Scardamalia, M., & Bereiter, C. (2003). Knowledge building environments: Extending the limits of the possible in education and knowledge work. In A. DiStefano, K.E. Rudestam, & R. Silverman (Eds.), *Encyclopedia of distributed learning.* Thousand Oaks, CA: Sage Publications.

Knowledge Building Environments: Extending the Limits of the Possible in Education and Knowledge Work

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There are dozens of software systems classified as knowledge building environments. 'Knowledge building environment' has an attractive 21st Century, knowledge society ring to it, but how is a *knowledge building* environment different from a *learning* environment and what makes it an *environment* rather than a *tool*? This article addresses these questions, providing answers that suggest that a fully-realized knowledge building environment is substantially different from a learning environment, incorporating different forms of support to accomplish a different level of process, and playing a role in a different kind of education or workplace culture.

Knowledge Building: The Foundation of Knowledge Building Environments (KBEs)

Although the term "knowledge building" now appears in tens of thousands of web documents, it is almost never defined, the implication being that its meaning is transparent from the juxtaposition of two familiar words. Yet the idea of knowledge as a human construction is a very recent notion in the history of thought, and even today it remains far from universally accepted. When the term "knowledge building" is used in business contexts it is roughly equivalent to "knowledge creation" and is associated with innovation, intellectual property, intellectual capital, and knowledge work. In educational contexts, however, knowledge building tends to be equated with such familiar approaches as learning-by-discovery, project-based learning, anchored instruction, and collaborative learning. Thus it is used as a synonym for "constructivist learning" (Wilson, 1996) and offers no evident advantage over this older and more familiar term.

As originally introduced into the educational literature, however (e.g., Bereiter & Scardamalia, 1989, p. 388) "knowledge building" carries a meaning closer to its meaning in business and professional contexts. That is, it refers to the creation and improvement of ideas that have a life out in the world, where they are subject to social processes of evaluation, revision, and application. One marker of a knowledge building environment is that it can support idea development in both education and workplace situations. This is in contrast to the common situation in knowledge-based organizations where one technology (often called "knowledgeware") is used in the creative work of the organization and an entirely separate technology (often called "courseware") is used for learning. Both economically and technologically, e-learning is treated as a separate world from the ongoing creative work of an organization.

KBEs bring these different worlds of knowledge work together into one coherent framework, while bringing innovation closer to the central work of the organization. Members are inducted into a progressive enterprise in which they are continually contributing to the shared intellectual property of the organization. They advance community resources through contributing their ideas, alongside resources from the world at large. Learning is necessitated by this process, and integral to it. The resultant community knowledge is a form of new information that other community members can all build on. In this context, learning results in something more than advances in the heads of individual members. Each advance precipitates further advances, with the result that at both the individual and group levels there is a continual movement beyond current understanding and best practice-- toward the ideal of "lifelong innovativeness."

Following from the learning/knowledge-building distinction, a KBE is defined as

> *Any environment (virtual or otherwise) that enhances collaborative efforts to create and continually improve ideas.*

That is a minimum requirement. An optimal KBE will exploit the fullest possible potential of ideas to be improved by situating them in worlds beyond the minds of their creators and compounding their value so that collective achievements exceed individual contributions. Among the characteristics of an effective KBE are supports for the formulation of knowledge problems, for preserving ideas and making them accessible as objects of inquiry, for dialogue that is democratic and favorable to idea diversity, for constructive criticism and analysis, for organizing ideas into larger wholes, and for dealing with recognized gaps and shortcomings of ideas. A local KBE gains strength by being embedded in a broader KBE: people beyond the local community pursuing the same knowledge goals. Thus, the ideal KBE is one in which the knowledge building work of a local community not only draws upon but affords some level of participation in the larger knowledge building activity of society.

The Knowledge Base for Design of KBEs

The social, cultural, and cognitive dynamics that inform the design of KBEs are summarized below. Knowledge scientists have studied the history of thought and its evolution, and the practices of novice and expert knowledge workers—listening in on their conversations, collecting sketches and artifacts produced and revised as problem solving proceeds, analyzing notebooks and other accounts of scientific breakthroughs, recording and analyzing team meetings, and analyzing protocols as problem solvers 'think-aloud.' The following are pertinent conclusions drawn from this work and from the writings of socio-cultural and constructivist theorists.

An innovation dynamic links social and technological advances. In the case of knowledge building, externalized, organizational memory provides a powerful resource for knowledge advancement (Norman, 1993); advances are realized through collective responsibility for knowledge creation (Scardamalia, 2002).

There are striking parallels in the processes of knowledge creation across age and field of inquiry. The knowledge building trajectory starts with the early, natural ability to play with ideas and extends to the not-so-natural and relatively rare intentional processes that serve to continually improve ideas. These knowledge intensive processes enable deep understanding and provide the essential link between learning and knowledge creation (Popper & Eccles, 1977).

Knowledge advancement is fundamentally a socio-cultural process, enhanced by cultures of innovation. Bakhtin (1986) uses the term "*intertextuality*" to indicate how the voices of others are integrated into what we think, write, and say. "Standing on the shoulders of giants" is a rough approximation. Cultures of innovation provide a broader base, making productive use of diverse contributions and allowing innovation to become the cultural norm (Drucker, 1985).

Ideas are the building blocks of invention. Their improvement starts with their objectification as cultural artifacts (Bereiter, 2002) and is enhanced by community discourses that maximize their potential. Aristotle's physics made it into our culture, and was superseded by Newton's; Newtonian physics gave way to Einstein's relativity theory; relativity was further advanced by quantum theory. Breakthroughs were not achieved through adherence to fixed beliefs or consensus as a goal, but through efforts to account for all unexplained or "anomalous" facts (Lakatos, 1970). Arguments and negotiations surely occurred, but advances were more dependent on identification of weaknesses in current constructions, designs for new proofs and demonstrations, and engaging others in critical review. Improving ideas, not winning arguments, is the essence of knowledge building (Scardamalia, 2002).

Knowledge builders take charge at the highest levels of the whole range of socio-cognitive activity that characterizes productive research and design teams. This includes goal-setting, resource providing, monitoring, and modification of goals and strategies in light of progress or difficulties—the same tasks that are reserved for teachers, curriculum experts, managers, standard setters, and evaluators in the learning paradigm (Scardamalia & Bereiter, in press).

Our expanded understanding of knowledge building opens the possibility of knowledgeware that renders these hidden dynamics transparent and embeds them in systems of interaction between people and ideas, leading to dramatically improved and expanded conditions for idea improvement. The ideal KBE would be one that makes this possibility a reality.

KBE: A synonym for CSCL?

Most references to "knowledge building environments" are to be found in web pages devoted to conferences or edited volumes on "computer supported collaborative learning"—CSCL (see Koschmann, 1996). CSCL and KBE are frequently treated as synonyms; in some cases they are explicitly equated. For example, Stahl (2000) defines a KBE as "a software environment designed to support collaborative learning."

It is also common for KBEs to be defined by a list of tools. These include such familiar CSCL tools as electronic bulletin boards and conferencing systems; email and chat facilities; and supports for argumentation, negotiation, reflection, and weighing evidence. They also include tools for knowledge management--for accessing, storing, organizing, filing, and searching documents and building repositories; tools for assessment and data-analysis; tools to support the work of facilitators, telementors, and geographically dispersed teachers working on common projects; tools to annotate and mark up artifacts and their representations; and tools to aid visualization and productive use of multimedia. Typically, different workspaces within the software provide access to the relevant tools (e.g, a communication space, an assessment space). There is also frequent emphasis on providing ready access to resources, both human and digital. Project-based learning technologies make use of all of these functions to support collaborative inquiry, to enable telementors to work with learners, to enable distributed communities to easily locate resources and curriculum projects designed to meet standards, to help teachers manage projects, and to enable learners to complete tasks successfully (Pea, 1993;

Linn & Hsi, 2000). CSCL software products referred to as KBEs span sectors and a wide variety of uses: knowledge management, organizational memory, special-purpose networks, professional development, and course delivery.

Although these various tools and features may play a role in knowledge building, they are equally relevant to CSCL in general and do not set a KBE apart. A KBE should be distinguishable from CSCL environments by virtue of its focus on processes of knowledge creation and idea improvement and by virtue of its ability to represent the resulting community knowledge. The following are recognizable characteristics of such an environment:

1. Support for self-organization that goes beyond division of labor. Inasmuch as the process of knowledge building is inherently self-organizing a KBE should support and remain faithful to these processes and the self-direction and advanced knowledge processes that they require. It certainly should not thwart them through strict editorial controls, turning the high-level management work over to facilitators, or use of fill-in the blanks, pre-packaged activities, and other micro-management strategies.
2. Shared, user-configured design spaces that represent collective knowledge advances built from the contributions of team members. Continually creating something greater than the best of the available contributions becomes a natural part of the day-to-day work of the organization.
3. Support for citing and referencing one another's work so that contributions to the evolution of ideas are evident and can become objects of discourse in their own right, much as is the case in the history of thought.
4. Ways to represent higher-order organizations of ideas and to signal the rising status for improved ideas as contrasted with their nondescript entry in threads, folders, and repositories where they are lost amid information glut.
5. Ways for the same idea to be worked with in varied and multiple contexts and to appear in different higher-order organizations of knowledge. Flexible import-export functions to allow all of the valued ideas and artifacts of an organization (or representations of them) to be incorporated into knowledge building discourse.
6. Systems of feedback to enhance self- and group-monitoring of ongoing processes and to tap idea potential—as distinguished from assessment and management tools used exclusively for filing, organization, and end-of-work or external evaluation.
7. Opportunistic linking of persons and groups—with possibility for crossing traditional discipline, sector, cultural, and age boundaries-- by virtue of contributions and shared knowledge building goals. Searches are not limited to finding notes and documents; the

ideas represented in texts and artifacts also serve a match-making function, allowing participants to locate others working on parallel problems, and to identify the cutting edge of their area of inquiry.

8. Ways for different user groups to customize the environment and to explore the within- and between-community corridors that extend and provide continuity to their knowledge work.

CSCL environments designed for collaborative learning and knowledge sharing typically lack these characteristics and accordingly should not be confused with KBEs.

Approaches to KBE Design

Collaborative learning environments generally follow either of two models. One is a message model, derived from e-mail and bulletin boards and extended to threaded discussions. "The most common element...is the discussion forum" that "allows people to respond to notes posted by one another. Typically there is a thread of responses to posted notes, with a tree of divergent opinions" (Stahl, 2000). In this model, messages appear in a serial or downward-branching order, as they do in conversation; they are typically unmodifiable—in fact, the only thing participants can do with them is respond with other messages. The other is a folder model, based on the familiar Macintosh and Windows desktops, expanded to accommodate shared folders. In this model the basic units are notes or documents, with some affordances for annotation, and the organizational framework is that of a filing cabinet. Neither of these models is based on any theory of learning, knowledge creation, or collaborative action. Instead, their basis is technical—taking an existing technology and repurposing it to serve educational needs.

More theory-based efforts have drawn on forms of discourse and models for individual and group learning, linking constructs such as articulation, negotiation, and shared meaning to tools that help accomplish those ends. For instance, Belvedere (1996) was specifically designed to structure and facilitate scientific argumentation.

Discourse undeniably plays an essential role in knowledge building. However, even a well-integrated collection of tools for different discourse types and media falls short of providing the essential supports for knowledge building, as outlined in the preceding section. A focus on toolsets is especially unfortunate if it is constrained by arbitrary characteristics of message- and folder-based technologies. There has been one short-lived effort to design the KBE "killer ap" through agreement on a set of interoperable tools that would combine to constitute such an application. A component-oriented approach to software design makes good sense at the programming level, but when applied at the level of functional design it tends to result in what critics call "featuritis"—a proliferation of individually attractive features that cumulatively defeat the basic purpose of the software.

A Knowledge Building Environment Designed from the Ground Up

As the preceding discussion suggests, an environment that actually serves the distinctive purpose of supporting knowledge building would have to begin with theory and principles. CSILE was built from the ground up to reflect a theory of knowledge building and principles drawn from earlier research on literacy, intentional cognition, and expertise (Scardamalia, et al., 1989). It was first used in a university course in 1983. By 1986 it was in daily use in an elementary school, and has been in daily use in increasingly varied contexts ever since. There are vast differences between CSILE's oft-cited components, and implementations in other environments. For example, its knowledge building discourse, including co-authorship of notes and views, is fundamentally different from threaded discussion; its scaffolds differ in design, function, and goals from the prompts, hints, and templates that are referred to as scaffolds in other environments; its community knowledge spaces reflect the socio-cultural underpinnings of idea advancement, designed to support the central workings of knowledge creating organizations, with ideas living and growing there. Knowledge Forum® (second-generation CSILE) reflects the further development of knowledge building theory based on extensive research with CSILE. It adds a second layer of knowledge building activity in the form of rise-above notes and views that encourage higher-order knowledge constructions, means for representing ideas in multiple contexts, and coherence-producing resources such as automatic referencing and linking of notes from different views and external sources.

Among the lessons learned during more than 15 years of daily use of CSILE/Knowledge Forum are the following: A KBE can increase opportunities and possibilities for knowledge creation, but it loses that capacity when it becomes overly prescriptive. It must provide a flexibility consistent with the emergent goals of knowledge creation. It should not use prompts, intelligent agents, prescribed projects, fixed task sequences, templates or other means to guide users to known endpoints. It must, instead, capture the human capacity for inventiveness and help convert that inventiveness into something of social value. In line with this, CSILE/Knowledge Forum is used in a wide variety of knowledge-creating organizations worldwide, and for a wide variety of special purposes, including: kindergarten-to-post-secondary education, courseware (higher education, virtual schools), knowledge management, professional development, health-care inter-professional team building, police academy training, document repository. It has, of course, also been used in ways inconsistent with its basic purposes. A KBE cannot impose knowledge building on groups committed to other approaches, but it can enhance the knowledge building capacity of communities committed to innovation.

KBE Design: Idea Improvement at the Center

KBEs evolve to incorporate new technology, but the challenge always is to use the new technology in ways that advance the knowledge building goal. CSILE/Knowledge Forum was invented at a time when networked computers were virtually unheard of in schools and the leading-edge communication technology was e-mail. It was the first technology to provide an educationally plausible reason for classroom computers to communicate with one another. Its evolution suggests the sorts of opportunities and challenges that accompany KBE design. The advent of the Internet made it easy to extend CSILE's knowledge building dynamics from local- to wide-area-networks, confirming the theoretical framework that assumed that CSILE's knowledge building dynamics were scalable to distributed communities and different ages and cultures. Moving from a client-server to browser-based implementation proved more difficult. Advantages of knowledge building discourse were lost to browser-dominant threaded discussion and the result was a shallower, linear landscape of ideas. Without drag-and-drop capabilities, the ability of users to collectively design graphical organizers for ideas and to personalize their environment was sharply curtailed. Major new redesign efforts are underway to take advantage of browsers while bringing idea-improvement and knowledge building discourse back to the center. Similarly, mobile technologies offer new forms of connectedness, while posing new challenges for sustaining collective efforts at idea improvement. Advances in automated content analysis open an abundance of possibilities for idea-driven, opportunistic, and creative efforts by teachers and students, but not without accompanying dangers that automated assessment techniques will subvert risk-taking with ideas.

The adequacy of any KBE must ultimately be judged by knowledge advances resulting from its use. Collaboration, discussion, and information sharing may all increase, but if there are no corresponding knowledge advances, we do not have an effective KBE. As the preceding discussion indicates, there is a great deal of interest in knowledge building and in technology to support it in education and knowledge work. Just beginning to form is an extensive design community (see www.ikit.org) explicitly dedicated to advancing understanding of how new knowledge is created and to developing the technologies and research required to advance that agenda.

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