing the intellectual productivity of students remains unclear at best.

People face physical limits on their intellectual productivity. Herbert Simon, a Nobel laureate in Economics at Carnegie-Mellon University, described some of the factors that limit the ability of professionals to solve problems or in his terms the "cognitive limits of rationality". Simon said that people have limited memory and limited processing capacity. A person unaided probably could not design a complex computer. Computer-aided design programs exist because the amount of processing and memory needed to design computers today exceeds the human capability of the best design engineers. Simon was one of the first people to point out that removing or relaxing the cognitive limits of rationality will increase intellectual productivity.

INFORMATION TECHNOLOGY

The primary benefit that information technology brings is better access to the knowledge base. Computer and communications technology generally is perceived as aiding computation and, of course, it does. But, if technology is going to have a major impact on intellectual productivity, the key is improved access to the knowledge-base.

Think for a moment of the ways that people access the knowledge-base. They talk to colleagues who happen to be knowledgeable, but that works only if you have a knowledgeable colleague and if you can reach that colleague. People use the library if the library is open, happens to be in reasonable physical proximity and has what you want. Most ways to access the knowledge-base depend on time and place constraints.

Clearly information technology can eliminate or greatly reduce time and place constraints. Even better, computing and communication technology is affordable now and continues to decrease in cost. Within one or several decades, every professional could have access to a computer workstation, and from that workstation could access most, if not all, of the existing knowledge- and skill-base. The cost will be surprisingly low. Even today, a library could print a copy of a book and give it to a student at a lower cost than to take the book off the shelf, keep a record and put the book back on the shelf when it is returned. It costs about $12.00 in the average library every time someone checks a book out. If the book is in electronic form, a lower cost solution is to give the student a copy of the book and say please never bring it back because the library cannot afford to have you bring it back. If the library can give the student an electronic copy instead of a printed one, the savings are still larger.

Even with the limited selection mechanisms now available, finding what you want in the skill- and knowledge-base is much easier with technology. For example, with the University of Houston automated card catalog, I can find books that I want to examine in a fraction of the time of the old card catalog. The workstations in my office and at home encourage me to make greater use of the library than I did before. As these processes evolve, professionals indeed will access the knowledge-base much more, and intellectual productivity will increase. Books, articles and working papers eventually will get into the electronic knowledge-base. The same effects hold true for automated search of the various reference databases.

Electronic technology also will improve problem-solving. Finding technology to help professionals solve problems always has been difficult because professionals deal mostly with unstructured problems. They try an approach, see if it works, and if it does not work, they try something else: an interactive process. Most technology before computers did not lend itself to dialogue; and people had a difficult time getting technology to help in problem-solving. Personal computers became popular because they represent highly int ractive technology. Further, generalized analysis programs, for example, LOTUS and VISICALC, are tremendously popular because they let a user engage in interactive problem-solving in a form defined mostly by the user, rather than defined mostly by the author of the program. Eventually most professionals will have access to expert guidance for problem-solving. You may have seen the slightly bizarre GM commercial about "Charlie". A couple with a malfunctioning truck pulls into a rural gasoline station. The sole attendant is not a mechanic, but he goes to consult with

"Charlie". Charlie, an expert system computer program, helps the attendant to diagnose the problem and tells him what to do.

Now that is a charming commercial, but it is also true. While we may not yet know how to build a computer program that solves every problem, by talking to experts, we can get ideas on how they solve problems and incorporate those ideas into computer programs to help human problem solvers. This approach has been done a number of times; it works and there are some successful applications. Expert systems are just another way to increase intellectual productivity. Added together, the promising uses of information technologies should produce significant changes in intellectual productivity.

CONCEPTS FOR THE EFFECTIVE USE OF TECHNOLOGY

Computers and telecommunications are in at universities. Students and faculty greet their arrival sometimes with great joy, generally with interest, and seldom with strong objections. At some places, students submit to decrees that every student must buy one, and faculty members, despite their well deserved reputations for penurious behavior, actually use their own money to buy them. In this environment, universities hardly need a plan for introducing technology. But if the goal is to increase intellectual productivity then a careful, thoughtful plan is essential. Some of the relevant ideas are independent use by students, problem-solving and access to the skill and knowledge-base.

Students should learn to use information technology in a self-directed context. One of the goals talked about in universities is how to teach students to learn independently. As noted earlier, most of the activities of students are structured and faculty members mostly tell them what to do. The goal is a model where students learn by themselves and technology can lend itself to that goal. A student can sit down and use a workstation without anybody directing his activities. One model is for faculty members to assign problems and for students to generate solutions in an open environment. Students should search the knowledge-base; find by themselves the appropriate knowledge, tools, and models; and apply them to complete the assignment.

Instruction on the use of technology should focus on solving problems in the student's discipline or profession not on the technology itself. At many conferences, people stand up and say how they teach all students to program because it is good discipline. Football and tennis teach good discipline too, but to learn how to use computers effectively you want to use computers for problem-solving in your discipline. Obviously, there are some people who need to learn to program very well and to learn the fundamentals of computer science, but the goal in history is to produce a great historian not a middling programmer.

You need excellent access if you are going to make technology work well. The technology has to be readily available. If you have to wait, or if you have to go a long way, people are not going to use it. We have endless results that support that the idea if you really want people to use something in their daily activities, it has to be easily accessible.

Technology neither should nor has to be constrained to fit within courses. One of the valuable aspects of a library is that libraries are not organized along course lines Universities should give students at least some exposure to problem-solving that is not course oriented. Business leaders who hire our students say that when those students get out on the job, they often do not know how to address complex problems. In the university, they are in a physics or an English course. So, if they see a problem, it is a physics problem or an English problem. Out on the job, a problem is just a problem. It does not fit anywhere, and students find that difficult. We should reinforce in students the notion that learning is really not related to courses. Courses are an administrative convenience that help use faculty and student time effectively, but they have little to do with the way the world is structured. Information technology can and should be available independent of courses. At present, much of the use of technology is imbedded in a course framework, is very directed and is very structured. If we give students a more unstructured environment, if we give them more independent activity, and if we break away from the course structure, then the intellectual productivity of our students should increase.

In a well designed computer-intensive environment, the library might contain general purpose problem-solving programs, and faculty would expect students to use those programs in many different courses. For example, programs that improve writing can be used across a whole variety of different courses. Programs that perform data analysis also apply to a variety of different courses. Of course, some programs will address narrow or specific areas that may relate to a single course.

For many issues that arise with intellectual productivity and technology, libraries offer excellent guidance. Information technology and libraries both relate primarily to information transfer, and libraries encourage independent use. Few if any universities require courses on how to use the library. Students master the basics of how to use the library by asking questions of fellow students or of librarians as the need arises. There is no mystique about the library; everyone is welcome. Librarians do not insist that you have to go through three basic courses in library science before you are allowed into the library. Too many universities believe that a student should complete one or more computer science courses before he can be trusted with a computer.

AFFORDABLE TECHNOLOGY

Information technologies clearly involve major costs for universities. Whether or not universities (or taxpayers) can afford to build computer-intensive environments is an appropriate question without a complete answer. For most universities, computing costs appear lower than or at most similar in magnitude to traditional library costs. If information technology indeed can increase intellectual productivity, then it represents a worthwhile investment. At this point, the best answer may be that we are engaged in a promising experiment. What is clear is that we should use technology in the most cost-effective manner possible.

Technology can enhance the sharing of resources. Resource sharing in the modern environment is misunderstood. The most familiar resource sharing model is a very large computer shared by many universities through complicated organizations, complicated networks, a lot of management and a big investment. The way we can share now with the new technology is quite different. Within several decades, we will see libraries that are electronic media-oriented. The traditional library will not go away, it will keep the books it has. But much of the new material in libraries will come in the form of electronic media. Libraries then can become distributed libraries and every school can share many libraries. One university may keep the best chemistry library in the world and other universities will share that chemistry library with additions for their special needs. Small colleges out in rural areas can have as good or better libraries as the great universities today. Technology has sometimes been accused of supporting the strong at the expense of the weak. In this particular case, smaller schools may be the great beneficiaries of the new resource sharing.

Technology today comes in small relatively low-cost units. Any school can share in the latest technology without having an elaborate organization and without investing a lot of money. All universities can share in the almost unbelievable cost benefits of maturing information technology. Indeed, the sharing of benefits of the maturing technologies may be the most important form of sharing in our society. Even individuals can share in these benefits. You can buy a personal computer and five or six programs, and you are in the intellectual productivity enhancement business. You don't need expensive training, expensive people or a big investment. The barriers to this kind of productivity enhancement are very low and increasingly large numbers of people are taking advantage of the opportunity.

Both universities and individuals also can benefit from traditional resource sharing via networks. Everything from super computers to stock market advice is available today and the choice is increasing rapidly. The point to emphasize again is the tremendous sharing opportunity that comes out of the nature of the currently existing technology. Institutions don't have to make large investments to participate in this kind of enhancement.

For universities or states, there clearly are risks and problems. If a university or a state does not have a clear strategy of what it is trying to do with information technology, it may be spending a lot of money and not getting much in return. For example, if a university decides to teach every student computer science, it will spend a lot of money on computing. If instead, the university trys to provide computing resources for students to become more productive in their basic disciplines, the cost can be significantly lower. It clearly is expensive (either to students or to the university) to provide or require purchase of a computer workstation for every student, and there are reasonable alternatives. Some students will want workstations, but for many students, shared workstations are more than adequate. The University of Houston has 30,000 students, but never for a moment has discussed having 30,000 workstations available. If a student wants to buy a workstation, the university trys to offer convenience and a good price. We believe that students can achieve intellectual productivity or the learning goals in environments that have from 3 to 10 students per workstation rather than one workstation per student.

Universities need not invest a lot in developing software for courses and it probably is a poor investment for a typical university. Most universities should invest first in already developed general purpose, problem-solving software or in access to knowledge-bases.

A university doesn't have to become the campus of the future overnight. If the goal is to become the campus of the future overnight, the university should to be prepared to pay a high price. Similar, the goals of the computer-intensive environment don't require the latest or most powerful computer; a modest personal computer for $500 to $1000 works well for many applications.The cost of being a leader in intellectual productivity is lower than the cost of being a leader in information technology.

THE ROLE OF THE STATES

Let me summarize what I think are the implications for states. State governments and universities many times have been somewhat uneasy neighbors. If arguments about intellectual productivity and about knowledge-based societies are correct, then the state has a tremendous interest in universities, and the state must become a partner with universities. Public as well as private universities are fundamental in the development of states over the next ten or twenty years, because increasingly, universities are supporting the economic development of the state.

Public universities, by and large are quantity oriented. The most commonly asked question is "how many students are we educating?" If the universities educate large numbers of students they generate political and financial support in a state. If one believes the arguments of intellectual productivity, universities must emphasize quality. It is not enough to have a college education; a graduate needs a good enough education to become an outstanding professional. Harvard is a great university, because of its distinguished faculty and large research programs but perhaps most important because its students have been major leaders. If a university can turn out highly capable graduates, it is a great university.

Several factors can affect financing in the states for information technology advances. States always have provided support for libraries. State governments hopefully now will recognize that computing environments and libraries are different aspects of the same process--information transfer mechanisms. Thinking of libraries and computing as the way to get access to the knowledge-base provides a perspective on financing. It is not unreasonable to ask students to pay some substantial share of the cost of educational computing. When students pay for something, they take it seriously. They try to understand it and try to use it.

Universities often place major support into research computing and less support into student computing. State support probably should go largely into educational computing. Research computing should stand largely on funds coming from research sponsors.

If one looks at technology and the way technology has been used, two problems come back again and again: recurring investment and maintenance. The university says "it must have a big computer," and the state buys a big computer. Five years later the university needs another one. The State says, "what is this, we bought you one." It is clear that if we are going to be successful in technology, we must have a plan that allocates regular capital funds every year; there is no other way to do it. We can't make one time purchases and expect to get anywhere. Universities don't buy library books only once, they make that capital investment every year. Information technology in all of its forms is exactly the same. Furthermore, despite jokes to the contrary, libraries don't buy books, place them in a big building, lock them up and say there is going to be no further cost. Once the libraries buys books or materials, more money is needed to maintain and operate the library. In many states today, there is a tendency not to provide funds for maintenance and operation of information technology. As a result, much of the technology is being used ineffectively.

CONCLUDING REMARKS

I wish to end where I began. A grand idea is essential to significantly improve higher education. The grand idea here is that society needs professionals who are going to be substantially more productive than professionals in the past. If we can use information technology to improve learning and as a result can turn out professionals who are better problem solvers, then we have made a major contribution to higher education and to the economy of the nation. While I have an optimistic view of the future, I know of no way to guarantee success. As with most major issues, we only can try and observe. But certainly the most promising path is to focus on the issues that are related to intellectual productivity and not to focus on teaching students about computers or computing. Part of the complexity that we see today in the information technology environment is there because we focused on the wrong issues. If we can focus on the essential issue--intellectual productivity--then the future may exceed our grandest expectations.