philosophy and social psychology of science and provides a conceptualization of knowledge creation that is as applicable to primary school education as it is to the creative work of scientists and designers. Knowledge building became a unifying theme for the varied projects of the Telelearning NCE and an idea that many of the innovations to be described in later chapters sought to embody. Whereas knowledge building is mainly focused on process, MOT is a conceptual framework that focuses on learnable content and skills. Growing out of instructional design theory (Reigeluth, 1987), MOT aims to provide a coherent basis for selecting and organizing elements of instruction.

Carl Bereiter

Knowledge Building

Knowledge creation has in recent years become the topic of numerous how-to-do-it books for managers and the focus of research into the workings of scientific teams. This trend is not surprising, given the high priority placed on innovation and "intellectual capital" and the rising expectations of scientific progress. But this trend seems to have little connection with knowledge as it is typically understood in education. Except at the graduate school level, education has little concern with creating knowledge that is new to the world. Yet there is a growing expectation that education at all levels should equip students for life in what Peter Drucker has termed the "Knowledge Society."

The concept of *knowledge building* serves to connect knowledge creation and knowledge work as these are understood in the adult world with essentially similar activity that can go on in schools. The connecting link is suggested in a paragraph by the philosopher of science, Sir Karl Popper:

> What I suggest is that we can grasp a theory only by trying to reinvent it or to reconstruct it, and by trying out, with the help of our imagination, all the consequences of the theory which seem to us to be interesting and important.... One could say that the process of understanding and the process of the actual production or discovery of... [theories, etc.] are very much alike. Both are making and matching processes. (In Popper & Eccles, 1977, p. 461.)

The essential message here is that, from the standpoint of process, creating knowledge new to the world and actively working to understand existing knowledge are the same; only the outcomes are different. "Knowledge building" gives a name to that process. A grade 6 student's description of the process is striking similar to Popper's:

> I think that I can tell if I've learned something when I'm able to form substantial theories that seem to fit in with the information that I've

> already got; so it's not necessarily that I have everything, that I have all the information, but that I'm able to piece things in that make sense and then to form theories on the questions that would all fit together..

The concept of knowledge building serves as a foundation for a wide range of innovative work spanning elementary school to professional practice and knowledge work. The concept originated in the work of the CSILE research team in Toronto (see Chapter 1), and has been developed through research over a period of years, from the 1990 SSHRC project, "Constructive Processes in Knowledge Building," to the Telelearning NCE, "Knowledge Building Communities" projects and is now being researched on a worldwide basis through an SSHRC Initiative on the New Economy project titled "Beyond Best Practice: Research-based Innovation in Learning and Knowledge Work."

The term "knowledge building" has come into wide use (more than 50,000 Web documents contain it, as of March, 2003). When used with reference to adult work, it usually has a meaning consistent with the idea of knowledge creation. When used with reference to education, however, it often serves merely as a glorified label for a broad range of constructivist activities, including collaborative learning, guided discovery, project-based learning, communities of learners, communities of practice, anchored instruction, and so forth. Accordingly, the principal theoretical effort has been to show how the adult meaning can be translated into a distinctive approach to education. To do this, it is essential to distinguish learning—the process through which the cultural capital of a society is made available to successive generations—from knowledge building—the deliberate effort to increase the cultural capital.

Dynamics of Knowledge Building

Knowledge building is work on the creation and improvement of ideas. The dynamic is social, resulting in the creation of *public* knowledge. In contrast to knowledge situated within the individual mind (the traditional concern of education) and knowledge situated in the practice of groups (the concern of situated cognition and communities of practice), public knowledge has an out-in-the-world character. Public knowledge can itself become an object of inquiry and the basis for further knowledge building. Thus there is the possibility of a knowledge *building dynamic*, that drives the continual advancement and improvement and creation of new knowledge. What makes knowledge building a realistic approach to education is the discovery that children as early as grade one can engage in it. Thus there is

a clear developmental link running from childhood education on into advanced education and adult knowledge work, in which the same process is carried out at increasingly high levels.

Although knowledge building grows out of the natural tendency to play with ideas, it has failed if students remain content with their ideas, no matter how impressive they may be. As in the sciences and scholarly disciplines, just as in the worlds of engineering and design, all good ideas are treated as potentially improvable. Once idea improvement becomes established as a norm, students will not only look critically at the ideas that are generated in their own community, but will look to authoritative sources for what others have accomplished, and how their own work stacks up. As E. O. Wilson has argued, if you dig deeply into any question you eventually get to deep underlying principles; and these are the principles that figure in enlightened curriculum guidelines and standards. Thus the challenge is to set in motion a process where community members are hooked on understanding. It is a more knowledge-intensive process, with potentially greater payoff, than following a guiding light.

In knowledge building classrooms, as in knowledge creating organizations, ideas are set forth as new cultural artifacts (Bereiter, 2002) to address problems of understanding and practice. New knowledge media allow these artifacts to be contributed to a community knowledge base—the parallel of publication in scholarly disciplines. This facilitates their use as shared intellectual property and gives them a chance for a life beyond the transitory nature of classroom discourse and its isolation from other discourses. In turn, they become objects for continual testing and improvement. Continuing advances in public knowledge result in continually setting higher standards of performance, reformulating problems at more complex levels, and increasing the amount of knowledge that is presupposed. Thus there is a compounding effect, much like the compounding of capital by investment. Supporting such compounding is the main challenge in the design of knowledge building principles, practices, and environments (Scardamalia, 2002).

A Knowledge Building Example

A common first-grade topic is the seasons, although it is often focused more on concrete manifestations of seasonal change than on the ideas behind it. In one knowledge building classroom, however, the students became interested in what causes leaves to change color in the fall. Various theories were proposed, and the students sought ways to test them. For instance, they put leaves in a freezer to see whether cold alone would cause the color change. Many of the theories were represented by drawings rather than text—for

instance, a theory that the cold cut off the chlorophyll to the leaves. Some months later, on a trip to a maple sugar farm, one of the children exclaimed, "My theory must be wrong. The sap isn't green!" A revised theory had the green sap descending through the center of the tree, while clear sap remained in the outer layer.

This example illustrates characteristics that are shared with knowledge creation at advanced levels but that are typically absent from school activities, even those of an explicitly constructivist or inquiry-oriented nature. First, although there is ample "hands-on" activity, ideas rather than tasks or activities are at the center of attention. Second, the pursuit of new knowledge is open-ended; it does not have a predetermined end-point, as in guided discovery. Third, the ideas are treated as objects of inquiry. Fourth, ideas are treated as improvable. And fifth, knowledge-building is ubiquitous; it is not confined to particular periods, projects, subjects, or contexts.

Indicators of Knowledge Building

Reducing knowledge building to activities and procedures tends to lead to "I-already-do-that" or to dependence on the specified activities. The challenge of knowledge building is to innovate at all levels—including the activities through which knowledge building is realized. Innovative work is going on in a wide range of nations, many linked through the Institute for Knowledge Innovation and Technology (http://ikit.org). To understand this work is to imagine an interconnected set of practices, with students in control, but their work far from aimless, demonstrating better-than-traditional learning, while opening the doors for knowledge creation. The following questions are intended to get beneath surface activities to reveal whether what is going on actually represents knowledge building:

- Are students empowered to take responsibility at the highest levels of knowledge work—to establish goals beyond what others set for them?
- Do students take pride in the knowledge advances of the whole community, share responsibility for what is accomplished, and value others' contributions as well as their own?
- Are ideas considered from the standpoint of improvability and potential usefulness or only viewed from the standpoint of personal expression or knowledgeability?
- Are the products of one unit of work input for another round of knowledge building or are they parceled out in time-and-topic-bound units?

- Does creative work with ideas occur spontaneously throughout the day or is it confined to certain higher-order thinking or student-inquiry times?
- Do discussions (oral or online) show persistent development of ideas or do they consist mainly of factual reports and brief exchanges of opinion?
- Is assessment part of the self-regulatory process of the organization, or primarily something imposed from outside?
- Do students view their work as an extension of the way ideas evolve in out-of-school contexts?
- Do students see their own minds and the world around them as a powerful source of improvable ideas, or is their role confined to asking questions, to which others have answers?

The main expectation is that, through long-term engagement in knowledge-building processes, students will move toward full membership in the large and historically extended community of people who build knowledge. This does not mean that other educational objectives are slighted. Evaluations indicate that students in knowledge building classrooms gain advantages in literacy, in a host of "21st Century Skills," in core content areas, in the ability to learn from text, and yet do not suffer in other areas of achievement (Scardamalia, Bereiter, & Lamon, 1994).

Marlene Scardamalia
For more information:
Scardamalia & Bereiter, in press.

A Description of MOT

The MOT (Modeling using Object Types) knowledge editor is an innovative modeling tool designed to enable users to construct visual representations of knowledge and knowledge relationships. It is useful to situate MOT within the context of other tools of its kind. Computer Assisted Software Engineering (CASE) tools are used by software engineers to build, transform and analyze complex models. As such they are not well suited to pedagogical engineering or business process re-engineering. On the other side of the spectrum, drawing tools enable users to describe a model, but do not include the underlying representation of objects. MOT is the first modeling tool to address the gap between drawing tools and CASE tools.

MOT was developed primarily for use by instructional designers engaged in pedagogical engineering and as such has a number of unique features. First, it is easy to use; teachers, business people and adult learners