Strengthening the Conceptual Foundations of Knowledge Building Theory and Pedagogy

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Abstract: The term "knowledge building," introduced in the late 1980s, has gradually acquired a distinctive meaning within the family of constructivist approaches in education. It refers to the creation of knowledge as a public good. It represents a positive answer to questions raised in a 1994 paper: "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?" New concepts such as Hakkarainen's "epistemic mediation," Stahl's "group cognition," Scardamalia and Bereiter's "improvable ideas" and their distinction between "belief mode" and "design mode" offer insight into how community advances in understanding are achievable.

Focus of the Symposium

A paper titled "Computer Support for Knowledge-Building Communities" (Scardamalia & Bereiter, 1994) is frequently cited as the definitive representation of knowledge building theory, pedagogy, and technology. However, all of these elements have undergone considerable subsequent development, not only by the original authors and their collaborators but also by others who, while recognizing the early work as a starting point, have proceeded either to infuse new ideas into the original conception or to embed the basic ideas of knowledge building in different theoretical frameworks. The key concept that continues to distinguish knowledge building from other constructivist approaches in education is that of creating knowledge as a public good, as distinct from its construction as mental content or as situated practice. Outside of education, the concept of *knowledge creation* has taken shape referring to the same process (Nonaka & Takeuchi, 1995). In fact, "knowledge building" and "knowledge creation" may be treated as equivalent terms (Paavola & Hakkarainen, 2005). In an educational context, however, it becomes important to establish in what sense students may be thought to create new knowledge (Bereiter & Scardamalia, 2010). More generally, the question "How is it possible?" looms much larger in education than it does in business and research contexts where knowledge creation is pursued. This symposium brings together thinkers who have been working at basic theoretical levels to establish sound and fruitful conceptions of knowledge building/knowledge creation. Among the ideas featured in this symposium are "epistemic mediation," "group cognition," "improvable ideas," and a distinction between "belief mode" and "design mode." Because of the diversity of ideas represented, this symposium is designed as a highly interactive one between the contributors and the audience, with the chair person moderating the discussion.

Contributors and Presentations

The role of epistemic mediation in knowledge building (Hakkarainen, Ritella, & Seitamaa-Hakkarainen)

The evolutionary history of human cognition appears to involve cultural invention of epistemic technologies, such as writing, that radically collectivize cognitive processes traditionally thought of as taking place within the human mind—resulting in what we here discuss as *epistemic mediation*. By *epistemic mediation,* we refer to a process of deliberately re-mediating personal or collective inquiry by creating shareable epistemic artifacts, such as texts, graphs, and models. It involves efforts of crystallizing, integrating, and synthesizing one's view at the edge of knowledge and understanding and using the resulting knowledge artifacts as a stepping stone for reaching a higher-level understanding at subsequent cycles of inquiry. The advancement of knowledge-creating inquiry appears to depend on a sustained struggle to crystallize evolving understanding in a growing network of epistemic artifacts. These artifacts, in turn, provide implicit or explicit hints and guidelines regarding promising directions of advancement and ways of going beyond the existing epistemic horizon. From an evolutionary perspective the present tremendous expansion of the Information and Communication Technologies (ICTs) is a continuation of the same process of epistemic mediation that took place at the advent of modern civilization and changed the architecture of human cognition as radically as earlier leaps in biological evolution (Donald, 2001). Collaborative technologies empower even elementary-school children in transforming their intangible ideas to digital and, thereby, also materially embodied artifacts with which they can be interact across long periods of time. In order to capitalize on epistemic mediation it appears, however, essential to cultivate shared knowledge practices that channel the participants' efforts into systematic pursuit of knowledge advancement. Knowledge building and other forms of serious inquiry cannot rely on mere oral interaction but must capitalize on epistemic mediation involved in systematic production of epistemic artifacts textual or graphic in nature.

The principal vehicle of epistemic mediation is writing that allows externalization, objectification, and materialization of the processes of thinking and reasoning for shareable epistemic artifacts in interaction with which subsequent inquiry takes place. As Brockmeyer and Olson (2009) argued, writing is not just recording of thought but constitutes its own system that has significant social, intellectual, and cultural consequences. This system relies on material-symbolic practices that enable creation of new kinds of epistemic objects, such as questions and theories, with which we can be in interaction. In order to elicit pursuit of novelty, knowledge-building inquiry has to capitalize on extended cognitive circuits that break boundaries between minds, bodies, artifacts and environments (Clark, 2008). In order to cultivate capacities of pursuing challenging inquiries, students have to be intellectually socialized to expand and augment their cognitive resources by deliberately working at external memory fields and writing for creating knowledge. As a social practice, writing is mediated by literate genres, i.e., socially and culturally recognizable, ritualized, and repeated production of typified epistemic artifacts in human collectives (Bazerman, 1988; 2004; Prior, 1998). Beyond genres of reporting textbook knowledge, the participants of technology-mediated learning have to learn to master academic writing focused on using writing as a tool of extending their thinking and deliberately generating new ideas and working theories. Epistemic mediation appears both to require and assist formation of a specific kind of identity as a prospective builder and creator of knowledge.

Bereiter and Scardamalia's knowledge building framework aims at making a Copernican revolution in education in terms of putting student-generated ideas at the center of education. When engaged in collaborative knowledge building, students are, in a very concrete way, engaged in working with imagined and anticipated objects that materialize and take their shape only after sustained collaborative efforts forcefully constrained by requirements of reaching coherent understanding or creating a functional product. Such open-ended objects appear to generate constantly novel questions and become more and more complex when pursued:

> Objects of knowledge appear to have the capacity to unfold infinitely. They are more like open drawers filled with folders extending infinitely into the depth of a dark closet. Since epistemic objects are always in the process of being materially defined, they continually acquire new properties and change the ones they have. But this also means that objects of knowledge can never be fully attained, that they are, if you wish, never quite themselves. (Knorr-Cetina, 2001, p. 181).

Technology-mediated learning environments and corresponding practices provide valuable resources for knowledge-creating inquiry in terms of assisting in building on, synthesizing, and rising above epistemic artifacts created. It appears that CSCL environments are children of hybridization in terms of providing material technology for sustained working with shared digital (but materially embodied) artifacts. Such knowledgeware technologies and associated practices of knowledge building allow working with distributed epistemic artifacts, and, thereby, elicit collectivization of inquiry and learning. Integrating CSCL technologies as instruments of one's activity is a developmental process in its own right; cultivation of innovative inquiry practices within a learning community is not possible without sustained iterative and expansive efforts at creating an adequate chronotope. Hence, technology enhances learning only through transformed social practices.

Understanding knowledge building as a small-group cognitive process (Stahl)

Knowledge building, whether carried out in classrooms, laboratories, or businesses, is almost always carried out in small groups. Accordingly, understanding it requires a theory appropriate to the level of small-group phenomena. The theory of group cognition (Stahl, 2006) stakes out the domain of group meaning-making processes as a new domain for scientific inquiry. Importantly, it distinguishes this domain from the traditional domains of sciences of individual learning and of the development of social practices in communities.

The move from the individual to the group level of description as foundational entails an important philosophical step: from cognitivism to post-cognitivism (Stahl, 2011). Although the literature on small groups and on post-cognitivist phenomena provides illuminating studies of the pivotal role of small groups, it does not account for this level of description theoretically. In the final analysis it is almost always based on either a psychological view of individuals or a sociological view of rules, etc., at the community level. None of the studies has a foundational conception of small groups as a distinct level. They confuse talk at the group level and at the social level, and they lack a developed account of the relationships between individual, group and community.

If we take group phenomena seriously as "first-class objects," then we can study: interpersonal trains of thought, shared understandings of diagrams, joint problem conceptualizations, common references, coordination of problem-solving efforts, planning, deducing, designing, describing, problem solving, explaining, defining, generalizing, representing, remembering and reflecting as a group. The VMT (Virtual Math Teams) Project was designed to explore the phenomena of group cognition and accordingly pursued the research question:

> How does learning take place in small groups, specifically in small groups of students discussing math in a text-based online environment? *What are the distinctive mechanisms or processes that take place at the small-group level of description* when the group is engaged in problem-solving or knowledge-building tasks?

While learning phenomena at the other levels of analysis are important and interact strongly with the group level, we have tried to isolate and make visible the small-group phenomena and to generate a corpus of data for which the analysis of the group-level interactions can be distinguished from the effects of the individual and community levels (Stahl, 2009). The design and continued enhancement of technology to support small-group meaning making was in response to emergent findings about the strengths and difficulties of these interactions. Research to date makes clear that rigorous and progressive research can be carried out on cognitive processes at the group level and that such research can contribute significantly to both the conceptual and technological development of knowledge building.

Improvable ideas: The foundation of Knowledge Building (Scardamalia & Bereiter)

Sophisticated people in any modern field—the people Robert Reich categorized as "symbolic analysts"--recognize the progressive nature of knowledge in their field. They recognize that the designs, tools, procedures, theories and even the core assumptions underlying their work are continually subject to change and improvement. Ensuring that tomorrow's ideas are better than today's is an implicit part of most "good" jobs. In a larger sense, it is civilization's main hope for solving the grave problems that beset it. Not only technical solutions but social, economic, political, and personal solutions call for breakthroughs in knowledge. Innovation is the new normal—"part and parcel of the ordinary," as Peter Drucker (1985) said—rather than a departure from the normal, as it was in previous generations. Yet schools seem to be preparing students for a world that preceded not only the current "knowledge age" but the 19th century "age of invention" as well. We are preparing them for a society in which progress depended on "the occasional happy thought," as Whitehead put it. Efforts to promote creativity as a "21st century skill" are grounded in an obsolete ideology; they are aimed at increasing students' ability to produce "the occasional happy thought." Whitehead (1925/1948), however, saw the 19th century as having achieved the professionalization of invention, the practice of bringing knowledge to bear on the deliberate creation of new knowledge.

It is not just traditional education, with its emphasis on knowledge transmission and skill practice, that falls short of preparing students for today's world. Educational standards, even the newest ones, fail to lock on to the knowledge-creating dynamic that characterizes progressive organizations, professions, and disciplines. Science standards call for familiarizing students with the uncertainties of empirical knowledge. Hypothesis testing and evidence-based argumentation figure prominently, but we see little that would acquaint students with how knowledge advances are actually made—how fruitful hypotheses are generated and how they are developed and improved to emerge as a full-blown inventions, designs, plans, theories, organizations, or works of art. Research by Windschitl (2004) has indicated that teachers themselves typically do not understand how science progresses beyond the accumulation of tested findings.

Naïve realism views scientific progress as the unproblematic accumulation of facts, but it is only one step up to view it as the problematic accumulation of uncertain empirical conclusions. That is movement from level 1 to level 2 in Carey and Smith's (1993) scheme. Level 3, at which science is viewed as a creative explanation-seeking enterprise lies beyond, and is evidently seldom reached in school science.

To the extent that this limitation extends to the whole curriculum, it indicates a serious deficit in education's ability to prepare students for the 21st century. Responsible education of all kinds strives to improve students' ideas. But educating students to be idea improvers is another matter, and this is where contemporary education seems not only to fall short but not even to recognize there is a problem. Since there are no tried and true ways to achieve this objective, our best bet is to engage students as fully as possible in the activity itself—sustained, collaborative, creative work with ideas. That, in essence, is what Knowledge Building aims to do.

Most constructivist educational approaches engage students in collaborative work, often sustained for longer periods of time than is typical in school curricula; sometimes it involves creative production (especially the production of media objects); and the most intellectually serious kinds strive to bring students into contact with the "big ideas" of the disciplines. So what is distinctive about Knowledge Building? It is focusing the sustained, collaborative, creative work on ideas themselves and their improvement—not on the representational media, not on the "scientific method" or its counterparts in other disciplines, not on the social structure and dynamics of classroom activity, but on ideas. All these other facets of scholastic life are important and warrant support, but they are subordinated to the goal of helping students become agents rather than only beneficiaries of idea improvement.

Idea improvement is a relatively modest goal, one that students can feel is within their competence, whereas dangling the models of Einstein and Darwin before them is likely to intimidate all but the boldest few. When we speak of idea improvement we do so in full awareness that "conceptual revolutions" (Thagard, 1992) may be needed when a theory or idea has reached its limit of improvability and needs to be replaced by a radically different one. Radical shifts are often required in students' conceptual development because their original idea (for instance, that up and down are absolute directions independent of gravitational field) quickly reaches its limit of improvability and must be replaced by a more fruitful concept. However, we propose that *as a working assumption* all ideas should be treated as improvable. This assumption encourages not only a skeptical attitude toward truth claims but also a constructive attitude, which favors preserving and building on the strengths of an idea rather than rejecting it out of hand as soon as it is discovered to have a flaw. Furthermore, common usage allows even radical changes to be called improvements. Thus, relativity theory is treated as an improvement over Newtonian physics, because it does not explicitly repudiate Newtonian physics but assimilates it into a larger conceptual framework. That kind of "rise above" improvement is especially germane to students' conceptual development and is something that a knowledge-building approach should promote.

It goes almost without saying that idea improvement, insofar as it involves movement from simpler to more complex ideas, is necessarily a self-organizing process. Self-organization is the only viable explanation of how growth in conceptual complexity is achieved (Molenaar, 1986). This is true even when the more complex concept is supposedly conveyed by a lecture or a text: grasping it requires constructive activity on the part of the learner that is equivalent to theory building (Popper & Eccles, 1977, p. 461). But when, as in knowledge building, the students are agents of their own production of more complex conceptual structures, the demands put on a sustained self-organizing process are likely to be greater. The greatest challenge for knowledge-building technology, accordingly, is to support a self-organizing process in the realm of ideas. This is something beyond supporting self-organization at the social level (which the new social media seem to be accomplishing to amazing effect) or self-organization in the planning and conduct of projects (which is the province of project management software and educational adaptations of it).

The approach we are advocating in designing next-generation knowledge-building software is to treat ideas rather than people or actions as the units in a self-organizing system. Social networks evolve and projects and processes evolve. All of these warrant feedback systems to support their evolution. But it is the evolution of ideas that occupies center stage and that these other kinds of evolution subserve. Thus we want to build idea network analysis, comparable to social network analysis; nearest-neighbor searches that identify neighboring ideas, even if they are located in different parts of a database; and ways for students' judgments of promisingness and importance and for their metacognitive awareness to feed into the process of idea evolution. Knowledge-building dialogue is key, for advances in community knowledge are not merely supported by dialogue but actually take place in it (Tsoukas, 2009). Among other well-known advantages of having discourse carried out online is the fact that it produces something semantic analysis tools can work on and hopefully provide feedback of a kind that will enhance the self-organizing processes of conceptual evolution.

These proposals are in line with a current trend to design self-organizing networks (Rycroft, 2003), whether Internet-based or not. They are at the opposite pole from threaded discourse, which seems almost to have been designed to thwart self-organization—or, at its worst, to thwart organization of any kind. They also stand in contrast to clickers and related kinds of response technology, which can be used in a variety of educationally beneficial ways but which keep the teacher in control of the information flow. Whether idea-centered knowledge-building technology can take advantage of FaceBook and Twitter kinds of technology is a challenge yet to be explored. The challenge may be framed as "sustained creative work with ideas meets short attention span."

"Design mode" as the essential mode of thought in Knowledge Building (Bereiter & Scardamalia)

A distinction between *belief mode* and *design mode* (Bereiter & Scardamalia, 2006) helps to define what is distinctive about knowledge building. Belief mode is and always has been the prevailing mode of formal education. It deals with the question, "What shall we believe?" The methods of dealing with this question have varied considerably over the years. Indoctrination marks one extreme, critical inquiry the other. Modern education generally favors critical inquiry, with an emphasis on evidence and logical reasoning, along with openness to opposing beliefs. Belief mode discourse almost invariably involves argumentation. The argument may be one-way, as in lecturing or sermonizing, or multi-directional, as in a class discussion; but in any case belief mode discourse is characterized by efforts to persuade.

One can read whole books on curriculum issues and classroom methods and never get an inkling that there could be any way of dealing with academic subject matter except through some variation of what we have just described as belief mode. Yet out in the "real" world, most productive thinking is carried on in a quite different mode. It is *design mode*: the mode of problem solving, invention, planning, and other creative knowledge work. In belief mode, key questions to ask about any proposition are "What are the arguments for and against?" and "What does the evidence show?" In design mode, the most challenging questions are "What is this idea good for?" and "How could this idea be improved or further developed?" These are questions almost never addressed in education, except at the highest university levels.

Both belief mode and design mode are important in knowledge building. Issues of truth and belief inevitably arise. The interactions between belief mode and design mode activity can be complex and are sometimes problematic. Our main point, however, is that design mode could be playing a much more significant role in education than it does now. Design mode does find a place in schools, but it tends either to lie outside the formal curriculum or to take the form of exercises. Putting on a play involves a lot of design work. Planning a trip to Mars, a popular "constructivist" activity in elementary schools, exemplifies design mode work as an exercise. But all *serious* academic work— work with important disciplinary ideas—goes on in belief mode. That is how it was with Socrates and his students, that is how it was in the medieval *sic et non*, and that is how it is in the present-day "thinking curriculum," even in its most epistemologically liberated, social-constructivist, and "postcolonial" forms. Even in inquiry-based or "hands-on" science education, the modal experiment is one that confirms or disconfirms a hypothesis (that is, a tentative belief). The actual construction and refinement of a coherent explanation of observed phenomena finds little or no place in the curriculum. Knowledge Building brings design mode into the heart of the curriculum, into the part that deals with core disciplinary knowledge.

A concrete example of fourth-graders operating in design mode is discussed by Zhang, et al, 2009). In the course of studying about light, children began to raise questions about rainbows. The initial answer they got from authoritative sources was the standard one that attributes rainbows to water droplets acting like prisms (they had already experimented with prisms). The students posed further questions arose, however, that took them deeper into the physics of rainbows: How could such a big thing as a rainbow be produced by tiny water droplets? Why are the colors of the rainbow always in the same order? Why do rainbows always take the shape of a semicircle? Students proposed theories to answer these questions and refined their theories on the basis of experimental and authoritative information. Scientifically adequate answers to these questions, such as could be found in *Wikipedia* and the websites of scientific organizations, required mathematics well beyond their level. But the qualitative theories the children did develop compared favorably to the information provided by school-oriented web sites and were superior to some of those that popped up first in a web search (Bereiter & Scardamalia, 2010). The common belief-mode question to arise in this kind of situation would be "Is this theory true?" The children were not indifferent to this question, but the design-mode question that drove their inquiry was the much more sophisticated one: "Does this theory explain the facts?"

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