A Brief History of Knowledge Building

Une brève histoire de la coélaboration de connaissances

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Abstract

Knowledge Building as a theoretical, pedagogical, and technological innovation focuses on the 21st century need to work creatively with knowledge. The team now advancing Knowledge Building spans multiple disciplines, sectors, and cultural contexts. Several teacher-researcher-government partnerships have formed to bring about the systemic changes required to accommodate pedagogical innovations that range from elementary to tertiary education and require new forms of teacher education. This paper tracks the evolution of Knowledge Building, starting with research on "knowledge transforming," "intentional learning," and other processes leading to the development of expertise. It provides an account of how the first networked collaborative learning environment was developed to support such processes and next-generation research and development to advance education for innovation and knowledge creation.

Résumé

La coélaboration de connaissances met l'accent sur le besoin, au 21e siècle, d'aborder la connaissance avec créativité. Notre équipe, qui travaille sur la coélaboration de connaissances, fait d'ailleurs appel à plusieurs disciplines, secteurs et contextes culturels. Des partenariats entre des professeurs, des chercheurs et des gouvernements ont été établis afin d'apporter les changements systémiques nécessaires dans le but d'accompagner les innovations pédagogiques qui s'appliquent de l'éducation primaire à l'éducation tertiaire et qui exigent de former les enseignants différemment. Cet article retrace l'évolution de la coélaboration de connaissances en abordant la recherche sur la « transformation de connaissances », « l'apprentissage intentionnel » et les autres processus menant au développement de l'expertise. Le texte relate comment le premier environnement d'apprentissage collaboratif en réseau a été mis sur pied pour soutenir de tels processus. Aujourd'hui, une

équipe internationale poursuit le travail en élaborant de nouvelles théories, pédagogies et technologies éducationnelles axées sur l'innovation et la création de connaissances.

This special issue of the *Canadian Journal of Learning and Technology* represents an important step in the evolution of Knowledge Building as a worldwide initiative, with research spanning multiple disciplines, multiple cultural contexts, students from elementary to tertiary education, teacher education, and teacher-researcher-government partnerships. Articles in this issue provide a sampling of this range of inquiries into the potential of an approach which, although clearly falling within the scope of what is known as "constructivism," is importantly distinct from other approaches sharing this label. To begin, we provide a brief historical account of how Knowledge Building came about, leading up to a set of 12 principles that define it in its present form.

Although the term " knowledge building" is currently used in about half a million Web documents, the term is seldom defined and its uses are far from consistent. For many educational writers it appears to be merely a way of adding a constructivist flourish to the term "learning." When used in a business context, the term seems to refer to knowledge creation and additions to an organization's "knowledge capital." This is actually closer to our own sense of the term, which applies equally to educational and knowledge work contexts. Knowledge Building has several characteristics not shared by constructivist learning in general, although common to organizational knowledge building. Two of these are:

> *Intentionality*. Most of learning is unconscious, and a constructivist view of learning does not alter this fact. However, people engaged in Knowledge Building know they are doing it and advances are purposeful.
>
> *Community knowledge*. Learning is a personal matter, but Knowledge Building is done for the benefit of the community.

As far as we can tell, we were the first to use the term "knowledge building" in an educational context; we have no way of charting its use in other contexts. In what follows we trace the concept of knowledge building as it has developed within the group that throughout much of its quarter-century history was known as the "CSILE/Knowledge Building Project" and that has expanded in the past decade to the much larger international community of the Institute for Knowledge Innovation and Technology (www.ikit.org) and its *Knowledge Society Network* (See Hong, Scardamalia, & Zhang, present issue; Scardamalia, 2003). No one can claim to own the term "knowledge building," and there are now several different groups doing sustained work on knowledge building and developing the concept in their own ways. To distinguish "knowledge building" in its broad and varied senses from "Knowledge Building" in the more specific sense used in our own research and that of contributors to this Special Issues, we put the former in lower case and capitalize the latter. We hope that a history of the concept of “Knowledge Building” within our own research group will be helpful to others who recognize that the term is not just a fancy synonym for learning and are trying to pin down the difference.

Antecedents

Learning, cognitive development, inquiry, and invention are probably as old as our species, but knowledge building is not. It is not just the concept that is relatively new but the process itself. The kind of inquiry that comes naturally is found in other mammals as well as human beings. It consists of examining, sniffing, or otherwise gathering information on anything novel that appears in the environment. However, with the notable exception of astronomical calculations—which were developed to an impressive level even in many Stone Age societies—systematic inquiry is only about 3000 years old (Watson, 2005). Myths are much older, and they have been credited as early versions of scientific explanation. However, myth-making lacks the element of sustained effort at theory improvement in the light of evidence that is the hallmark of systematic inquiry. Aristotle was unquestionably a systematic inquirer, but it was not until the Renaissance, 2000 years later, that Aristotle's formulations began to be subjected to the kind of testing and improvement that now characterizes all kinds of disciplined inquiry (Mason, 1962). Knowledge building began to flourish in the sciences from the 17th century onward, but it was not conceived of in the constructivist terms that "knowledge building" implies. It was conceived of, as many proponents of "the scientific method" conceive of it still, as a kind of detective work or puzzle solving. The idea of knowledge as a human construction did not really take hold until well into the Industrial Revolution, the "Age of Invention" (Whitehead, 1925/1948).

Invention, we have said, is as old as the species, and this is plausible if we count as inventions stone tools, agriculture, domestication of animals, number, and writing. These are all innovations that profoundly influenced the future development of human societies. But who were the inventors, and did they know they were inventing something? Probably not. These inventions evolved slowly, over thousands and in some cases millions of years. The key processes were noticing, replicating, and imitating (Donald, 1997). At points along the way brilliant ideas may have played a part in the evolution of inventions, but it was not until the 19th century that we find people making a career of inventing. Thomas Edison, with his "invention factory," set a new standard that transformed invention into something that could be pursued deliberately, systematically, and with a foreseeable rate of production: "a minor invention every ten days and a big thing every six months or so" (cited in Boorstin, 1973, p. 528).

Inventions are obviously human constructions. (And note that it is the inventive idea or design that is patented, not its physical embodiment.) But if an idea for controlling the flight of an airplane is a human construction, why not a theory that explains flight? With recognition of this parallelism, the final stone was in place for a full-blown constructivism that recognizes all kinds of intellectual products as human constructions: theories, algorithms, proofs, designs, plans, analogies, and on and on.

Constructivism became known to educators mainly through the work of Piaget. The importance of social processes related to constructivism can be traced to Vygotsky, who emphasized culture and human interaction in learning. While Piaget tended to focus on developmental processes of individual learners he was fully conscious that the growth of knowledge in the sciences and the growth of knowledge in the child are at bottom the same process (e.g., Piaget, 1971, ch. 5). However, what was picked up in education was the psychological aspect, which holds that individual knowledge growth is a constructive process. This is at least an implicit premise of all cognitive theories, and so by itself a statement like "learners construct their own knowledge" does nothing but identify the speaker as assuming a cognitive stance (Vuyk, 1981). There is also a radical philosophical constructivism, asserting in effect that socially constructed beliefs are all we have and that there is no possibility of matching knowledge constructs against an external reality (Boudourides, 2003). An important point about the concept of Knowledge Building as we understand it is that it does not imply any particular position, pro or con, on this controversial issue. That is, as long as you accept that theories, histories, and the like are human constructions, you can hold any epistemological position you wish concerning the truth or foundation of such constructions.

From Intentional Learning to Knowledge Building

The concept of Knowledge Building did not emerge full-blown. It progressed through several stages. The following is a rough chronology, based on a succession of research programs:

1977-1983: Knowledge-Telling versus Knowledge-Transforming

This was a period of wide-ranging research on processes of written composition. The information processing demands of writing appeared to be very high, and so one goal of our research was to explain how children cope with these demands (Scardamalia, 1981). The answer we arrived at was something we called the "knowledge-telling strategy." This strategy consists of telling what one knows, in more-or-less the order it comes to mind, with genre constraints and preceding text as the principal retrieval cues. This is a highly efficient strategy that enables young writers to quickly and easily complete writing assignments that more mature writers labour over. The more mature writers employed a more complex strategy, "knowledge transforming," which involves a cycling between writing concerns and concerns about knowledge and belief. Although less efficient in getting the job done, the more mature strategy has the important benefit that the writer's knowledge and beliefs undergo development through the composing process, whereas "knowledge telling" has little or no effect on the writer's knowledge. The distinction between these ways of dealing with knowledge becomes increasingly relevant with the advent of technologies such as the wiki, which are frequently heralded as environments supporting knowledge building, although the technology itself can as readily be used for knowledge telling as for knowledge transforming, depending on the goals of the writers and the socio-cognitive context. The focus of our applied research shifted from trying to improve students' writing to supporting more active knowledge processes in writing (Scardamalia, Bereiter, & Steinbach, 1984) and designing technology to provide such support.

1983-1988: Intentional Learning and Cognition

A paper and experimental trial of an intentional learning environment gave direction to the next five years of research and technology development. The paper was titled "Schooling and the Growth of Intentional Cognition: Helping Children Take Charge of Their Own Minds." It was published in Hebrew in 1983 (Bereiter & Scardamalia, 1983). An English version of the book in which it appeared kept being delayed and was eventually abandoned, with the result that the original English version was not published until 2002. The learning environment was CSILE—Computer Supported Intentional Learning Environment (Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989).

Intentional cognition is "something more than 'self-regulated learning,' more like the active pursuit of a mental life" (Bereiter & Scardamalia, 2002, p. 246). "Self-regulated learning" is usually thought of as a set of study skills and learning-to-learn strategies [http://www.gifted.uconn.edu/siegle/SelfRegulation/section2.html]. Intentional learning, as we formulated the concept, entailed several ideas that pointed in the direction of Knowledge Building (Scardamalia & Bereiter, 1985). These include:

1. Higher levels of agency (Scardamalia & Bereiter, 1991a). Students take responsibility not only for meeting learning objectives set by the teacher but for managing the long-term acquisition of knowledge and competencies.
2. Existing classroom communication patterns and practices as obstacles to intentional cognition. Even though teachers may try to encourage inquiry and independent learning and thinking, common characteristics of the classroom environment militate against it and instead increase dependence on the teacher (Scardamalia & Bereiter, 1996).

Several strands of research developed during this period (summarized in Bereiter & Scardamalia, 1989). Two of these would later converge on the development of Knowledge Building pedagogy and technology.

The process of expertise and the expert-like learner.

The finding that novice writers carried out writing assignments with less apparent effort than more expert writers seemed contrary to all the findings emerging from the burgeoning field of research on expertise (Scardamalia & Bereiter, 1991b). However, a series of graduate student theses carried out by students of ours showed that this was not so unusual. Comparable results appeared in music (Ghent, 1989), medicine (Tal, 1992), second-language learning (Corbeil, 1989), and learning computer programming

(Ng, 1988). The explanation appeared to be that on well-defined problems, such as textbook physics or many medical diagnoses, experts of course have an easier time of it, but on more open-ended tasks such as writing on a given topic or preparing to perform an unfamiliar type of music, experts or expert-like learners define the task at a higher, more complex level. This makes the task more difficult but also more rewarding and edifying. Over a career span, we conjectured, people who become experts and who continue to advance in expertise are people who practice progressive problem solving; as parts of their work become automatic, demanding fewer mental resources, they reinvest those resources into dealing with tasks at a higher level, taking more complexity into account (Bereiter & Scardamalia, 1993). Those who do not follow this route become experienced non-experts. School activities seldom encourage progressive problem solving, and so it is only the rare "intentional learners" who transcend the routine and assimilate school tasks to a higher-level cognitive agenda of their own (Ng & Bereiter, 1991).

Computer-Supported Intentional Learning Environments (CSILE).

In order for intentional learning to become the norm rather than the exception in schools, several things had to change. First, students needed supports to help them execute higher-level cognitive processes on their own. "Procedural facilitation" is a general scheme for providing supports based on functional analysis of the processes in question (Scardamalia & Bereiter, 1983). Second, the community itself needed to become a sustaining force for knowledge advancement. As a starting point, the flow of information in the learning environment needed to be changed so that the teacher was no longer a limited-bandwidth bottleneck through which most information passed. There had to be more opportunity for student-to-student feedback. There had to be more scope for knowledge-related goals that were more than goals of satisfying the teacher. Although many educational innovations addressed these needs in limited and often subject-specific ways, it seemed that recently emerging networked computer technology might offer a more general solution to the problems.

The dysfunctionality of classroom communication structures reveals itself in traditional classroom activities—the classic "project" in the elementary school and the "research" or "course paper" at higher levels. Each student gathers information on a topic and presents it in a report that is usually read only by the teacher, who usually has time to provide only brief feedback. Although the student productions may be posted on a bulletin board or, in recent times, presented as a slide show or a Web page, there is usually no follow-up and no particular reason why the students should be interested in one another's work or should continue to improve their ideas after the report is submitted. The earliest version of what was to be called CSILE (pronounced "seesil") addressed this situation in a large university class. The year being 1983, the technology was quite primitive. Nevertheless, allowing students to read what others had written and comment on their work produced results encouraging enough that we began planning a more fully functional system. We took our ideas to colleague Bob McLean, who had been involved in the specifications that gave birth to the Icon, a state-of-the-art educational computer that provided networking capabilities and other functionality previously unheard of at the school level. Within a few weeks he created a shared database to which all students' online work could be contributed and made available to others. This community space opened up opportunities not only for student-student interaction but for the building of community activity around shared knowledge objects. Thus the seeds of Knowledge Building were there, even though the conceptual foundation for "community knowledge" was still in its infancy (Scardamalia, et al., 1989).

We assembled a development team and within two months had a fully functional collaborative learning environment ready to install in experimental classrooms. The software provided procedural supports derived from our earlier work on writing. The main ones were "thinking types," which labeled knowledge operations such as problem posing, conjectures, new information, and—importantly—INTU, which stood for "I need to understand." Because so much of knowledge creation in the academic disciplines consists of theory development (see the concluding paper by Bereiter & Scardamalia, present issue), we experimented with engaging students directly in presenting and refining their theories. Our experiments showed that even the youngest students took easily to presenting theories. This represented an important step in taking a more direct approach to knowledge creation. Our intent was to add other procedural supports as the need arose, but to our surprise the students seemed to progress nicely in collaborative Knowledge Building with only a limited set of supports for presenting, commenting on, and referencing students' theories, problems of understanding (INTU), ideas in support of their theories, and efforts to state better theories. In addition to text notes, students could produce graphics with ability to zoom in to more detailed or subordinate graphics (for instance, clicking on the refrigerator in a kitchen scene and zooming in to a picture of the inside of the refrigerator). Thus graphics became an alternative way of representing knowledge, one in which many students became remarkably adept.

1988-Present: Knowledge Building

One of the ideas behind our work on intentional learning was that curiosity alone is not sufficient to motivate sustained inquiry. Longer-term goals are needed, which is where intentional learning comes in. During early trials of CSILE, we saw instances where a combination of curiosity and intentional goal-directed inquiry produced impressive achievements. We had a videotape of one child guiding us through his CSILE notes and drawings all leading to an explanation of why people are able to talk and chimpanzees are not. We came to refer to it as our "million dollar" video, because people were so impressed that it was instrumental in getting us the grants that enabled further development and testing of CSILE. Nevertheless, it reflected individual knowledge advance, with help from peers, rather than collective advancement of community knowledge. As time went on we began to see something emerging in CSILE classrooms that involved all the students. It was what we would eventually call a "Knowledge Building culture." Contributing to the solution of knowledge problems became what you had to do in order to be part of the classroom community. Thus a motive came into play more powerful and sustaining than the motives at work in intentional learning; it was the simple and virtually universal desire to belong.

A Knowledge Building culture does not arise spontaneously. It is not bred into the human genome. A supportive environment and teacher effort and artistry are involved in creating and maintaining a community devoted to ideas and their improvement. We believe this is evident in the articles in this issue and references cited in those articles. However, as Knowledge Building spreads throughout a school, the task becomes easier because children are coming into class already socialized to Knowledge Building values and practices and they become the primary agents in socializing newcomers. See, in particular, the article by Moss and Beatty, present issue.

The "official" launch of work on Knowledge Building came in 1988 with a project funded by Apple Computer and titled, "The Design of Knowledge-Building Environments." Although the research proposal did not explicitly define Knowledge Building or distinguish it from learning, the basic elements of the emerging concept were there, as indicated by section headings: "Knowledge-processing environments with generative capacities" (as contrasted with ones that merely record and display knowledge); "Management of knowledge in a community"; and "Interrelating different 'worlds' of knowledge" (which drew on Karl Popper's distinction between the "world 2" of subjective thoughts and the "world 3" of public knowledge). By the time of a 1994 paper by Scardamalia, Bereiter and Lamon, however, Knowledge Building had come to be more clearly distinguished from learning. We asked,

> Can a school class, as a collective, have the goal of understanding gravity or electricity? Can it sustain progress toward this goal even though individual members of the class may flag in their efforts or go off on tangents? Can one speak of the class—again, considered as a community, not as a mere collection of individuals—achieving an understanding that is not merely a tabulation of what the individual students understand?

A positive answer to these questions has radical implications. It suggests that knowledge be treated as community property rather than as mental content and that collective work be focused on improving *the knowledge itself* rather than improving the contents of students' minds.

This conceptual step yielded a definite separation between intentional learning and Knowledge Building. Intentional learning is the deliberate enhancement of skills and mental content. Knowledge Building is the creation and improvement of knowledge of value to one's community. You can have intentional learning without Knowledge Building and, in principle at least, Knowledge Building without intentional learning; but the two together make a powerful combination.

In technology, Computer Supported Intentional Learning Environment (CSILE) evolved into Knowledge Forum®. Knowledge Forum contains a number of innovations aimed at supporting the collaborative construction of community knowledge. The centerpiece, which evolved from the graphical notes in CSILE, is the graphical view, on which note icons related to a particular Knowledge Building effort can be placed and arranged on a background to provide a higher-level representation or organization of ideas. The view thus becomes a community workspace rather than merely a list of entries. Higher-level views can be constructed that connect to lower-level views. Typically, students are put in charge of a view and responsible for dealing with problems of redundancy, relevance, and the like.

The most complete published account of Knowledge Building pedagogy and technology is a chapter in the *Cambridge Handbook of the Learning Sciences* (Scardamalia & Bereiter, 2006). In a commemorative volume for Ann Brown (Scardamalia & Bereiter, 2007) we contributed a chapter in which we draw contrasts between Knowledge Building and what is in many respects a "near neighbor," Fostering Communities of Learners.

Knowledge Building Principles

Twelve "Knowledge Building principles" have been developed that can serve multiple purposes—as pedagogical guides, technology design specifications, and bases for evaluating existing practices. Together they give a picture of Knowledge Building as we currently conceive of it. In summary form, the principles are as follows:

> **Real Ideas, Authentic Problems.** Knowledge problems arise from efforts to understand the world. Ideas produced or appropriated are as real as things touched and felt. They cause things to happen, they develop momentum, they create reactions and counter-reactions.
>
> **Improvable Ideas.** The working assumption in Knowledge Building is that all ideas are improvable. Although some ideas may turn out to be unimprovable, this is not to be judged in advance of efforts to improve their quality, coherence, and utility. According to this principle, it is all right for students to advance ill-conceived or half-baked notions, provided they subsequently work to improve them.
>
> **Idea Diversity.** Idea diversity is essential to the development of knowledge advancement, just as biodiversity is essential to the success of an ecosystem. Ideas are improved through comparison, combination, and alignment with other ideas, and enriched by distinctions and recombinations. To understand an idea is to understand the ideas that surround it, including those that stand in contrast to it. Idea diversity creates a rich environment for ideas to evolve into new and more refined forms.

Rise Above. Creative knowledge building entails working toward more inclusive principles and higher-level formulations of problems. It means learning to work with diversity, complexity, and messiness, and out of that achieve new syntheses. By moving to higher planes of understanding, knowledge builders transcend trivialities and oversimplifications and move beyond current best practices.

Epistemic Agency. Participants recognize both a personal and a collective responsibility for success of knowledge building efforts. Individually, they set forth their ideas and negotiate a fit between personal ideas and ideas of others, using contrasts to spark and sustain knowledge advancement rather than depending on others to chart that course for them. Collectively they deal with problems of goals, motivation, evaluation, and long-range planning that are normally left to teachers or managers.

Community Knowledge. Knowledge Building has as its aim to produce knowledge of value to others. This distinguishes Knowledge Building from learning and accordingly it needs to be kept clearly in mind, especially in educational contexts where personal learning is also an objective.

Democratizing Knowledge. All participants are legitimate contributors to the shared goals of the community; all take pride in knowledge advances achieved by the group. The diversity and divisional differences represented in any organization do not lead to separations along knowledge have/have-not, or innovator/non-innovator lines. All are empowered to engage in knowledge innovation.

Symmetric Knowledge Advancement. Expertise is distributed within and between communities. Knowledge does not move only from the more knowledgeable to the less knowledgeable group; the ideal arrangement is one in which both groups gain in knowledge through their participation in a joint effort.

Pervasive Knowledge Building. Creative work with ideas is integral to all knowledge work, and all tasks and activities represent an occasion for knowledge work.

Constructive Uses of Authoritative Sources. To know a discipline is to know the authoritative sources that mark the current state of knowledge and its frontiers. Knowledge innovation requires respect and understanding of these sources, combined with a critical stance toward them.

Knowledge Building Discourse. The discourse of Knowledge Building communities results in more than the sharing of knowledge; the knowledge itself is refined and transformed through the discursive practices of the community—practices that have the advancement of knowledge as their explicit goal.

Concurrent, Embedded, and Transformative Assessment. Assessment is part of the effort to advance knowledge--it is used to identify problems as the work proceeds and is embedded in the day-to-day workings of the organization. The community engages in its own internal assessment, which is both more fine-tuned and rigorous than external assessment, and serves to ensure that the community's work will exceed the expectations of external assessors

The principles link together into a system and we urge against treating them as a checklist. One principle, especially difficult to implement, is "Improvable Ideas." In conjunction with the principles of "Epistemic Agency," and "Community Knowledge" it implies collective responsibility for knowledge advancement. All serious educational programs aim to improve students' ideas, but overwhelmingly it is the teacher's responsibility to make this happen, whether through direct instruction, guided discovery, or some means of inducing cognitive conflict. The assumption seems to be that students will remain perfectly satisfied with their own ideas unless something is contrived to produce a change. But in a healthy Knowledge Building culture, the shared goal of advancing a knowledge frontier has dissatisfaction with the current state of ideas as a presupposition. There is no need to induce cognitive conflict; the need to improve existing ideas is constitutive of the community, it is why the community exists in the first place. We find that teachers who cultivate a sense of ideas as improvable have an easier time developing a Knowledge Building community. Even very young students come to understand that, as one child put it, "the more you know the more you know what you don't know." And attention to what is not known—cutting edge issues in the classroom and in the field—help sustain the creative energy of the community, with students coming to feel themselves part of a knowledge-creating culture in which participants have worked for millennia to improve ideas.

Where is Knowledge Building Heading?

For some years we have been arguing that the emerging "knowledge age" poses an educational challenge that can best be met by adopting a Knowledge Building approach. This message finds a receptive audience around the world, especially in countries where capacity for knowledge creation and innovation is seen as a society-wide challenge rather than the province of a highly trained elite. That is why we have made "the democratization of innovative capacity" a major theme of public pronouncements about Knowledge Building. Boosting innovative capacity is a high priority in all developed and developing nations, and linking this priority to educational priorities at all levels is bound to happen. Economic competition may be the driving force, but the need extends well beyond that. As Homer-Dixon (2000, 2006) has argued, there is an unprecedented need for "ingenuity," for good ideas to address problems such as resource shortages, global warming effects, deadly epidemics, and genocide; and the need is especially acute in poor nations. In advancing "ingenuity," schools have a dual responsibility, both to develop talent in working creatively with ideas and to disseminate ideas themselves, especially those powerful ideas in science and other fields that serve in generating new ideas. Knowledge Building as an educational approach meets these two responsibilities.

It engages students deeply in creative work with the most important ideas currently recognized.

Unfortunately, there is a wide gap between recognizing the need to increase and democratize innovative capacity and knowing what to do about it. This represents an "ingenuity gap" in its own right, and a gap that can perpetuate other ingenuity gaps. Outmoded concepts of creativity and electronic makeovers of traditional school activities provide handy ways to avoid coming to grips with the actual complexities of the challenge. We cannot say that Knowledge Building in its present state provides the ultimate answer. It only provides the best provisional answer we are aware of, while work goes on to provide a better one.

A better answer almost surely depends on a deeper understanding of knowledge creation. The existing theory, as promoted in knowledge management circles, describes an iterative step-wise process that bears only a superficial resemblance to the lived experience of knowledge creation and leaves the mysterious parts unexplained (Gourlay, 2006). An adequate theory must take into account the self-organizing character of knowledge creation (Stacey, 2001), where self-organization and emergence are recognized at all levels from the neural to the cognitive to the socio-cognitive and on up to the epistemic, where it is ideas themselves that interact to form more complex ideas. We predict that eventually all learning, cognitive, and educational theories will be reconstructed on the basis of self-organizing systems concepts; Knowledge Building theory is no exception and more amenable to such reconstruction.

On the practical side, much more effective means need to be invented for promoting collective responsibility for idea improvement. Continual idea improvement is the hallmark of a progressive society, and the present age calls for this responsibility to be much more widely distributed than before; yet "improve your theory" is a challenge almost never encountered outside advanced graduate work. The first obstacle to overcome is a conceptual one: Even the most strongly committed constructivists we talk to are stymied by the fact that children cannot be expected to make original contributions. We have tried repeatedly to answer this objection, but it keeps re-arising, like the undead in a horror movie. A number of articles in this special issue provide examples that may convince readers that what students do in Knowledge Building classrooms compares favorably with what many professionals do that gets credited as knowledge creation. However, in the final article in this special issue we try to develop a realistic conception of knowledge creation as cultural practice that can include students, even quite young ones, as legitimate participants.

Among those who accept that children can be legitimate creators of knowledge (mainly because they have seen it happen), the pedagogical design challenge is more down-to-earth. As noted previously, working to improve ideas does not come naturally the way generating new ideas does. The challenge is to make this unnatural act normal, commonplace, universal, and enjoyable. Similar challenges are faced by education all the time. Speaking is natural but reading is not (Gough & Hillinger, 1980). Nevertheless, most people master reading to the point that it becomes "second nature"—to such an extent that in some situations people have to exert effort *not* to read what appears before them. A comparable state would be for students to find it natural, almost irresistible, to pursue the question, "How could this idea be improved?" Such a state may or may not be a realistic educational goal, anymore than it is realistic to expect every student to become an avid reader or a lover of learning. But it suggests a line of educational development that educators have scarcely begun to explore and that in the future may be on a par of importance with developing "a nation of readers" or a "community of learners."

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