Foundations for the Learning Web

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Abstract: The *learning web* was presented (Norrie and Gaines, 1995) at EdMedia'95 as a systemic approach to the modeling and support of knowledge processes in a learning society. This article addresses the rationale for, and systemic foundations of, the learning web, its implications for restructuring the higher education system, and the role of information technology in supporting that restructuring. Two associated articles report on the implementation of some of the technologies necessary to support the learning web (Gaines and Shaw, 1996), and some preliminary experience in applying them in undergraduate education (Shaw and Gaines, 1996).

1 Reengineering the Educational System

The recession has caused people in general and governments in particular to reassess all aspects of the systems which support our society. We have come to accept basic education and continuing educational opportunities as natural rights that should be universally available without regard to individual financial circumstances. However, the cost of providing these rights has now become a major issue for tax payers and governments. The direction of social change is such that major restrictions on universal access to education will not be acceptable. Hence, the pressure is on the educational system to restructure to be more cost-effective.

Schools and universities have undergone substantial downsizing in the past decade and may have to undergo more. Businesses have gone through similar downsizing during the recession and many of them have gone further than this in examining their fundamental natures and their reasons for existence. Rather than attempt to continue in the same way, using the same processes but with greater efficiency and reduced costs, they have analyzed the customer demand underlying their markets and attempted to reengineer their businesses completely to address that demand using new processes (Hammer and Stanton, 1995).

Like all new approaches to commerce, the *business process reengineering* movement has had some aspects of a fad, and has been used as an excuse for actions which are independent of, or contrary to, the basic logic of process reengineering. However, there is a compelling logic in the notion that large institutions should periodically reexamine the basis of their existence, and question whether they adequately understand the needs that they were established to satisfy, and whether, if they have that understanding, their processes address those needs in a reasonable way.

A major literature has developed in recent years that critiques universities and concludes that they are failing to fulfill their functions from a wide range of perspectives (Sykes, 1988; Kimball, 1990; Wilshire, 1990; Douglas, 1992). In general, these studies provide evidence of significant problems but do not offer effective alternatives. Indeed many of them seem primarily concerned with a return to the 'old values', however they are conceived. Those that make a detailed analysis with a view to redesign do so within the existing infrastructure (Wilson and Daviss, 1990; Clotfelter, Ehrenberg, Getz and Siegfried, 1991; Kerr, 1994; Kerr, 1995) and do not examine the potential for radical change.

There is also a long-standing literature on alternative approaches to the classical university with emphasis on *open learning* (Thorpe and Grugeon, 1987; Reddy, 1988) through *distance education* (Daniel, Stroud and Thompson, 1982; Thorpe, 1993) and *lifelong learning* (Boshier, 1983; Smith, 1983; Husen, 1986). In general, these studies provide evidence that there are attractive variants to classical university education, and ways to make access more truly universal through a more flexible system. However, they also largely build on the existing system, emulating standard university education as closely as possible, and not questioning whether the conceptual foundations of that education are themselves subject to change.

We suggest it is time to reexamine the social needs that led to the formation of universities and their evolution to their current mandates and modes of operation. Many problems are arising because the universities are still seen as physical rather than virtual institutions (Dolence and Norris, 1995). Many problems are arising because a labor-intensive approach to teaching that was cost-effective in highly selective institutions has been propagated to universal access. Many problems are arising because content, pedagogy and assessment are all in the hands of individual instructors, and there are no independent standards of effective teaching and learning.

Technology can address some aspects of these problems, and is essential to most potential solutions, but technology alone cannot solve them. We need to reexamine the fundamentals of higher education and be prepared to reengineer the system before technology can be usefully and wisely applied. The learning web concepts are one attempt to do this based on a deep model of the way in which knowledge processes arise in society. We are attempting to apply the concept to learn more about its implementation, and also to use it within existing institutions to explore how much change is possible from within. In the long term, development of the learning web will involve collaboration across many groups world-wide, each of whom has some component of the necessary knowledge support technology.

2 Systemic Aspects of Higher Education

In modeling the knowledge processes in society, we have adopted a *collective stance* in which the human species is viewed as a single organism recursively partitioned in space and time into sub-organisms, or agents, that are similar to the whole (Gaines, 1994). These agents include societies, organizations, groups, individuals, roles, and neurological functions. Notions of expertise arise because the organism adapts as a whole through adaptation of its interacting agents. The phenomena of expertise correspond to those leading to distribution of tasks and functional differentiation of the agents. The mechanism is one of positive feedback from agents allocating resources for action to other agents on the basis of those latter agents past performance of similar activities (Gaines, 1988). Distribution and differentiation follow if performance is rewarded, and low performers of tasks, being excluded by the feedback mechanism from opportunities for performance of those tasks, seek out alternative tasks where there is less competition. The knowledge-level phenomena of expertise, such as meaning and its representation in language and overt knowledge, arise as byproducts of the communication, coordination and modeling processes associated with the basic exchange-theoretic behavioral model. This model has been linked to existing analyses of human action and knowledge in biology, psychology, sociology and philosophy, and used to analyze the role of information technology in supporting activities in the lifeworld.

The collective stance model has implications for the ways in which we conceive teaching and learning. The human species is essentially a learning agent. In relatively static physical and social environments learning will be slow. However, our species has now itself initiated such rapid and ongoing changes in these environments that it must learn to cope with them at an ever-increasing rate. As Wojciechowski (1983) has noted, the growth of knowledge can itself be regarded as the major source of the problems that demand the generation of further knowledge. This positive feedback loop now drives our existence as a species.

The model provides some interesting insights into the differentiation of activities into ‘teaching’ and ‘research.’ All individuals may be seen as acquiring expertise through ‘research,’ and as having social pressures to disseminate that expertise through ‘teaching.’ The dissemination of expertise through teaching is an essential complement to its formation through learning as a social process for creating continuing and large-scale resources from short-lived and limited-capacity individual agents. There is no social value in the expertise of a particular individual unless that expertise is propagated in some way. This suggests that we characterize a researcher by the community that he or she teaches, that is to whom the researcher delivers knowledge. If that community is small then the research is specialist. Natural divisions into communities of mutually teaching individuals correspond to knowledge disciplines and sub-disciplines. The disciplinary structure of academia is functionally determined by the teaching relationship within this broad interpretation.

The emphasis of the collective stance model on the positive feedback processes generated by reward structures throws light upon the problems that universities currently have in attempting to promote teaching as a professional responsibility of at least equal stature to research. The inception of refereed journals some 300 years ago provided a mechanism for both disseminating knowledge and evaluating the products of research that leads to a system promoting excellence in research. The North American higher education system has no similar mechanism for promoting excellence in teaching. On the contrary, most institutions have minimal constraints upon the content of a particular course so that the instructor defines the content, teaches it, and examines it. There is no mechanism for external evaluation and hence no possibility for feedback processes promoting excellence. Control is exerted at the wrong level by requiring each course to conform to approximately the same distribution of grades. The meaningless nature of the processes involved can be seen by noting that, under the current system, an instructor whose students all attain ‘A’ grades will be criticized, whereas the same instructor under a system where the students were assessed independently to national standards would be rated an excellent teacher. The current system also is negative to collaboration between students since it is not in one’s interest to improve another students chances of getting an ‘A’ if it reduces one’s own.

Thus, the collective stance model has many implications for teaching and learning that are independent of issues of technological support. There is no ‘right’ way of restructuring the system, but any way that neglects the essential processes involved is unlikely to succeed no matter how much technological support is provided. The learning web approach above all else emphasizes the dynamics of human knowledge processes, and the introduction of support technology needs to be based on a deep understanding of those processes.

3 Learning Curves of Technological Convergence

For those who have been involved in educational technologies and the roles of computers in education and society throughout their lifetimes and have seen many false dawns and promises, an obvious question must be ‘why now?’—why should we expect to be able to use information technology to facilitate radical change in the educational system when we were not able to do so in the 60’s, 70’s and 80’s? Information technology itself arises out of social processes and can be modeled through the ‘learning curves’ involved in those processes (Gaines and Shaw, 1986). Beninger (1986) provides a socially-grounded rationale for computing and information technology as yet another step in the “control revolution” commencing in the 1800s as a response to the increase in the speed, volume and complexity of industrial processes:

> *“The Information Society has not resulted from recent changes but rather from increases in the speed of material processing and of flows through the material economy that began more than a century ago. Similarly, microprocessing and computing technology, contrary to currently fashionable opinion, do not represent a new force unleashed on an unprepared society but merely the most recent installment in the continuing development of the Control Revolution.” (Beninger 1986)*

This analysis provides an adequate systemic and historical account for the majority of the significant phenomena associated with the “information age.” It is a significant, but not isolated or revolutionary, stage in an ongoing process of industrialization which is itself grounded in the social needs generated by human population growth beyond a level sustainable without technological support. What came first, the population growth or the technological support for it, is too simplistic a question to have a meaningful answer—one is dealing with a system having strong positive feedback loops that seem themselves adequate to account for much of the perceived autonomy of living systems (Ulanowicz, 1991). Toulmin’s (1990) thoughtful and provocative account in *Cosmopolis* of the modern era as a response to a sixteenth century social crisis is in itself sufficient to undermine any concept of autonomous origins for the seventeenth century enlightenment that resulted in science, industry and the information age.

There is a simple phenomenological model of developments in science technology as a logistic “learning curve” of knowledge acquisition (Marchetti, 1980). The logistic curve has been found to be a useful model of the introduction of new knowledge, technology or product in which growth takes off slowly, begins to climb rapidly and then slows down as whatever was introduced has been assimilated. Such curves arise in many different disciplines such as education, ecology, economics, marketing and technological forecasting (Dujin, 1983; Stoneman, 1983). One problem with using them predictively is that the asymptotic final level can only be estimated in retrospect, and attempting to determine the form of a logistic curve from data on the early parts is notoriously sensitive to error (Ascher, 1978). However, fitting logistic curves to historic data gives a very precise account of the development of major technologies such as the successive substitutions of one form of energy production for another (Marchetti and Nakicenovic, 1979).

It has also been noted in many disciplines that the qualitative phenomena during the growth of the logistic curve vary from stage to stage (Crane, 1972; De Mey, 1982; Gaines and Shaw, 1986). The era before the learning curve takes off, when too little is known for planned progress, is that of the inventor having very little chance of success but continuing a search based on intuition and faith. Sooner or later some inventor makes a *breakthrough* and very rapidly his or her work is *replicated* at research institutions world-wide. The experience gained in this way leads to *empirical* design rules with very little foundation except previous successes and failures. However, as enough empirical experience is gained it becomes possible to inductively model the basis of success and failure and develop *theories*. This transition from empiricism to theory corresponds to the maximum slope of the logistic learning curve. The theoretical models make it possible to *automate* the scientific data gathering and analysis and associated manufacturing processes. One automaton has been put in place effort can focus on cost reduction and quality improvements in what has become a *mature* technology.

Figure 1 shows this BRETAM sequence plotted along the underlying logistic learning curve. In most industries the learning curve takes some tens of years and the major effects are substitution ones. Substitution occurs when an old technology has reached maturity and a new, more effective technology, reaches a point on its learning curve where it economically replaces the old one. There is also a secondary phenomenon that when a technology reaches a point on the learning curve where it is cost-effective and reliable new technologies develop dependent on the first one. For example, the electric lighting and appliance industries developed as the power generation industry came to offer cost-effective and reliable electricity supply.

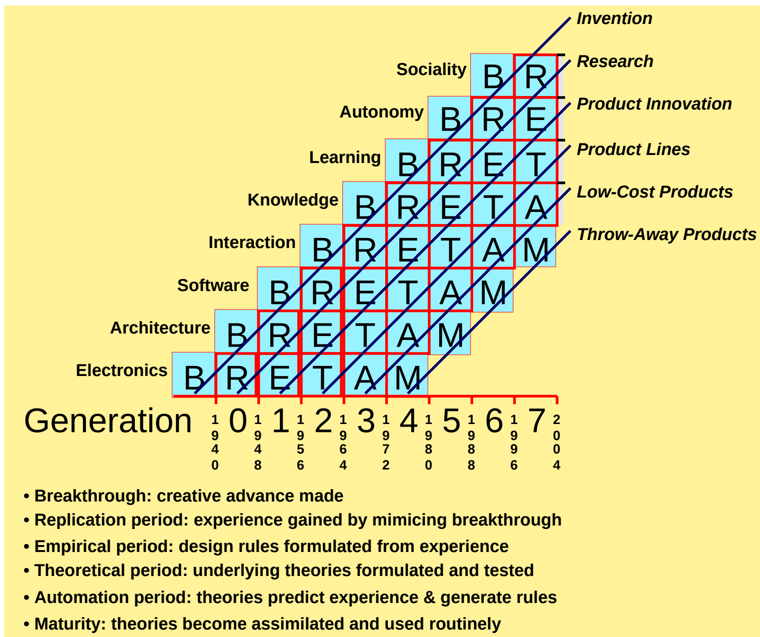

Figure 1 Learning curves underlying the evolution of information technology

The dependent technologies themselves develop along their own learning curves and may come to support their own dependents. Figure 1 shows a tiered succession of learning curves for dependent technologies in which a breakthrough in one technology is triggered by a supporting technology as it moves from its research to its empirical stage. Also shown are trajectories for invention, research, product innovation, long-life product lines, low-cost products and throw-away products. One phenomenon not shown on this diagram is that the new industries can sometimes themselves be supportive of further development in the industries on which they depend. Thus, in the later stages of the development of an industrial sector there will be a tiered structure of interdependent industries at different stages along their learning curves.

This model of the tiered infrastructure of information technology was used at the first ICAL in 1987 to provide an account of changing patterns of innovation in educational technology over the years (Gaines, 1987). Two things have changed since then. First, we have another 8 years of data which has confirmed the predictive power of the model—information technology has continued to develop along the trajectories predicted without significant deviation. Second, the emphasis 8 years ago on the increasing role of machine intelligence was misguided—research into artificial intelligence and expert systems has failed to fulfill its aspirations and promises. What has happened instead is that computer-mediated communication has been very effective in empowering human intelligence. News groups, list servers and the World Wide Web enable us all to tap into human expertise on a scale never previously possible. A quote from the early seventies before any of these technologies existed captures the essence of the matter:-

> *"No company offering time-shared computer services has yet taken advantage of the communion possible between all users of the machine...If fifty percent of the world's population are connected through terminals, then questions from one location may be answered not by access to an internal*

data-base but by routing them to users elsewhere—who better to answer a question on abstruse Chinese history than an abstruse Chinese historian." (Gaines, 1971)

News groups and list servers now operate in precisely the manner suggested, with questions being posed and answers being given by experts in the relevant domain, a learning web in action.

Technologically, the critical trajectory for computer-mediated communication in Figure 1 is that in the 7th generation commencing in 1996 *interaction* technologies become mature and cross the divide between low-cost generally affordable products to the virtually throw-away products that are affordable throughout the educational system. It is the maturity of electronic technology, digital architectures, software technology and interaction technology combined that is leading to the digitization of telecommunication technologies and their *convergence* with computer technologies (Negroponte, 1995). This is leading to convergence of the cable television, telephone, computer and media industries towards an 'information highway' (Trainor, 1994; Maney, 1995), and it is this consumer application of digital telecommunications and computer technologies that is creating a mass market for low cost products that can be used for computer-mediated communications in education.

4 Conclusions

This article has addressed the rationale for, and systemic foundations of, the learning web, its implications for restructuring the higher education system, and the role of information technology in supporting that restructuring. It models knowledge processes in human societies from a collective stance which views the human species as a single organism recursively partitioned in space and time into agents that are similar to the whole. It models the formation of expertise in society as a positive feedback process in which agents allocate resources for action to other agents on the basis of those latter agents past performance leading to functional differentiation of individual learning agents. It models various aspects of education as a means of disseminating expertise to create continuing and large-scale resources from short-lived and limited-capacity individual agents. The role of information technology is modeled as one of providing *knowledge support systems* that expedite the processes of knowledge formation and dissemination. The learning curves of information technology are themselves modeled to provide insights into the present *convergence* of telecommunication and computer technologies to provide the so-called 'information highway' that makes it possible to implement the learning web on a large scale.

The technological infrastructure to support the learning web is becoming available now and will be widely available by the year 2,000. However, the educational infrastructure to use it effectively is not yet in place. Universities have to reengineer their processes to take advantage of the new technologies and develop new roles as service providers on the information highway. To do so they need a much deeper understanding of their existing roles in society. The learning web concepts are one attempt to provide a basis for such understanding.

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