Learning
and
INTELLIGENT
SYSTEMS

National Science Foundation

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Lifelong Learning

I want to talk about the notion that learning is a lifelong activity. I will follow the charge the NSF people gave me, and structure what I say with this question in mind: What is the state of knowledge?

I would first like to claim that we follow what I call the "gift-wrapping approach" to technology. This notion is structured after the finding in many businesses that information technologies have really not produced the productivity gains people had expected. The main argument in the business reengineering community is that technology was added to existing world processes, but the processes themselves were not changed. With the gift-wrapping approach to technology, we have this world of education with Skinner-type models of instruction and, in the world of working, Taylor-type production lines. We wrap technology around this world instead of reconceptualizing the underlying processes. My first claim is that we have to move beyond Skinner and Taylor in thinking about what work is, what learning is and what collaborating is.

Beyond Skinner and Taylor		
there is a "scientific," best way to learn and to work	→	problems are ill-defined and wicked
separation of thinking, doing, and learning	→	integration
assumption: task domains can be completely understood	→	partial understanding
all relevant knowledge can be explicitly articulated	→	knowledge is tacit
teacher/manager as oracle	→	teacher/manager as facilitator/coach
operational environment: mass markets, simple products and processes, slow change, certainty	→	customer orientation, complex products and processes, rapid and substantial change, uncertainty and conflicts

This table outlines Skinner/Taylor-like thinking versus the thinking in which we should engage. These are all issues that are highly debated in the environment of business reengineering. People think about how to get away from the traditional separation of thinking, doing and learning, and to find new ways to separate things. In the field of teaching, there is a lot of effort being given to moving away from the teacher or manager as an oracle who stands up in front talking, to the teacher or manager as facilitator or coach. My claim is that we have to get to that point, and not just think about technology as a gift-wrapping element.

For my second point, I will use an idea from Neil Postman, who says you cannot do philosophy with smoke signals.[3] In the good old days, people used smoke signals to alert neighboring castles that the enemy was coming. Postman's claim is that you cannot engage in philosophy this way, and my claim is that current computer systems, to a large extent, do not support the goals of enhancing creativity, imagination, contextualized learning, or learning-on-demand.

Popular Misconceptions in Learning and Education

I want to illustrate this with a number of misconceptions floating around. The first one is that computers, by themselves, will change education. I have worked for the last 25 years in this field, and I have witnessed repeated attempts by the computer-assisted instruction world to remedy all problems in education.

The second misconception, which came up in the context of the National Information Infrastructure, is that information is a scarce resource. The National Information Infrastructure was sold with the myth that every schoolchild in America will have access to a Nobel Prize winner. While this is true at the

hardware level, I am sure that Herb Simon would not be delighted to find 1,000 or 10,000 e-mail messages in his mailbox every morning. So the scarce resource is not information. The scarce resource is human attention and ability to deal with huge amounts of information.

Another misconception is that just because information is available on the World Wide Web, this is automatically a better way of transmitting it. Wherever the information is, we still have to process it, and we still have to understand it. Throwing information at people may not necessarily solve all problems. This is a problem that we have encountered numerous times in our research over the last few years, where we have been trying to understand our situations in interdisciplinary collaboration or in teacher-to-student interactions.

The notion of ease-of-use is also very misleading. In the Knowledge Navigator tape we saw a little while ago, and in many other futuristic tapes, the future of learning is pictured as a person sitting in a chair and pushing a button here and a button there. The message conveyed is that if you want, to learn something, this is how it will happen. But learning always requires engagement. It will require affection and personal relevance. Learning to play the piano well isn't easy, and yet a lot of people do it. When we think about technology, we should not only reflect on ease-of-use, but also on these other dimensions.

The last misconception I want to mention is that the most important objective of computational media is to reduce the cost of education. Sure, there is no doubt you want to do this. But I think we should also think about increasing the *quality* of the educational experience.

To return to the question of the state of knowledge, the last point I want to make is that, in some ways,

we are not addressing the potential magnitude of the change. What the change ultimately will be is probably very difficult to determine. In my mind, we are facing a change similar to the introduction of reading and writing to societies 2,000 years ago. Computational media should be looked upon not as another little piece of technology, but as something with the potential to do for society what reading and writing did. If you read Socrates and Plato, you find several interesting discussions in which reading and writing were not regarded as being only positive.

Lifelong Learning—More Than Adult Education

One of the big challenges in the years and decades to come for fundamental interdisciplinary research is the notion of lifelong learning, where this means more than adult education. From our perspective, it covers and unifies everything from an intuitive learner at home, to scholastic learning in school and university, to the skilled domain worker in the workplace. When you can divide the number of requirements like that, working and learning needs to be much more tightly integrated. Some people say learning is a new form of labor, and if I take this audience here today, in my mind, this is probably a true statement, i.e., for most of us, working means to a large extent learning.

How do we engage people in solving self-directed, authentic problems? There has been quite a bit of discussion about how we can build more constructionist environments, to augment and complement classroom teaching. Trying to do so, the big question becomes: How can we create technological developments to support this environment? A focus of our research for a number of years has been the question of what it would mean to support more learning-on-demand. In my mind, this violates a number of very fundamental principles on which our whole educational system is built, but which are no longer maintainable. If you

look at the currently practiced front-loading model of education, I would argue that coverage is impossible and obsolescence cannot be avoided. Since there was a lot of discussion about interdisciplinary research earlier, it is clear that the individual human mind is limited. We should think not just about individual learning, but about organizational and collaborative learning.

The last point I want to make is that lifelong learning is hard. I guess we experience this ourselves. Three years ago nobody knew what the World Wide Web was. Now, as you well know, many people believe that not knowing what the World Wide Web is leaves you out of the cyberspace culture. A different story is to learn to use the World Wide Web for truly meaningful tasks. An even bigger challenge is not just to use the World Wide Web as a consumer, but to be an active contributor and designer, using it as an everyday citizen as a medium to express our thoughts and our opinions. A new literacy is needed to do so, and this literacy will not come for free but will require serious learning.

Another example that lifelong learning requires much more than having new technologies: We (as a university research center) have been collaborating with NYNEX for several years. NYNEX employed approximately 3,000 COBOL programmers in 1996. The problem of building large, complex software systems with tools of the 1990s rather than with archaic tools of the 1960s is not solved by going to them and saying: Well, today we have SmallTalk and C++. There are much larger problems to think about with regard to lifelong learning.

We have a project going on now supported by NSF with schoolteachers that focuses on understanding that teachers also must be lifelong learners and what that entails. This is another big problem. In our research, we have developed a set of hypotheses for computational environments and used them to

ground our system-building efforts in some theoretical framework that supports this notion of lifelong learning.

What would it take to build a successful interdisciplinary investigation? We have been involved in a number of collaborations, but I think the problem that Snow, in his two cultures—or, I would say today, many cultures—identified is one of the critical problems; people have illustrated this in the previous talks.

So, what is the response of the relevant science and engineering communities? My first claim is that the future is not out there waiting to be discovered; it has to be invented and designed. The interesting question is: Who does this? If you believe, for example, that Hollywood does this, then you have one way of seeing the future. What will we do with the National Information Infrastructure? Well, having 500 TV channels may be one consequence of it.

And what about the current state of affairs at universities? Having spoken about other organizations, I want to point out that I'm a faculty member of a university and that I believe there are quite a few things wrong with current universities. They are lecture-dominated and curriculum-dominated. We have taught some classes where we wanted to incorporate more learning-on-demand elements. But where is there room for authentic, self-directed learning activities if, at the beginning of a three-month course, you provide students with micro-managed curriculum telling them exactly what type of things will be dealt with and when? I think that in our university environment we overemphasize the notion that students solve given problems. In the real world, problems really do not exist. We always intermix problem framing with problem solving. Another artificial aspect of most university or school problems is that there are right

or wrong answers. In the real world, this is rarely the case. We have to rethink, from a lifelong learning perspective, what a university education will mean in the future.

What is the long-term societal impact of this research? Here is a quote from Einstein: "Wisdom is not the product of schooling, but the lifelong attempt to acquire it." We have to think about what I call the redefining of the roles of high-tech scribes. In the Middle Ages, the average person had to go to a scribe to express herself or himself. In today's world, we find a similar situation with respect to computational media: Only high-tech scribes can master them. And the high-tech scribes have an interest in sustaining this role. This will be one of the big challenges: To avoid creating an elite group of high-tech scribes.

Another thing I consider fundamental in what we are facing is a change of mindsets. I mentioned earlier the notion of teachers as lifelong learners, which means teachers should not look upon themselves as truthtellers or oracles, but as coaches, facilitators, mentors and learners (see table on page 6). It would be an incredible educational experience for a student in high school to see his or her teacher struggling with a problem. But, today, that is frightening to many teachers. We want to create a society that is not limited to consumers of modern technology. My complaint about the World Wide Web would be that currently most people dealing with it are consumers. I briefly mentioned the "500 TV channel" future. Illich, in his outspoken criticism, calls schools and universities reproductive organs of a consumer society.[4] We can devise many technical challenges from this.

What will be the basic skills in the future? There's a lot of debate in all the sciences about "basic skills." If most relevant knowledge for the working world must be learned on demand, which is a claim I would defend, what is the role of basic education? One could argue it is to empower people to learn on demand.

By focusing on a lifelong learning perspective, we have had the opportunity to think a lot about school-to-work transition. This has been a concern for many organizations. I strongly believe that the world of working and living relies on—you can agree with me or not—collaboration, creativity, definition of and framing of problems, dealing with uncertainty, change, distributed cognition (distributed intelligence), and symmetry of ignorance. If this is the case then the world of schools and universities needs to prepare students for a more meaningful life in the world. Planning to employ learning systems and intelligent systems in our educational institutions, we must judge them from these perspectives.

Discussion

Comment: I have a couple of broad comments. One of the hardest things for us to do is to enrich our notions of what we mean by interdisciplinary. As long as we have the semantic tag or label that we throw on this, we're not going to deepen our understanding of the technology that we need and the kinds of processes required to really make it work. There are two points not brought out as strongly as they could be. One goes back to theoretical foundations, which is also a very long-term activity, but one that often goes in parallel with interdisciplinary work. So, part of what we need is much better theory, much better formalisms; for example, formal foundations that allow people to make the assertions and the boundaries of their discipline more explicit, more processable, more analytic, so that they can, in fact, be combined with other disciplines.

Speaking as a neuroscientist and as someone who has worked on space systems—two highly interdisci-

plinary areas—part of what happens is that in the building of a real system or even in scientific endeavors in brain science, we often develop a sort of data-dictionary level of interaction. People learn to talk, and they gradually intuit the problems and the foundations of another field. But what we really need to do is create some new foundations for scientists, including, for example, the ability to integrate models at a formal, explicit level.

To put it a slightly different way, this is something that Nora Sabelli, John Cherniavsky and several others of us have been dealing with between our NSF and DARPA educational projects. Right now, people think that the big problem with technology demonstrations is turning them into technology insertions. That certainly is one problem, and we're dealing with it. So you package, let's say, an educational tool with real curriculum or real pedagogy, and you make that transfer.

But there's something else that needs to go on that people are not addressing. It is not the technology transfer; rather, it is what we call climbing up to the systemic level. How do I take superb technology demonstrations and insertions and actually climb up to a systemic level? What is the information? What is the instrumentation that I have to do at the technology insertion level or transfer level that allows an organization like a school or a hospital or a manufacturer to make system-level tradeoffs about how to use the technology?

It's not just what we're referring to when we talk about scaling up, which is a commonly known as model replication; this is much more difficult, because it involves real tradeoffs between how you are doing things now and how you envision doing them in the future. There are some qualities that haven't even been represented and made explicit enough to reason about.

Comment: I have a comment in reaction, in part, to hearing some of the wonderfully wise statements that Norbert Wiener made a couple decades ago. Disciplines haven't always been around. They're evolving entities in themselves and they come into existence for various reasons. In my own career, I've seen interdisciplinary work lead to new subdisciplines and disciplines. There's an interesting distinction between, on the one hand, nurturing the formation of an active new discipline—which often comes as interdisciplinary work with its own peer review process, its own potentially revised or modified jargon and terms, and its own conferences—and, on the other hand, nurturing a flash-in-the-pan new scholarship that goes on when somebody who finds himself steadfast in statistics, for example, starts thinking about graphical models and computational constraints. There's an interesting interplay between what we mean by interdisciplinary work in terms of the creation and nurturing of new disciplines and the evolution of old disciplines, versus nurturing individuals and what they're doing.

Dr. Joseph Bordogna, National Science Foundation: I will stand on dangerous ground here and try to summarize what everybody has been saying. It has to do with changing the academy from reverence to reductionism, to innovation through integration. It is a real shift, and I am not sure we can insert things with the present leadership. We have to spend time educating the new students. I hear a lot of things; for example, in engineering, one might call it project-based learning: You do things, or hands-on, teamwork, invent the future, and so on. What we're attempting to do in engineering education, with all three engineering schools, is to really implement these things so that graduates have independence through not only knowing something in depth, but also possessing a functional literacy across a variety of disciplines. As a result, they can

see disparate pieces and integrate them to get something out the door.

So, I feel comfortable with what you are saying; it validates the sort of ad hoc way in which we have made a big investment at NSF in the last 15 years, in changing the undergraduate engineering paradigm. In essence, we still graduate people who have been taught that to know your special thing deeply is the reason you're revered—not necessarily the reason you are hired and compensated, but the reason you are revered. That is the holy grail. We have to change this so that, at the baccalaureate level to begin with, students graduate with an understanding that it's much more complicated than that. The word interdisciplinary does not have the right cachet. You have all talked about that, especially the first speaker. And because the cachet is in an area where it mitigates against making these changes, it can be very emotional. We have to attack it at its root.

When we did the Collaborative Learning for Technologies work, we had an argument about a phrase; I think this relates to what you have mentioned. The phrase was: Applying technology to learning. That phrase is wrong. The right phrase is: Integrating technology with learning, to create a new paradigm. That is what I think everybody is saying here. I like what I am hearing because it makes me at least feel more confident that we are on the right road in our initial investments to get at this.

Dr. Fischer: We talked a lot about interdisciplinary research, and it seems to me the disciplines are something which we have created; they are not God-given. What comes first? What comes first is that our society faces real problems. Disciplines, after being created at some point in time, often live a long life. But the world moves on; our goals and needs change. And inevitably, a mismatch between the problems we are facing and the existing disciplines will emerge. These problems do not fall neatly into one discipline or another. There is nothing a priori that says we have to accept a given set of disciplines. Interdisciplinary is only a consequence of accepting certain discipline structures that we have at the moment. I often say that at universities we recommend change to everyone else, but when it comes down to changing ourselves, giving up the set disciplines or allowing people to get tenure or a Ph.D. in an interdisciplinary area, we are much more resistant.

Comment: I think the last comment, in particular, about the universities having trouble restructuring is particularly important. I wonder if members of the panel have any comments or advice on what NSF might be able to do, with regard to its structures, to position itself to respond to the creativity of the community, and not just to have you fill holes in boxes that we seem to create. Somebody must have thought of that—what they would do if they were czar.

Comment: My comment has to do with the question of having at least part of the funding devoted to very high-risk proposals, as a way of getting away from the conservatism of both established programs and established review groups. These established groups do a fine job in a lot of areas, so you wouldn't want to get rid of them. But certainly a fraction of their funding could go into a program where you simply say to somebody: Okay, here's a certain amount of money, go out and find people you think would be interesting to support. And use your own judgment, like the military agencies tend to do.