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14

Schools as Knowledge-Building Organizations

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Although schools are learning organizations in the sense that they promote learning, few would quality as learning organizations in the larger sense of the term now current in organizational theory (Senge, 1990; see Rohlen, Chapter 13, this volume). Indeed, from an organizational standpoint schools are often seen as bureaucratic institutions particularly resistant to the kind of purposeful change from within that characterizes learning organizations. But what would it mean for schools to become learning organizations? There are two quite different ways of answering that question. One would constitute an overhaul in management and the organization of work in order for schools to do a better job of performing their traditional functions. The other is a much more radical transformation, in which the basic job of the school is altered. Most current school reform, whether it involves new management structures or the introduction of new standards and curricula, is of the first kind. In this chapter we explore the second, more radical, and also harder-to-grasp form of transformation, which we believe is necessary if schools are to realize their potential in a knowledge society.

Traditionally and typically, schools are service organizations. They provide a variety of services, mainly but not exclusively aimed at the promotion of learning in their clients, the students. (In important senses the clients are not only the students but their parents and the larger society as well, but students are the immediate recipients of most services.) Thus, the first kind of transformation mentioned above involves changes much like those that would occur in any service organization that sets about functioning as a learning organization: layers of management are reduced, and the rank-and-file employees (mainly the teachers in this case) are given fuller responsibilities and are more involved in corporate decisions. A great deal of change of this kind is already underway in many places. Site-based management replaces centralized administration, teachers are given a large measure of control over curriculum, choice of educational materials, and so on. All this is with the aim of providing better services to the clients. And as with many modern organizations the clients are being brought into the Improvement process as well. In Ontario, for instance, the Royal Commission on Learning recommended that each school be required to establish a school-community council with membership to include parents, students, teachers, and representatives from various other sectors of the community.

The second and more radical kind of transformation may be put in perspective by considering a fundamental question: what kind of education will best prepare students for life in a knowledge society? Typical answers to this question list characteristics that such education should foster: flexibility, creativity, problem-solving ability, technological literacy, information-finding skills, and above all a lifelong readiness to learn. Within the service framework just described, the job of the schools is to turn these into educational objectives and thence into learning activities, assessment criteria, and the like. That is already happening as new curriculum guidelines and performance standards emerge (e.g., New Standards, 1995; Ontario Ministry of Education & Training, 1995). But there is another way of approaching the question, which is to consider what kind of experience offers the best preparation for life in a knowledge society. The obvious answer is experience in a learning organization. The implications of this disarming answer are quite radical, however. For if schools are to constitute the learning organizations in which students gain experience, the role of students must change from that of clients to that of members. This means changing the function of the school from that of service provider to that of a productive enterprise to which the students are contributors. But what is that productive enterprise? To what are the students contributors?

The idea of students as participants, along with teachers and perhaps others, in a collaborative enterprise has been around at least since John Dewey but has been taking a more definite shape over the past decade in various experimental programs. The new approaches are all to some extent based on the model of the scientific research team, which has also served as an inspiration for reforms in industry (T. Peters, 1987) One popular formulation of the idea is "cognitive apprenticeship" (Collins, Brown, & Newman, 1989), which captures the notion of students as junior members of a discipline rather than as recipients of instructional services. The term is not quite apt, however. As a rule, students are not apprentice teachers and school teachers are not practitioners of the disciplines they teach, and so the apprenticeship metaphor does not fit. A. L. Brown and Campione (1990, 1994) have used the term "fostering communities of learners" to characterize the very impressive approach they have developed. In it, teaching and learning are closely intertwined. In a typical activity, different groups of students research different aspects of a topic and then instruct the members of the other groups. Perhaps the most thoroughgoing application of the research team model is in what we call "collaborative knowledge building" (Bereiter & Scardamalia, 1992; Scardamalia, Bereiter, & Lamon, 1994). This approach rests on a recognition that the construction of knowledge, as it goes on in the learned disciplines and applied sciences, is different from learning although closely related to it. The distinction is obvious in the work of a scientific research team. The team's job is to produce new knowledge. The individual and collective learning that goes on within the group is secondary-a by-product of knowledge production and a contributor to it (Bereiter & Scardamalia, 1996). Some uses of the term "learning" include innovation within it (see Rohlen, Chapter 13, this volume), but common usage can obscure the central theme we emphasize here, the construction of knowledge.

In classrooms that adopt the collaborative knowledge-building approach, the basic job to be done shifts from learning in the conventional sense to the construction of collective knowledge. The nature of the work is essentially the same as that of a professional research group, with the students being the principal doers of the work. Thus, in the ideal case, there is a complete shift from students as clients to students as participants in a learning organization.

Two terms that may be applied to this kind of educational approach are "problem-based learning" (Savery & Duffy, 1995) and "project-based learning" (Blumenfeld et al., 1991). However, both of these terms cover a range of educational approaches of a less radical nature. Problem-based learning often consists of set problems, such as diagnosing a medical case, explaining a demonstrated scientific phenomenon, or planning a trip to Mars. Community knowledge building, by contrast, deals with problems that arise within the community-real phenomena that people are puzzled about, real texts in need of interpretation, and so on. Project-based learning is often focused on the production of tangible products, such as multimedia presentations, whereas the focus in knowledge building is on the knowledge itself, its physical representation being secondary.

On the face of it, it may seem strange to claim that focusing education on knowledge represents a radical transformation; yet educators in our experience invariably recognize it as radical, once they grasp the idea. But grasping the idea is not easy, and it seems to be more difficult for educators than it is for people in knowledge-based businesses, for instance. The reason, it seems, is that in the educational context people tend to think of knowledge exclusively as content residing in people's minds. The conception of knowledge as resource or knowledge as product, as something that can be created and improved, bought and sold, discarded as obsolete, or found to have new uses-this conception is commonsensical to people in knowledge-based businesses. It can coexist with but is not the same as the educators' conception of knowledge as stuff in the mind. The essence of our argument is that children destined to live in a knowledge society need an educational experience that makes this other conception of knowledge a part of their commonsense understanding as well, a concept that gives meaning to the work they do from day to day.

AUTHENTIC KNOWLEDGE BUILDING

The authenticity of students' knowledge-building efforts is crucial to the conception we are trying to develop of schools as learning organizations. In traditional schools students do work. Indeed, interview studies indicate that to most students and to many teachers, doing schoolwork is basically what school is about (Bereiter & Scardamalia, 1989; Doyle, 1983). But the work only has meaning in relation to benefit gained by the worker. Thus it is analogous to the bodybuilding work one may do in a gymnasium. In more child-centered schools, students have more freedom to pursue their own interests and curiosity and thus to take a more active part in their own mental development. But in neither case do the students gain the experience of doing productive work that has value beyond the satisfaction of their own or their teachers' needs. Community knowledge building, by contrast, is aimed at producing something of value to the community-theories, explanations, problem formulations, interpretations, and so on, which become public property that is helpful in understanding the world and functioning intelligently in it. The knowledge that is created may not have much value beyond the local group (we will discuss current efforts to overcome this limitation later), but within that group students are contributors to a common good. Like workers in a modem industry, they are contributing to the knowledge resources of the organization.

But how authentic can student knowledge building be? Aren't the students in reality only pretending to be scientists, historians, mathematicians, or whatever? There are two notable differences between knowledge building as it goes on in schools and as it goes on in professional research groups that prompt such skepticism. A professional research group usually has a specific problem area-AIDS research or the ecology of the Great Barrier Reef, for instance. An elementary school class, however, has the whole world as its problem area. But so did Aristotle. Breadth of scope does not disqualify a research program as scientific or scholarly. *The job of an elementary school class that adopts a knowledge-building approach is to construct an understanding of the world as the students know it.*

The other difference, of course, is that a professional research group is expected to produce knowledge new to the world, to solve problems that have never been solved before, whereas students, with rare exceptions, will only produce knowledge that is new to them. Furthermore, the knowledge constructed by students will mostly be derived from reference books and other secondary sources, less frequently from experimentation and primary data. This does not discredit student knowledge building, however. We will pursue this point at some length, because it requires the revision of several popular notions about science.

Producing knowledge new to the world is an achievement, not a process. A research team might find out that what they took to be an original finding had already been reported by someone else. This would diminish their achievement, but it would not make the work they had done any less scientific, any less authentic. What makes work "scientific" is a matter of continuing controversy and is not a matter to be settled here; but we may at least agree that science is a form of social practice that goes on, with wide variations, in groups recognized as scientific. To the extent that the practices of any group conform to those of recognized research teams, the group may be said to be practicing real science-regardless of its achievements. During the Cultural Revolution in China, many scientists were forced to abandon their research for more than a decade and were also denied access to scientific journals and to communication with foreign researchers. When that terrible experiment in the suppression of inquiry ended and these people went back to their work, they of course had a great deal of catching up to do. It would be some time before they could begin making original contributions to knowledge again, but they did not have to wait that long to start functioning again as real scientists. They could do that as soon as conditions allowed them to resume the social practices that constituted doing science in their culture and discipline. We see school-age students as being in a similar situation, except that they have about 500 years of science to catch up on instead of 15. They can begin functioning as real scientists as soon as they are able to engage in a form of social practice that is authentically scientific, one that is concerned with the solution of recognizably scientific problems in recognizably scientific ways. Analogous arguments can be made about authentic functioning in history, literature, and other disciplines that students may venture into in their knowledge building efforts.

Many educators of a constructivist persuasion would accept the preceding argument as it applies to experimentation and other "hands-on" activities of students, but they would not extend it to the very large part of student knowledge building that depends on information and ideas drawn from reference books and other authoritative sources. Indeed, they might reject this as not knowledge construction at all but mere receptive learning, or "knowledge transmission," as it is sometimes called. Any theoretically sensible construal of constructivism, however, will recognize that understanding is a constructive process regardless of where the information comes from. In judging whether authentic knowledge building is going on, the question to ask is not whether students are doing experiments as opposed to reading books but whether they are trying to solve knowledge problems. Doing experiments or tramping the bushes collecting plant samples in no way guarantees that they are. Trying to make sense of information about a topic of interest almost always ensures that they are.

Construing knowledge building as the solving of knowledge problems has the advantage that it puts scholars who are advancing the frontiers of knowledge under the same umbrella as students who are engaged in building an understanding based largely on knowledge that has already been set forth. Constructivism's important contribution here is in the recognition that, though the achievement is different, the process is essentially the same. As Sir Karl Popper put it,

> 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. (Popper & Eccles, 1977, p. 461)

Scientists devote a good deal of time to trying to understand what their colleagues are up to and what they have accomplished (Dunbar, 1993). In doing so, they are reconstructing solutions rather than creating them de novo, Just as students do who try to understand how we see colors by working their way through a textbook explanation. The inventive and the reconstructive processes are so much alle and merge into one another so smoothly that participants in a lively research meeting would probably be hard put to say where reconstructing left off and working on new ideas of their own began. Similarly, students who are actively trying to solve a knowledge problem will move readily between developing ideas of their own and trying to negotiate a fit between their own ideas and information obtained from an authoritative source.

This dual character of knowledge building comes through in the following interview excerpt. A middle school class was studying the major biomes. The speaker and his classmate, Brian, were trying to determine why trees do not grow in the Arctic tundra:

> "I thought it was because a tree would freeze, but then I realized that a tree probably couldn't freeze. I don't know about that because me and the kid that's working are still kind of writing.

> But I thought it was probably just because of the water would freeze and now I realize that its not-its definitely not just the water. There's the wind, nutrients, and the permafrost, and the daylight and everything basically plays a factor in it so....
>
> "There's a speaker that came to talk about tundra. And so Brian got to go to that because he had studied tundra and he asked. And my new learning is all about what he told me and why trees don't grow. Actually, we don't really agree with the speaker on some of the things.... He said that the roots weren't very deep. And I figured this didn't make sense because so what if roots aren't deep? Because if the roots are very shallow in the rain forest because there's not any nutrients deep down in the rain forest, so there's not many roots. And then I asked several tundra people.... We kind of think that he's partially right, but we don't understand why that would be true. We believe in that there isn't much water there, but we don't understand why it's for the tree, because obviously the tree needs water to grow. But there's not much water in the desert..."

The last remark reflects the fact that the student also consulted students in another group who were studying deserts, in order to find out how trees got along there with little water.

This example illustrates characteristics that, distinguish knowledge building from ordinary school learning activity:

1. The student and his classmates exercise a high level of responsibility. What they are responsible for, however, is not a tangible product such as a display or a presentation (although that may come later). They are responsible for achieving advances in their group's knowledge.

2. Although worthwhile learning undoubtedly occurs, learning is not what they are responsible for. Instead, they are accountable for contributing to the solution of problems-in this case, the problem of why trees do not grow in the arctic tundra.

3. The problems they are working on are not practical problems (such as how to survive in the Arctic). They are knowledge problemsmainly problems of explanation.

When we speak of a school functioning as a knowledge-building community, on the model of research teams and other knowledge-building organizations in the adult world, we have in mind a school in which activity of the above kind is the major occupation of the students. Such work need not be limited to the natural sciences, of course. It may venture into all curricular areas; but always the focus is on the solution of genuine problems of understanding.

THE NEED FOR A NEW DISCOURSE MEDIUM

The centrality of discourse to knowledge creation has come to be recognized throughout the sociology and philosophy of knowledge (Harre & Gillett, 1994). It reveals itself in the variety of discourse forms, ranging from hallway conversations and brown-bag lunches to peer-reviewed archival journals, that make up the fabric of communication within every discipline. By contrast, knowledge-related discourse in schools tends to be sporty, ephemeral, severely time bound, and almost unavoidably dominated by the teacher, who acts as the hub through which communication passes (Cazden, 1986). Computer network technology, however, provides possibilities for more decentralized forms of discourse that have more of the knowledge building capabilities of discourse in the disciplines. CSILE (Computer Supported Intentional Learning Environments) was developed with a view to realizing these possibilities.

CSILE was not intended to replace either teacher-led or small-group discussion. Both of these have a place in any classroom. Rather, CSILE was designed to complement these in ways that further promote community knowledge building. CSILE is an asynchronous discourse medium, which means that participants do not have to be engaged at the same time, as they do in an oral discussion or in a telephone conversation. In this way it is like e-mail. But, unlike e-mail, it does not consist of person-to-person messages. Instead, it consists of contributions to a community database, which resides on a server and is accessible to everyone in the network. Thus, the knowledge represented by notes in the database is preserved and continually available for search, retrieval, comment, and revision. The database as a whole serves to objectify the advancing knowledge of the group.

Knowledge Forum-is a second-generation CSILE product that includes Views, which provide high-level graphical organizers for notes and allow notes to be linked to any organizational framework; Rise- above notes that encourage summarization and allow notes to supersede other notes; customizable Scaffolds to support discourse (e.g., theory- building discourse such as "My Theory," "I Need to Understand," or "New Information"); and Reference features that create automatic bibliographies and allow quick access to cited on-line information. For a fuller description, see Scardamalia and Bereiter, 1996 (or visit the CSILE Web site at http://csile.oise.on.ca).

As is true of any medium, much depends on how it is used. In the course of a decade of classroom experimentation, practices have been developed that make good use of CSILE's distinctive supports for knowledge building. We may refer to these practices as collectively constituting a *knowledge-building pedagogy*. Keeping in mind that the objective is not to replace one kind of practice by another but to add missing elements and redress imbalances, we may characterize knowledge building pedagogy by means of a series of contrasts with conventional practices:

• *Problem focus versus topic focus*. Traditional schoolwork, of both the didactic and the project-based variety, deals with knowledge organized around topics. Unless the topics happen to be of high intrinsic interest, they are likely to result in low motivation, low transferability, and rapid forgetting (Bereiter, 1992). Problem-based learning (Savery & Duffy, 1995) has developed as antidote to these difficulties. Knowledge-building pedagogy is a distinctive variant of problem-based learning, emphasizing problems of understanding and explanation rather than decision problems, as is more often the case when problem-based learning is used in professional education. A problem focus is supported in several ways. A special field on each note encourages users to identify the problem they are addressing, and if a note builds on another, it inherits the problem statement of the parent note, thus aiding coherence and focus. Students enter new problem statements, and can view related problems identified by others.

Scaffolds also help to frame the field of discourse, encouraging students to produce "I Need to Understand" notes that identify knowledge they require in order to advance on their problems.

- *Production of knowledge objects versus media objects*. Knowledgebuilding pedagogy deals with knowledge rather than with the containers of knowledge. Whereas typical school "projects" involve producing a visible object, such as an illustrated report or (the latest rage) a Web page, Knowledge Forum objects are notes or composites of notes, which others respond to on the basis of their content, not their production values. These text and graphic notes are contributed to Views, which are the high-level visualizations of the work on a particular problem or issue. Notes and Views may be converted into illustrated reports, Web pages, multimedia presentations, and so forth, but they do not need to be converted for their value to be evident.

- *Contribution versus display*. The traditional class "recitation," as well as much of traditional written work, is concerned with students demonstrating what they know (or do not know), whereas in normal life using conversation to display what one knows is egotistical. One is supposed to say things that contribute to the common purpose. Although knowledge display (including its formalization in subject-matter tests) has its place in education, knowledge-building pedagogy relegates it to special purposes and places the main emphasis on contributions to the progress of knowledge-building discourse.

- Theory improvement versus finding answers. A long-time ideal of learner- centered educational reform has been to have the curriculum driven by children's own questions (Isaacs, 1930; Weber, 1971). However, when children know they are going to have to seek answers to questions, they tend to ask the kinds of straightforward questions that they can readily find answers to in school books, thus defeating the purpose (Scardamalia & Bereiter, 1992). This difficulty can be surmounted by having students first state a problem, then offer a conjecture (hence the "My Theory" Scaffold support in Knowledge Forum), and then undertake to improve upon that conjecture (Scardamalia, Bereiter, Hewitt, & Webb, 1996). Whereas answers are often unattainable, improvement on initial conjectures almost always is. Not only does this result in more experience of success, it also comes much closer to the way scientific advancement actually takes place.

- *Sustained versus single-pass knowledge creation*. Freewheeling classroom discussions are often full of good ideas and questions. However, these are unlikely to be followed up or to lead anywhere unless through the teacher's Socratic guidance. Knowledge Forum also provides a medium for generating abundant ideas and questions, but these are preserved, continually available for further discussion and revision. Analysis of tracking data indicates that significant conceptual change is closely related to students' returning to earlier notes and revising them in the light of classroom comments and new information (Oshima, Scardamalia, & Bereiter, 1996).

- *Public versus person-to-person communication*. Classroom discourse presents anomalies with respect to audience. Oral communication is almost always directed to a single person, usually the teacher. Written composition typically has no intended audience at all, which reduces it to mere exercise (Applebee, 1984). Knowledge-building pedagogy shifts the focus to that which characterizes knowledge work generally: communication that is implicitly directed toward everyone "to whom it may concern."

• *Opportunity for reflection versus 1 -second wait time*. A remarkable finding about recitation and teacher-mediated discussion is that teachers typically wait about 1 second for a response before calling on someone else or responding to the question themselves (Rowe, 1974). An asynchronous medium lets students take their -time in formulating a contribution. It also reduces the social and emotional barriers that prevent some children from taking part in oral discussions (Lampert, Rittenhouse, & Crumbaugh, 1996).

Although none of these pedagogical shifts is dramatic, in combination they can produce a radical transformation of schooling processes. The students are assuming collective responsibility for the solution of knowledge problems, and the teacher is helping the students grow into that responsibility.

EXAMPLES AND FINDINGS

Table 14.1 provides a sampling of contributions by grade 5 and 6 students to a fairly representative CSILE discussion. A curriculum unit in science or social studies is typically launched by the teacher's framing a very general problem that is central to the relevant discipline. It is then up to the students to formulate the more specific problems that will enable their inquiry to move ahead. The early contributions to a discussion typically consist, as illustrated by the first nine items in Table 14.1, of *conjectures*-usually naive-and questions-often quite cogent, like why we have two eyes rather than one or three. The naive conjectures do more than provide a starting point for knowledge advancement. They bring to the fore the students' relevant knowledge, which they are going to have to use in making sense of the new information they encounter and which it is hoped that they will try to reconcile with the new knowledge. (The alternative of leaving one's existing knowledge off to the side and treating the new knowledge as if it applied to a different world appears to be one of the ways in which serious misconceptions take hold; Vosniadou & Brewer, 1987.)

Table 14.1. Contributions of Grade 5/6 Students to Discussion on "How Does the Eye Work?"

- "I think a special set of nerves carries messages from the eye to the brain and back. These messages tell the brain what the eye 'sees.' "
- "I think that the eye works by when the light behind the eye builds up and the light goes through lots of tiny blood vessels and comes out a lens in the front of the eye, that way the lens gives the eye something to see clearer through. I think that when the brain tells the eye to look at something the eye immediately turns to the object."
- "Why two eyes not one eye or three eyes?"
- "Why do people have different coloured eyes-does it affect their eyesight at all or does it just happen by chance?"

- "Why do people see up things right and they see upside-down things on the inside."
- "What are nearsightedness, farsightedness, astigmatism and presbyopia? I would like to know if they are permanent and if not, must they heal naturally? Can they be prevented before they start, or can you be born with one or more of them?"
- "I think that the eye works like this: When the person looks at the picture like a tree the picture turns upside down in the brain but in our eyes it looks like it is not upside down."
- "I think that 20-20 vision is when you can see 20 feet behind and 20 feet in front, and I think that 20-20 vision is the best vision that you can get."
- "The eye provides visual information by changing light waves into nerve impulses that are interpreted in the brain."
- "In a small area, what a person sees is detected by nerve cells. These cells are spread out on the retina, which lines the inside of the eye. There are two types of nerve cells: rods and cones. There are over one hundred million rods in each of your eyes, they detect black and white. There are only seven million cones to detect colour. Each time light hits a cone or rod, they send a nerve signal which goes out of the eye and down the main nerve passage to the brain. At the brain's 'sight centre" the impulses are sorted out to create an image. The black and white pictures are combined with the colour pictures, and then the two images from both eyes are combined.
- "I need to understand why people can see in the light but not in the dark?"
- "Cones and rods that send the picture right to the brain, you can see the picture, it does not have to go to the eye."
- "When our eyes open, our central nervous system is exposed which causes our brain to be well prepared for any sudden moves. It will cause our eyes to blink or shut."
- "I think the eye sees more what the brain wants to pay attention to that what enters the eye. So when the eye sees something it is more the brain that is at work to see what it wants to pay attention to."
- "If our lens doesn't change what we see upside down, will our nerves still flip what we see over and would we realize that we are not really upside down?"
- "Last night I learned that when you think you are looking at something, you're not. It is really like bouncing off the object and then the fight goes to your eye. That is the reason why you can't see things in the dark. So there is no light to bounce off the object and hit your eye."
- "White light is the light called when it already reached your eyes. When the fight gets to the retina the image that you saw is upside down. Then nerves in our eyes sends the message to the back of the brain that is called cortex. In this part of the brain the depth and another thing gets together and colour and shape gets together, then they travel in front of your brain to make the right figure. One third of the brain is for sight."

Over the course of the discussion, as new information is brought in from books and from an expert whom students could consult, one can see the students' statements beginning to take on the shape of standard scientific explanations of vision, although oversimplifications and misconceptions still appear. The students are clearly engaged in what we earlier described as reconstruction. They are not simply parroting the authoritative sources. They are reconstructing what they have read or heard so that it makes sense in fight of what they already know and reconstructing their prior knowledge in light of the new information. As Popper said, these are "making and matching processes." The following two entries were spaced a day apart, with input from a medical doctor occurring in between. The refinement of understanding that they exhibit is clearly not simply a matter of absorbing what the expert said; it is a matter of incorporating new information into a knowledge-building effort that was already well advanced:

> "95.04.04.
>
> Today I learned that the Fovea is sensitive to colour because of the cones. And I also learned that Rods help you to see in the dark. I also learned that there is a yellow spot in the middle of your Fovea, it is called the Macula Lutea. The reason why the Macula Lutea is yellow is probably because red and green cone detectors perhaps reflect yellow."

> "95.04.05.
>
> Today I learned that our educated guess (hypotheses) was wrong. It is yellow because inside our retina there thousands of blood vessels, except near the fovea where the macula Lutea is. There is very little amount of Blood vessels near it and the tissue around it also gives its colour. He also said that the reason why there is a minimal amount of blood vessels in front of our fovea is because they might interfere with the cones that identify colour."

The teacher's role in a discourse like this consists mainly of one-on-one discussions with students about their contributions. Thus, the teacher is not leading or taking responsibility for the knowledge-building effort but is helping individual students shoulder their responsibilities. The technology is virtually indispensable here. It is what enables the teacher to monitor what is happening and provide individual coaching without intruding upon the discourse itself.

In another publication, we examined a CSILE discussion that arose spontaneously in another school and that went on for 3 months, comprising 179 entries (Bereiter, Scardamalia, Cassells, & Hewitt, 1997). Beginning as a personally oriented discussion about growing, it evolved into a scientific inquiry into what regulates bodily growth. Besides pursuing various knowledge sources, the students undertook an empirical study of parent-child correlations in height so as to test whether height was genetically determined. Hakkarainen (1995) has studied a number of CSILE discussions on science topics to ascertain the extent to which they conform to canons of scientific inquiry. His conclusion, buttressed by independent judgments from two philosophers of science, is that the students collectively exhibit a high level of what may properly be called scientific thinking. Hewitt (1995) has traced the changes that took place in one classroom over 3 years as the focus was shifted from personal knowledge accumulation to the collaborative solution of knowledge problems. One of the interesting markers of this shift was an increase in the number of epistemological terms occurring in students' notes. Research in progress by Jan van Aalst (1999) indicates that contributions to knowledge advancement tend to come from students who write a substantial number of notes early that explicate their naive conceptions. In view of the concern that many educators express about student discussions propagating misconceptions, this is a potentially important finding. It makes sense that misconceptions are more likely to be changed if they are brought out into the open rather than remaining hidden from view, as they evidently have been in ordinary school programs.

TEACHING AND LEARNING

A focus on knowledge building does not negate the school's responsibility for individual students' learning. From a learning standpoint, it replaces one indirect means by another. In typical modern schools, learning is an indirect consequence of schoolwork and projects of various sorts. In what we have been describing, individual learning is an indirect consequence of knowledge building. An important reason for distinguishing knowledge building from learning in this context is in order to make sense of that last statement. Such a distinction also makes it evident that there is no incompatibility between a focus on knowledge building and the use of direct teaching. In every organization there are procedures and bodies of information to be teamed and skills to be acquired that are necessary for productive work within the organization. Sometimes these can be learned informally as one goes along, but often it is expedient to teach them in a direct manner so as to ensure that everyone learns them and so as to get on with the main work. The same is clearly true in schools, where the things that need to be learned include such basic skills as reading, punctuation, and mental arithmetic.

Some educators act as if a constructivist pedagogy outlaws direct instruction and skill practice, whereas a dear conception of knowledge building as productive work allows the teachers to take a pragmatic approach to learning. They may leave it to come about as a by-product of knowledge building where that proves adequate, but they are ready to move in with more direct approaches as needed. Evaluations of CSILE indicate significant gains in literacy as a by-product of all the reading and writing that go into CSILE-mediated knowledge building (Scardamalia et al., 1992). There are indications that CSILE-based activities can enhance mathematics learning as well (Tiessen, 1996), but we see no way to get around the need for active (though not necessarily didactic) teaching in this area (cf. Lampert et al., 1996). To be avoided is the all-too-common phenomenon of spending 3 years not quite teaching children their multiplication tables.

Teaching in a knowledge building school is not a simple matter, however: on the one hand, teachers are active participants in the collective effort to build an understanding of the world; on the other, they are professionals charged with the welfare and educational advancement of their students. The two roles are compatible, but only with some adjustment. Teachers report it to be exhilarating and liberating to engage in knowledge building along with their students, and in doing so they help authenticate it as real knowledge building rather than routine exercises or playacting. Yet it cannot be the same for teachers as for students, especially as years go by and problems that are new for the students become familiar to the teacher.

In our experience, the teachers who remain continually fascinated and involved are ones who have a dual interest. They are interested in advancing their understanding of history, geology, biology, cultural anthropology, and so forth; and each year they experience some advances themselves as they work with students on problems in those areas. But they are also interested in understanding the process of understanding itself. The students' efforts (and their own as well) to explain phenomena, to grasp theories, and to overcome naive conceptions are an endless source of insights into that distinctively human phenomenon, the pursuit of understanding.

An interest in understanding how understanding grows does not seem to be a feature of most people's curiosity. It is an acquired interest, and one that teacher education programs ought to be passionately dedicated to developing. Without it, we find, teachers tend to remain detached from students' knowledge- building efforts and to reduce knowledge-building activities to merely another set of schoolwork routines.

EXPANDING THE KNOWLEDGE-BUILDING COMMUNITY

Up to this point, our discussion has dealt with knowledge-building communities developed within classrooms. This leaves students isolated from other communities that are engaged in building understanding of the world (e.g., from adult scientists) and also from other parts of the education system, such as curriculum planners. The Internet is already being exploited as a way of breaking down the isolation of classrooms, with exchange of e-mail between distant schools, cross-school research projects, and "ask the expert" arrangements with adult volunteers. As an Internet application, Knowledge Forum offers possibilities of forming actual communities of knowledge-building groups in which school classes are a productive part rather than a client population.

We are currently engaged in experiments that link classrooms and teachers to other classrooms and teachers, to science and art museums, Students at secondary and University levels, educational researchers, subject matter specialists, and research scientists. Different groups carry out their own knowledge-building work using Knowledge Forum, but they will be able to visit other databases and observe, comment, add links to notes in other databases, and construct views reflecting their own perspective on issues of mutual interest. Thus, for instance, science museum curators planning an exhibit on vision might visit databases like the one described earlier, where they can identify potential difficulties students will have in understanding demonstrations and can even try out design ideas on the students. The students, in turn, can visit the curators' database and make comments that could affect the design of the exhibit. Another kind of cross community interaction involves elementary school students and medical school students studying the same health-related problem, with the possible inclusion of researchers engaged with the same problem.

Unlike the many "ask the expert" arrangements that are being tried through e-mail, the knowledge-building approach sticks closer to the idea of a community engaged in solving shared problems. Instead of the experts being cast in the role of question answerer or unpaid teacher, they are free, as are other participants, to find their own roles, to pitch in and help in whatever ways and to whatever extent they wish. Thus, the classroom work on vision discussed earlier could be enhanced by, for instance, giving students access to Chapter 8 in this volume and to the computer-mediated discourse among scientists discussing development of the visual system. The students could insert comments and questions, but these would be addressed to the whole community and would not put pressure on any individual to respond. Max S. Cynader or Barrie Frost or some of their students could in turn visit the elementary school database and get involved in the discussions to whatever extent they wished and in any of the variety of ways that the medium affords.

We have also experimented in a very limited way with breaking down the separation between student discourses and curriculum planning discourses. A database was seeded with the mandated curriculum objectives related to what the students were studying. The students linked their work to appropriate objectives and commented on the relationships, identifying what they saw as additional objectives worth specifying. Although there was no two-way interaction-to curriculum officials were -involved-the experiment demonstrated that students could make contributions to curriculum planning as well as providing rich data for anyone investigating curriculum problems. We are, of course, hopeful that at some point officials at a provincial or state level will want to join in and open up their discourse as well-to students, teachers, researchers, and parents.

These efforts are not based on an exalted idea of what students can contribute. Our assumption, rather, is that students are legitimate members of a knowledge society, albeit novices in most respects. The concept of "legitimate peripheral participation" (Lave & Wenger, 1991) thus nicely represents their role. Like newcomers to any cultural practice, they must work gradually into the centers of activity, and they do so by contributing in ways that are within their growing capacities and that are acceptable to the old-timers. Ordinary schooling provides hardly any opportunity for this kind of peripheral participation, and so students graduate into the work world with little sense of how to function in it. When entering a manual occupation, learning may occur rapidly because so much of the activity is open to view. But much of knowledge work is invisible. The approach we are taking is aimed at developing from an early age the social practices that make people responsible participants in the work of a knowledge society.

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NOTE

1. Practical problems and design problems (e.g., producing a computer simulation or designing a space platform) can have considerable educational value, and we do not question their place in school programs. But because of the way the world runs, such student activities are almost invariably a form of play or pretense and so do not meet the criterion of productive knowledge work that has value beyond the worker's own needs.