Reflections on the transformation of education for the knowledge age.

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The target of true 21st century education should be the advanced knowledge processes that scientists, scholars, and employees of highly innovative companies engage in daily. These processes must be built into the social fabric of communities, and into the technologies that support their work, so that creative knowledge work is as integral to schooling as it is to our most high-powered knowledge-creating organizations. Compared to the rapidly changing face of information technology, the rate of change in schools appears several orders of magnitude slower. This evident gap has caused anxiety among school people and impatience in the surrounding society. The result has been great pressure to wire the schools, train the teachers, and raise standarts. But what is taking shape today as a result of the "get wired" and the "raise test scores" movements, is not education addressing the needs of the 21st century. It is 20th century, industrial age education supercharged by high-stakes testing and high-tech tools.

New knowledge media provide new opportunities and means for addressing fundamental problems in education. But there are now so many designs for educational environments that choosing between them is difficult. Advancing the state of the art will require greater clarity regarding different possibilities and the ways in which designs reflect different underlying theoretical frameworks and research bases. This article highlights a particular form of online environment, a knowledge building environment (KBE), and contrasts it with online environments designed more specifically for course delivery, computer-mediated projects, and distance learning. Although a KBE can be used for these purposes, its distinctive strengths emerge in contexts—educational and other—where the emphasis is on knowledge creation and sustained idea improvement.

1. Socio-Cognitive Dynamics of Knowledge Building

In his book *The Mind's New Science,* Howard Gardner elaborated the role of cognitive science in uncovering what goes on in minds and between people as they solve problems. Through studying expert and novice problem solvers in action, cognitive scientists have uncovered the cognitive activity that underlies expert problem solving. Carl Bereiter and I focused our early studies in this field on novices who were on a trajectory to become experts, as opposed to novices who evolve into experienced non-experts (Bereiter & Scardamalia, 1993). Results from this work, from the broader base of cognitive, socio-cultural, and constructivist theorists, from the history of science, self-organizing systems, and memetics (the evolution of ideas), have made it possible to identify the socio-cognitive dynamics of knowledge building. Salient features include:

Knowledge processes:

• direct engagement with problems of understanding

• work with emergent rather than fixed goals

• evolution of goals toward higher-level formulations of problems

• self-organization around promising new directions rather than mandated work on other-directed and scripted activities

• work at the edge of competence

• self-monitoring and self-correction, without undue dependence on external evaluation

• engagement with knowledge intensive processes that lead deeper and deeper into the field of inquiry

• productive use of idea diversity

• risk taking

• responsibility for high level socio-cognitive activities such as setting and refining goals, providing resources, and identifying different perspectives

Cultures of Innovation

Cultures of innovation enable the processes listed above and encourage collective responsibility for knowledge creation. They additionally support the discourses and reflective processes required for continual idea improvement, ensuring innovation becomes the cultural norm.

There are parallels in the processes of knowledge creation across disciplines and cultures, and a developmental trajectory that extends from early, playful work with ideas to the sustained, disciplined creativity of mature knowledge workers. By taking advantage of these parallels and continuities we can identify generic systems for the design of KBEs. Before elaborating these we take a closer look at online learning.

2. Online Projects, Distance Education, and the Internet

The first exposure most educators have to computer networks is through distance media such as email, computer conferences, computer-mediated projects, website visits, teleconferences and courseware. Online learning environments are now so inextricably related to the use of the Internet that many educators have never experienced the potential of a local-community network or intranet. And many fail to see its value for students who meet face-to-face.

There is less skepticism regarding the value of intranets in business contexts where there are real costs, and loss of productivity associated with covering old ground over-and-over. Under these conditions the value of local-area-networks to support organizational memory is obvious. Education, in contrast, has been built around tasks and activities designed to cover old ground. Creating an organizational memory under these conditions could, arguably, result in little more than a record of naïve understandings. But even in organizations where the value of organizational memory is evident, a gap typically exists between "knowledgeware" and "courseware." The former is used to support the knowledge productivity of the organization, the latter for online learning. The result is separation of e-learning from the ongoing creative work of the organization. A KBE aims to integrate the ongoing creative work of the organization with learning.

Theoretically it should be possible to get from distance learning to knowledge building. However, designs have not advanced in this direction. Courseware, for instance, has come to include administrative systems that facilitate the creation of course lists, presentation of course outlines, and compilation and reporting of grades. Users become increasingly dependent on these adjunct facilities to run their courses. This fine-tuning of environments for specific educational activities leads to the need for different online environments for different purposes. KBEs, in contrast, aim to make explicit and support interactions that lead to knowledge advances across a broad array of contexts.

3. Knowledge Building Environments (KBEs): Interactions Within and Across Communities,

Intranets, and the Internet

Carl Bereiter and I introduced the concept of "knowledge building" into the educational literature in the 1980's to bridge the gap between innovation as carried on in the larger knowledge society and similar work that can be carried on in education. Knowledge building is activity focused on the generation of new knowledge and the continual improvement of ideas. Knowledge builders do more than learn--they produce ideas that have a life beyond their own minds, beyond personal notebooks, and beyond short-lived discussions. Knowledge building requires that ideas be revisited, revised, linked to other ideas, raised to higher status, reframed in light of new findings, and evolve into new forms. The overarching goal is to transform education by shifting emphasis from staying abreast of information to contributing to the development of new cultural artifacts; from individual learning and achievement to the building of knowledge that has social value; from focus on tasks and activities to a focus on continually improving ideas; from a focus on set course outlines to systems of emergence and self organization; and from a predominantly facilitator-directed discourse to distributed knowledge building discourses (Bereiter, 2002; Scardamalia, 2002).

The power of a local-area-network

Our design of online environments started in 1983 before the World Wide Web. Computer Supported Intentional Learning Environments (CSILE) made use of a local-area-network to create a multimedia community knowledge space. From the first use to this day we have experienced enormous potential in the use of this community space for transforming the intellectual life of classrooms and courses.

Advantages of long-term organizational memory

CSILE was not management, planning, or productivity software retooled for educational use; it was technology specifically designed to support knowledge creation. With traditional educational media, ideas are recorded in course papers; blackboards and walls serve as display spaces, with items posted there for approximately 2-6 weeks. E-learning spaces often mirror these qualities. For example, if we consider courseware environments such as WebCT, it supports threaded discussions, with ideas recorded in notes that are not revised after they are saved. The time during which those ideas are actively reviewed and worked on is limited to the duration of the discussion. Course papers are typically submitted online as end-of-course contributions. KBEs, in contrast, provide long-term organizational memory, and supports for continually improving ideas in both local- and wide-area-networks. There are many opportunities for ideas to come to life after periods of inactivity, through multi-faceted searches and reconstructions of knowledge spaces designed to keep ideas from being encapsulated in discussion threads or other bounded contexts.

Supports for interactions within and between communities

KBEs place a high priority on interactions between people and ideas, enabling a flow of information within and between organizations, disciplines, sectors, cultures, and ages, and encouraging participants to work continuously at the cutting edge of their understanding and the field. Consistent with this goal is the need for integrated Intranet/Internet protocols.

4. The Evolution of a Knowledge Building Environment

Growing numbers of online environments are described as KBEs in the literature on Computer Supported Collaborative Learning. This review focuses on the evolution of CSILE, the founding KBE, which is now in second-generation form as Knowledge Forum®. Knowledge Forum, in turn, supports the *Knowledge Society Network*, a cross-age, cross-discipline, cross-sector, cross-culture community of knowledge building communities. CSILE has been grounded in research from the outset. The original and continuing goals of the project are firstly to make advanced knowledge processes accessible to all participants, from small children to graduate students. Secondly, to promote the creation of community knowledge (Scardamalia, 2002) and the on-going improvement of

ideas. And thirdly, to provide a collaborative medium in which to carry out knowledge building processes

CSILE was first prototyped in 1983, in a university course of over 300 undergraduate psychology students. By 1986 a fully-functioning networked version was in daily use in an elementary school, thanks to Bob McLean who created a network database that had the capabilities of a conferencing system (it allowed comments on other people's entries, for instance, and display of the identities of contributors) but it had the cumulative properties of a database. The second-generation environment, Knowledge Forum, published by Learning in Motion (http://www.knowledgeforum.com), offers both browser and client versions, with the Internet enabling Knowledge Forum's distinctive supports for advanced knowledge processes to operate in both local- and wide-area contexts. The ease with which it has been possible to integrate local and global initiatives supports the theoretical framework from which designs were derived. Furthermore, the advent of the wireless age is opening up new possibilities for Knowledge Forum, such as synchronization of online and offline knowledge building. Currently in version 4.5, with version 5 under development, Knowledge Forum continues to evolve in response to research findings and new opportunities.

From the earliest days of educational computing, leadership was defined through model-school projects that demonstrate what classrooms enhanced with ICT (information and communication technology) should look like. Typically, these classrooms exemplify discriminating consumership and creative use of off-the-shelf technology. This trend was broken in 1993 when Apple released CSILE under the name, "Collaborative Learning Product." Apple's press release announced:

Apple Introduces Ground-Breaking Product....

During a meeting of key education press at Apple headquarters today, the company introduced... Collaborative Learning Product, an integrated, research-based product and the first collaborative learning offering available for the K-12 education market. ....

Apple set this product in a league of its own, distinguishing it from bulletin-board services and electronic mail, citing its affordances for inquiry-based work and knowledge construction, its basis in research, and its ability to address the skill requirements identified by U.S. Dept. of Labor 1991 Secretary's Commission on Achieving Necessary Skills for the Workplace of the 21st century. They cited the following skills: "*... the ability to organize resources, to work with others, to learn a variety of technologies, as well as the ability to acquire, understand, and evaluate information*."

As the Apple press release claimed, CSILE represented a new generation of educational technology that specifically addressed the educational challenges of the 21st century. There have since been a number of experimental efforts to build knowledge building tools and environments. However, Knowledge Forum is the only product continuously improved over the years based on research results arising from active and diverse user communities and reflecting knowledge building theory, principles, and practices. Knowledge Forum development is theory-driven, but takes advantage of advances in technology to continually enhance and unfold the knowledge building agenda.

The Knowledge Society Network

This network, supported by the Institute for Knowledge Innovation and Technology (www.ikit.org) helps to define a vision of a knowledge society. Schools, workplaces, and community and health care organizations are part of a network of institutions, all changing in response to new information and communication technologies. These technologies are altering both the nature and expectations for knowledge work. It is generally accepted that computer-supported extended learning communities are required to achieve the much heralded 'knowledge society.' But despite much enthusiasm surrounding such a society and the new 21st-century skills it will require, there is little analysis of what it might look like or how we are to achieve its anticipated knowledge advances. One thing that is evident is that there is urgent need for design experiments aimed at exploring challenges and implications, which

is precisely what the KSN aims to facilitate. The KSN already supports work in education (grade 1 to graduate), health care, community, and business contexts, in the Americas, Asia, and Europe. Nurturing a knowledge-building culture within the local community remains a vital and challenging part of this work.

The KSN is an example of a knowledge network as defined by Stein, Stren, Fitzgibbon, and MacLean (2001). Knowledge networks:

• produce new knowledge through transdisciplinary research on problems as they are experienced across international boundaries in different contexts;

• produce 'operational' knowledge, acquired through context-bound interactions among multiple sectors of expertise; and

• disseminate knowledge by blurring the boundaries between participants and researchers, thereby ensuring that 'global' knowledge is introduced locally and that 'local' knowledge shapes and, at times, redefines global knowledge. (p. 4)

1 Tasks and Activities versus Understanding. There are striking differences between what typically goes on in classrooms and courses and what goes on when experts are at work on knowledge problems. In the former the focus is on tasks and activities generated by teachers and facilitators; in the latter the focus is on problems of understanding growing out of previous problem solving efforts. Online environments for knowledge creation require rendering hidden dynamics of knowledge building transparent and embedding them in enabling environments that reflect knowledge work as it goes on in knowledge-creating organizations. If we accept this analysis of the challenge underlying the design of KBEs, then an environment that is only effective in educational contexts is not a KBE. This design framework, along with our understanding of the dynamics of knowledge building presented above, has informed the design of CSILE/Knowledge Forum, as elaborated below. For a more detailed account see Scardamalia (2004).

2 Knowledge Building Supports in Knowledge Forum. CSILE/Knowledge Forum is built around a multimedia community knowledge space that provides supports for the creation of notes and for displaying, linking, and reconstructing ideas to produce increasingly high level, coherent, and novel accounts. Shared, user-configured design spaces allow users to deal with idea diversity while going beyond given contributions. In addition to providing organizational memory, the evolution of ideas is evident in the citations, references and build-ons that accompany the rising status of ideas that have undergone review and achieved broader usefulness. Opportunism in idea advancement is supported by multi-faceted search, notification, and other supports for linking people and their ideas. A customizable environment enables within- and between-community explorations that extend and provide continuity in knowledge work.

Through these and other means it is possible to view ideas from multiple perspectives, and for teams to form and dissolve, with members working individually or through group authored notes and views. Multimedia, multiple-literacy supports provide a way in for all participants to a common discourse, and flexible build-on structures provide an alternative to downward branching threaded discourse. Idea connectedness is further facilitated through annotation, citation, and reference links, and advanced knowledge processes are supported through customizable scaffolds and supports for elaborating problems of understanding. "Rise-above" notes and views help users synthesize ideas, create historical accounts and archives, and reduce redundancy. . They also aid idea improvement by promotingnew ideas that preserve the value of competing ideas while sorting out their incompatobilities. Idea improvement is further reflected in publication and high-order conceptual frameworks.

Research tools work in the background of Knowledge Forum to automatically record activity patterns, which can then be fed back into the work as it proceeds, rather than waiting until the end of a unit of

work to provide feedback, when it is too late to make adjustments. Across many contexts, the use of CSILE/Knowledge Forum has led to advances in textual, graphical, and computer literacy, as well as to depth of inquiry, collaboration, and a host of mature knowledge processes (Scardamalia, Bereiter, & Lamon, 1994; Scardamalia, 2002).

5. New Developments and New Design Challenges

Anytime, anywhere, anyone access to technology has become the mantra of online education, with newer mobile technologies such as Personal Digital Assistants (PDAs) promising to bring this goal ever closer. From the point of view of knowledge building, the goal is not ubiquitous computing but rather pervasive knowledge building. Just as the Internet can support quite varied forms of online work, ranging from courseware to knowledge networks, mobile technology can be used in quite varied ways. For example, PDAs can support personal work and customized assignments, creating a sense of individual ownership. But from the perspective of knowledge building theory, mobile devices have greater educational potential as intermediaries between individual minds and minds in society. This design challenge is evident in research by Nirula, Woodruff, Scardamalia, and MacDonald (2003), and Teplovs, McLean and Scardamalia (1999). Mobile devices are used to beam ideas to community spaces and to download Knowledge Forum's community spaces to mobile devices for offline work, and later updating the community space. Pervasive knowledge building places the design challenge at the intersection of socio-cognitive and technological innovations. As important as technology is, it alone cannot do the job. If socio-cognitive and technological innovations are not in synchrony — if there is no interest, no time, no use — then anytime, anywhere, anyone access makes little difference.

As the design of educational technology becomes a theory-driven science, and as digital technologies become embedded in the normal workings of society, we should see a shift from current popular and divisive questions such as "Is online or face-to-face education better?" to questions that are concerned with realizing the full potential of new knowledge media: "How can we maximize the affordances of traditional and new knowledge media to improve education?" In the course of answering the latter question designers will take advantage of the full range of local- and wide-area-network possibilities for transforming education. At that point online learning as a specialty sub-field will likely disappear and education will move a step further toward a progressive design science that channels the potential of new media into increasingly effective theories and designs.

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