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The Knowledge Creation Metaphor –

An Emergent Epistemological Approach to Learning

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Abstract: We argue that beyond metaphors, according to which learning is a process of knowledge acquisition by individual learners (a "monological" approach) or participation to social interaction (a "dialogical" approach), one should distinguish a "trialogical" approach, i.e., learning as a process of knowledge creation which concentrates on mediated processes where common objects of activity are developed collaboratively. The third metaphor helps us to elicit and understand processes of knowledge advancement that are important in a knowledge society. We review three approaches to knowledge-creation, i.e., Bereiter's knowledge-building, Engeström's expansive learning, and Nonaka and Takeuchi's organizational knowledge-creation. We give a concise analysis of the trialogical character of the knowledge-creation approach, and illustrate how the third metaphor may be applied at the school level.

Introduction

Rapid changes in present, networked, knowledge society give rise to new challenges to human competence. Productive participation in knowledge-intensive work requires that individual professionals, their communities, and organizations continuously surpass themselves, develop new competencies, advance their knowledge and understanding as well as produce innovations and create new knowledge. Human work is more and more focused on deliberate advancement of knowledge rather than just production of material things (Bereiter 2002). This challenge concerns both education and working life; in order to be able to productively participate in knowledge work, young students have to learn to go beyond individual efforts and collaborate for the advancement of knowledge. In parallel with changes in society, conceptions, practices, and social organization of learning also have to be transformed so as to facilitate corresponding individual and cultural competencies.

Epistemological issues related to learning and knowledge are becoming increasingly important. It is argued that there is a great deal of 'epistemification' taking place in present-day society (Stutt & Motta 1998); our tools and technologies embed more and more meanings, and embody ever more knowledge and intelligence. We are working in complex and heterogeneous networks that consist of humans and various artifacts (see Latour 1999). In order to facilitate our more sophisticated activity, we are creating and using cognitive artifacts that are more knowledge-laden, smart and autonomous. Knowledge and related concepts, such as expertise and intelligence, increasingly define our activity in the knowledge-based society. In order to conceptualize and understand the nature of work and activity in this society, one has to learn to understand the various types of knowledge and how they are used and made to grow. In other words, a kind of epistemological shift is needed within teachers, educational psychologists, cognitive scientists, students, and all other participants interested in developing the educational system to answer the emerging challenges.

The issues are addressed in this paper by examining the relations between three metaphors of learning: knowledge acquisition, participation, and knowledge creation. The three metaphors are closely connected to the way knowledge is understood in different conceptions of learning. Who is the subject of learning? Is it the individual, or communities, or what? What kind of knowledge should be learned, and how? In this paper it is argued that a conception of learning

adequate for a knowledge society does not only address transmission, or construction of existing knowledge to individual students (acquisition metaphor), and neither is it enough to emphasize various processes of socialization and growing up to communities and their values (participation metaphor). Both of these are valuable, yet a third metaphor of learning is needed that goes beyond these two. In the following, the third approach will be called 'the knowledge-creation metaphor' to indicate that it is a kind of individual and collective learning that goes beyond information given and advances knowledge and understanding: There is collaborative, systematic development of common objects of activity. We argue that this kind of an approach is *emergent*; although it has various historical roots, it is not proposed as something totally new. We think that this kind of an approach is more and more important in order to be able to answer the challenges of the knowledge society. It should be reckoned more consciously as an important alternative way to understand learning and cognition.

In the present article, we will review first the two, predominant metaphors of learning and the proposed third metaphor. We will analyze three influential models concerning learning and innovative inquiry, which appear to represent essential aspects of the knowledge creation process, i.e. the model of knowledge building by Carl Bereiter (2002), the model of knowledge creation by Ikujiro Nonaka and Hirotaka Takeuchi (1995), and the model of expansive learning by Yrjö Engeström (1987, 1999a). We argue for the third metaphor of learning by identifying common aspects in these three approaches. Finally, we will examine educational implications of the knowledge-creation approach for science education and conceptions of learning. Can the knowledge-creation approach be applied in school settings? What does it mean in the school context? These are very large questions, and we can propose only a few suggestions here.

An Outline of Three Metaphors of Learning

Anna Sfard (1998; see also Lave & Wenger 1991; Wenger 1998) has distinguished two core metaphors of learning, i.e., two basic ways of understanding the area of learning, *the acquisition metaphor* and *the participation metaphor*. The division is very rough because the idea is that these two basic approaches can be seen to underlie manifold, various models and theories of learning. At the same time, it is an informative division because it represents basic everyday and scientific conceptions of learning in an intuitive way. As we understand metaphors of learning,

they may be considered to represent “ideal types” (as used in sociology after Max Weber), i.e. they bring forth constellations of typical features related to learning; but the exact combination of these features, or all of them, do not have to be involved in any individual case. Ideal types present typical combinations of features in a simplified, schematic way. More concrete approaches to learning can combine these features in different degrees and different ways; approaches may also combine elements from different metaphors. For example, classics of educational thinking (by Piaget, Vygotsky, Dewey) are probably classics just because their theories have aspects from different metaphors of learning; or at least they can be interpreted from various perspectives. But the benefit from the metaphors (as ideal types) is that they highlight certain basic attitudes and approaches towards learning. They concern not only learning but have clear affinities to ideas about human cognition in general, for example to the debate between cognitivist vs. situated perspective on human cognition and activity (see Anderson, Reder & Simon 1996; 1997; Greeno 1997).

The acquisition view relies on the idea that knowledge is a property of an individual mind; an individual is the basic unit of knowing and learning. One version of the acquisition view is the traditional cognitive approach that has highlighted the role of mental models or schemata in learning (Gardner 1985, Neisser 1976), often without recognizing the importance of environment or context at all (cf. Fodor 1981). So this approach is easily connected to a 'folk theory' of mind according to which the mind is a container of knowledge, and learning is a process that fills the container, implanting knowledge there (Bereiter 2002). On the other hand, this metaphor appears to be connected also with active, constructivistic theories of learning, that is, individualistic versions of constructivism. The acquisition view emphasizes *propositional* knowledge and *conceptual knowledge structures*. Logically organized knowledge structures and generalizable knowledge are seen as an ideal for intelligent activity. Humans can be seen as symbol-processors. In many ways, this is a Cartesian view of human activity and epistemology; knowledge is something that is processed inside the human mind with logical means, and mind is seen as separated clearly from the material world and also from the cultural and social environment (Fodor 1981).

An alternative approach, says Sfard, is *the participation metaphor* of learning, according to which learning is an interactive process of participating in various *cultural practices* and shared learning activities that structure and shape cognitive activity in many ways, rather than

something that happens inside individuals' minds (see e.g., Lave & Wenger 1991; Brown, Collins, & Duguid 1989). Accordingly, learning is seen as a process of becoming a member of a community and acquiring the skills to communicate and act according to its socially negotiated norms. The focus of the participation view is on activities, i.e., on 'knowing', and not so much on outcomes or products (i.e., on 'knowledge' in the traditional sense). Generalizable rules, or conceptual knowledge as such are *not* seen as so important, rather the situated nature of human knowledge and cognition is emphasized. Human activity is indexically bound to its social and material environment. Knowledge does not exist either in a world of its own or in individual minds, but is an aspect of participation in cultural practices. Cognition and knowing are distributed over both individuals and their environments, and learning is 'located' in these relations and networks of distributed activities of participation. Within the participation metaphor, learning is a matter of participation in a social process of knowledge construction, 'enculturation', or 'legitimate peripheral participation'.

The division of two basic metaphors of learning is very fundamental. Neither of them, however, appears to be sufficient when addressing processes of deliberately creating and advancing knowledge. Yet there are theories and models related to learning, which we call theories of *innovative knowledge communities,* that explicitly emphasize innovative aspects in relationship to learning and epistemology. The acquisition approach and the participation approach *can* both be developed so that they take innovative aspects into account, but it can be argued (as these theories of innovative knowledge communities do) that this is not where these approaches are at their best, as we shall now elaborate. The acquisition approach presupposes pre-given structures of knowledge that an individual learner is guided to assimilate, or construct. Although this process may involve creativity and elicit emergence of new meaning connections, knowledge advancement has not been the main focus on this metaphor. Within the frames of cognitive science, there have been valuable attempts to model and simulate processes of scientific discovery (starting from e.g., Simon 1977). While these investigations have been illuminating in their own terms, these have very often, however, been narrowly focused on searching through conceptual structures (Boden 2004; for criticism of this view, see McDermott 1990). The role of social communities, larger networks, and research instruments has been left outside of these frameworks. Increasing consideration of collaborative aspects of knowledge creation (e.g., Okada & Simon 1997; Thagard 1999) has, however, somewhat broadened the traditional cognitive view in

these respects. The participation approach, in turn, focuses on increased mastery of a community's knowledge without a deliberate effort for transformation. Since the model focuses on adaptation to existing cultural practices, it does not prompt one to pay any special attention to creative changes in these practices.

The theories on innovative knowledge communities are thus a basis for a third approach of learning which we have called a *knowledge-creation metaphor of learning* (Paavola, Lipponen & Hakkarainen 2002; Hakkarainen, Palonen, Paavola, & Lehtinen, in press). In the next section, we will concisely present the theories of innovative knowledge communities which are a basis for the third metaphor. The basic division is as follows: The acquisition view represents a "*monological*" view on human cognition and activity, where important things are seen to happen within the human mind, whereas the participation view represents a "*dialogical*" view where the interaction with the culture and other people, but also with the surrounding (material) environment is emphasized. The knowledge-creation view represents a "*trialogical*" approach because the emphasis is not only on individuals or on community, but on the way people collaboratively develop mediating artifacts (see Figure 1).

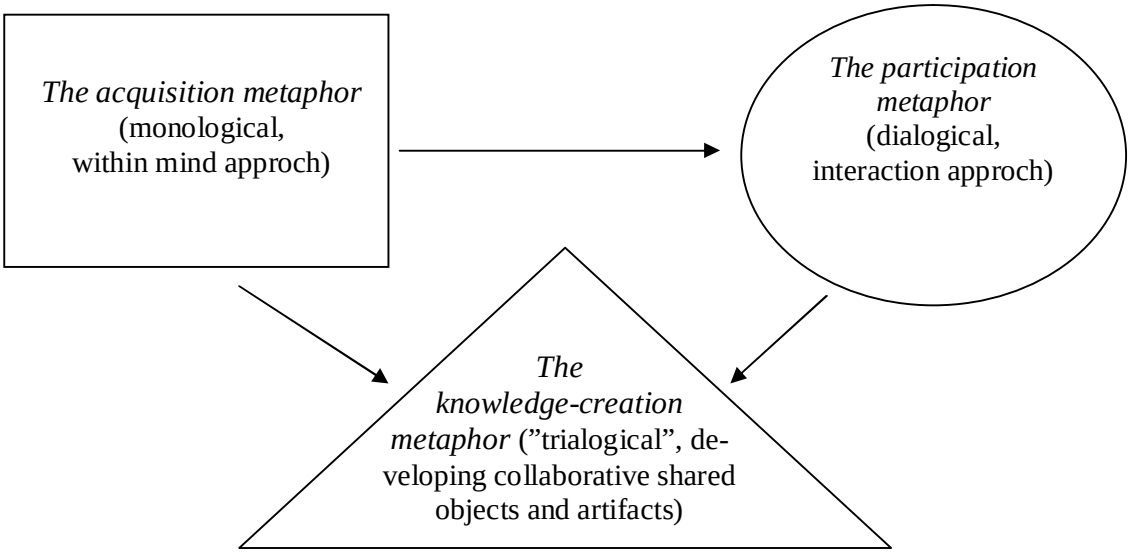

Figure 1. Three metaphors of learning

Characteristic of the knowledge-creation approach is to examine learning in terms of creating social structures and collaborative processes that support knowledge advancement and innovation; in this sense it becomes close to the participation view. Further, the knowledge-creation approach addresses the importance of generating new ideas and conceptual knowledge. In this sense, it has commonalities with the acquisition view because conceptual knowledge is emphasized. The conceptions of knowledge in the background of knowledge-creation models, however, vary a great deal; some of them emphasize more the conceptual aspects of creating knowledge whereas others address innovations embedded in new practices and social structures. In the present article, these different views of knowledge creation, are, however, interpreted as complementary.

Table 1 presents an abstract description of some basic features of the three metaphors of learning. Each one of the metaphors has its distinct focus, theoretical assumptions, and units of analysis. Yet there are no clear-cut theoretical and methodological boundaries between these approaches. We do not consider these metaphors as mutually exclusive; all of them are needed in order to adequately capture learning processes. These metaphors may not be ordered from weakest to strongest because they appear to answer different kinds of questions, and in order to understand the complexity of human cognition we need to address all of these levels of abstractions and the associated questions.

Table 1. An overview of the ideal typical characters of the three metaphors of learning

	Knowledge acquisition	**Participation**	**Knowledge creation**
Main focus	A process of adopting or constructing subject-matter knowledge and mental representations	A process of participating in social communities Enculturation, cognitive socialization Norms, values, and identities	A process of creating and developing new material and conceptual artifacts Conscious knowledge advancement, discovery,

			and innovation
Theoretical foundations	Theories of knowledge structures and schemata, Individual expertise Traditional cognitivist theories Logically-oriented epistemology	Situated and distributed cognition Communities of practice Sociologically-oriented epistemology	Knowledge-creating organizations Activity theory Knowledge-building theory Epistemology of mediation
Unit of analysis	Individuals	Groups, communities, networks, and cultures	Individuals and groups creating mediating artifacts within cultural settings

There are several models that depict learning and inquiry as a process of creating or articulating knowledge rather than just assimilating existing knowledge or participating in prevailing practices. It is characteristic of this kind of knowledge advancement that it takes place within innovative knowledge communities rather than only within individuals. Next we analyze three models that represent this kind of an approach by emphasizing creative aspects in knowledge advancement and learning

Three Models of Innovative Knowledge Communities

In educational psychology and applied cognitive science there are some influential models of learning and knowledge advancement that emphasize the meaning and process of knowledge creation. We briefly present three such models: Carl Bereiter's theory of knowledge building (Bereiter 2002), Yrjö Engeström's theory of expansive learning (Engeström 1987), and Ikujiro Nonaka and Hirotaka Takeuchi's model of knowledge creation (Nonaka & Takeuchi 1995). We

maintain that these models give a fruitful way of analyzing what is important in innovative learning and in knowledge communities more generally; they start from differing perspectives. It is crucial that the degree to which they are fruitful and suggest new approaches to pedagogy not only be determined by reflection, but by practice, experimentation, and empirical investigation. In this article we will not go into detail about these models, but emphasize those aspects that shed light on the knowledge creation metaphor of learning (see a more thorough comparison: Hakkarainen, Palonen, Paavola, & Lehtinen, in press).

KNOWLEDGE-BUILDING COMMUNITIES

Carl Bereiter's (Bereiter & Scardamalia 1993; Bereiter 2002) knowledge-building approach has emerged from cognitive studies of literacy, intentional learning, and process aspects of expertise. It has guided cognitive research on educational practices in a wide variety of contexts and, in substantial ways, has given birth to and shaped the research field of computer-supported collaborative learning (e.g., Koschmann, Miyake, & Hall, 2002). In the background of this model are observations, according to which some children are expert-like learners in the sense that, in learning situations, they set up themselves similar kinds of challenging tasks as experts do, even if they do not have experts' knowledge. They orient themselves in learning situations in a way that makes a problem more complex and, at the same time, maximizes their learning and knowledge advancement. Empirical observations indicate that such knowledge-building goals may characterize not only individuals but also communities. Bereiter characterized *knowledge-building processes* that involve working at the edge of one's competence, progressively setting up higher standards of performance, and seeking collective knowledge advancement beyond individual learning. Relying on Whitehead's notion of disciplined progress, Bereiter argued that setting up of a community that is deliberately focused on going beyond the limits of existing knowledge, is essential to knowledge creation.

Bereiter's theory of knowledge building uses Karl Popper's distinction of three basic realms as its starting point. According to Popper, besides physical and material reality (World 1) and the reality of mental states (World 2), there is third realm (World 3) which encompasses conceptual entities, such as theories and ideas. The important point is that human beings do not operate only in the mental realm; within their culture, they understand and develop objects be-

longing to the third realm (World 3). Although World 3 is dependent on World 2 and World 1, it is still quite autonomous in relationship to these two. Bereiter argues that prevalent epistemology and mainstream theories of learning are generally too mentalistic and individualistic; they do not usually take into account the fundamental significance of World 3. They are still based on the mind-as-a-container metaphor. Learning is seen as an accumulation of ready-made information to the human mind, where mind is understood as a kind of archive (this folk epistemological notion is close to the acquisition metaphor of learning discussed above). This kind of learning, argues Bereiter, should be replaced by deliberate activity for building knowledge together, which means collaborative efforts to create, develop, understand, and criticize various conceptual artifacts, that is, objects in World 3. This activity is akin to what happens in scientific communities, where the central aim is not only to learn something but to collaboratively develop new ideas, methods, theories, models, and so on, that then become available for subsequent use.

EXPANSIVE-LEARNING COMMUNITIES

Yrjö Engeström's theory of expansive learning is strongly rooted in the tradition of cultural-historical activity theory (see e.g., Engeström, Miettinen, & Punamäki 1999). It is not easy to describe this model briefly because of its cross-disciplinary and multifarious nature. Engeström forcefully criticizes mentalistic or 'Cartesian' approaches to learning and expertise (e.g., Engeström 1987). Learning is one form of human activity. It is based on actions in collective activity systems that take place within larger socio-historical contexts. The meanings of *mediating artifacts* (tools and signs) and activities are emphasized. Learning is an 'activity-producing activity' and 'mastery of expansion from actions to a new activity', i.e., a central aim in learning is to produce new forms of activities (Engeström 1987, 125). Learning is based on expansive cycles of development.

Engeström's models have been applied to educational and workplace contexts to explain patterns and practices and to promote individual and social transformations. They provide a basis for his well-articulated interventional tools that allow an individual or a community to reflect on its practices and deliberately bring about changes so as to overcome tensions and disturbances of the prevailing activity system. The process of expansive learning may be described in an ideal-typical way according to the following scheme of organizational learning (Engeström 1999a, pp.

383-4). The cycle starts by 1) individual subjects questioning and criticizing of some accepted practices; which is followed by 2) analyzing the situation, i.e., analysis of those (historical) causes and empirical inner relations that are involved in the activity system in question. Then participants engage in 3) modeling a new solution to the problematic situation. And they are 4) examining the new model, experimenting and seeing how it works, and what potentialities and limitations it has. Participants undertake 5) implementing the new model in practical action and applications, and then, 6) reflecting on and evaluating the process. Finally, participants engage in 7) consolidating the new practice into some new pattern. Knowledge-creation is addressed in the model in the form of new practices that emerge through achieving a collective zone of proximal development by adopting, socio-culturally, the most advanced practices within a community.

KNOWLEDGE-CREATING ORGANIZATIONS

Ikujiro Nonaka and Hirotaka Takeuchi's (1995) model of knowledge creation is focused on innovation in organizations. More specifically, their book presents a model, by analyzing various cases, intended to account for how Japanese companies became so successful after World War Two. Their main interest is not in investigation of learning or inquiry as such, yet, they are modeling very similar epistemological processes. They start with a criticism of the dominant Western tradition in epistemology that one-sidedly emphasizes conceptual and explicit knowledge (which can lead to "paralysis by analysis"). This has resulted in a Cartesian split between subject and object, and between mind and body. Processes of creating knowledge have been neglected, because the understanding of these processes, according to Nonaka and Takeuchi's model, requires interaction between explicit and tacit knowledge. Tacit knowledge, which is of central importance in innovation, means personal knowledge and beliefs embedded in individual experience.

Nonaka and Takeuchi highlight the importance of metaphors, analogies, and fuzzy intuitions in the emergence of novel ideas and innovations. Although people may have difficulties in conceptualizing and reflecting on a new phenomenon, they have a rich body of tacit knowledge that is considered to be a fertile ground for insights and mental leaps. Tacit knowledge can be used to facilitate knowledge creation through a 'knowledge spiral' (i.e., the spiral of knowledge creation) involving four types of knowledge conversion (Nonaka & Takeuchi 1995, pp. 62-73), i.e., a) from tacit knowledge to tacit knowledge, which Nonaka and Takeuchi call *socialization*

(learning to understand tacit knowledge through participating in an expert community), b) from tacit to explicit knowledge i.e., *externalization* (transforming tacit knowledge in a public form), c) from explicit to explicit knowledge, i.e., *combination* (synthesizing expert knowledge), and d) from explicit to tacit knowledge, i.e., *internalization* (learning to master expert knowledge through sustained practices). The authors propose that such creation involves passing through several 'ontological' levels, i.e., individual, group, organizational, and inter-organizational levels in order to be effective for all people and for a whole organization. According to Nonaka and Takeuchi, knowledge is created and transformed 'spirally' from the individual level to the organizational level and finally between organizations. The focus in Nonaka and Takeuchi's model is on activity surrounding creation of knowledge and not only on knowledge in itself.

A "Trialogical" Approach to Learning

The three models of innovative knowledge communities have some basic differences, but there are many similarities that can be seen to be a basis for a more general view, which we call *the knowledge-creation metaphor* (Paavola, Lipponen, & Hakkarainen 2002; Hakkarainen, Palonen, Paavola, & Lehtinen, in press). To begin with, these three models can all be seen as emphatically promoting the idea of striving for something new. Bereiter's model has its roots in the idea of dynamic expertise and progressive problem solving (Bereiter & Scardamalia 1993). The basic point in the model of knowledge building that characterizes human experts is constant striving to advance beyond present knowledge. What is central in Engeström's model is the idea of *expansive* learning, a continued striving to make qualitative changes in activity systems (Engeström 1987). He criticizes 'reactive forms of learning' which presuppose a given context and given task, whereas *expansive learning* is a new type of learning. In expansive learning, the aim is to transcend the given context and to create new ones. Nonaka and Takeuchi's starting point is to criticize dominant western epistemologies and theories; such approaches have too much concentrated on knowledge per se, whereas their own model concentrates on active creation of knowledge (Nonaka & Takeuchi 1995, p. 6).

All these models depict innovative processes as happening within *communities*. In this sense, they are near the participation metaphor of learning. But these models do not represent the ideal type of the participation metaphor because they do not focus on the interaction between

people but on specific *objects* of activity being systematically developed within these communities. That is why we call the interaction "*trialogical*"; it concentrates on the interaction *through* these common objects (or artifacts) of activity, not just between people, or between people and environment. In Bereiter's theory, these common objects of activity are conceptual artifacts; in Engeström's theory, practices and activities; and in Nonaka and Takeuchi's theory, products developed in companies. All these theories are intended to describe and explain innovations, how to organize the collaborative processes of developing new, common objects of activity.

Engeström's theory of expansive learning is a part of the cultural-historical activity theory. One basic starting point for the activity theory is L. S. Vygotsky's conception of *mediation*. Vygotsky (1978) emphasized that human activity is *mediated* activity; that we humans are not reacting directly to our environment but our activities are mediated by signs and tools. According to activity theory, tools and signs are cultural artifacts that

> "… overcame the split between the Cartesian individual and the untouchable societal structure. The individual could no longer be understood without his or her cultural means; and the society could no longer be understood without the agency of individuals who use and produce artifacts." (Engeström 1999b)

In activity theory mediation is the conception or the key that is seen as transcending typical dichotomies in social sciences between, for example, individual and society, or between material and conceptual "realms" (Engeström 1999a).

The notion of *trialogue* has its basis in activity theory's notions of mediation and object-oriented activity systems. Trialogue means that by using various mediating artifacts (signs, concepts, tools) and mediating processes (such as practices, or the interaction between tacit and explicit knowledge) people are developing common objects of activity (such as conceptual artifacts, practices, products, etc.). We call the third metaphor of learning the knowledge-creation metaphor of learning, yet an apt (but clumsier) name for it could be the *artifact creation metaphor of learning*. Artifacts are object-like things that are produced by humans, and the models of innovative knowledge communities concentrate on processes where people collaboratively create and develop such conceptual and material artifacts and related practices for a subsequent use.

All models of innovative knowledge communities depict innovative processes as fundamentally social, but at the same time emphasize the importance of individual competencies and

initiative. The reason is that these models represent attempts to describe the dynamics of innovation. The danger of the acquisition and the participation metaphors of learning is that they end up being reductionist; the acquisition metaphor by reducing inquiry and learning to individual mental process; and the participation metaphor, by reducing everything to social processes of participation. The basic idea in the knowledge-creation metaphor is that individual initiative serves the communal effort to create something new, and the social environment feeds the individual initiative and cognitive growth. Such phrases may sound like rhetoric without much content. But the idea is that all these models of innovative knowledge communities signify attempts to make explicit those processes through which the interaction between individual expertise and communal knowledge becomes materialized in a fertile (and we would like to say, *trialogical*) way as common objects of activity are developed. This mediated interaction does not happen without appropriate scaffolding and structuring. In Nonaka and Takeuchi's theory, there should be mechanisms that insure that individuals' tacit knowledge and hunches are explicated productively on the communal level and then, further, on the organizational level, and that organizational and communal knowledge become internalized for the use of individuals. In Engeström's theory, individuals question the accepted practices, and this is one important initiative for new learning cycles within the activity system (Engeström 1999a, 383). In Bereiter's theory, individuals with their problems of understanding are trying to create and evaluate conceptual artifacts for communal use.

In the title of this paper, we refer to an *epistemological* approach to learning, in particular, because the three metaphors can be seen to differ in their ways of understanding the role and nature of *knowledge* within human learning and cognition. The *acquisition metaphor* emphasizes conceptual knowledge, and the ideal is logically organized knowledge structures, which also guide human activities and skills. From the knowledge point of view, the *participation metaphor* emphasizes a kind of knowledge that Gilbert Ryle (1949) called "know how," knowledge that emerges and manifests itself as a part of on-going activities within the surrounding environment. Knowledge as such is not so important, but is a part of these activities. Crudely stated, people do not act in certain ways because of their knowledge, but they know things because they act in certain ways. The participation metaphor also emphasizes the social character of knowledge; knowledge is constructed in social interaction and within cultural settings. In the *knowledge-creation metaphor,* knowledge embedded in mediating artifacts and skills and practices is em-

phasized. People "put" (or embody, objectify) knowledge on these artifacts: scientific theories, plans, models, instruments, and so on. Another important point in the knowledge-creation metaphor is how the interaction between different forms of knowledge (like conceptual knowledge, know how, tacit knowledge) is organized, for example, how tacit knowledge is explicated and conceptualized to communal use, or how the interaction between practices and conceptual models helps to develop new practices.

We are *not*, however, here trying to analyze the basic epistemological theories (in the philosophical sense) behind these metaphors and theories. But these three metaphors are, of course, related to more basic, philosophical theories concerning epistemology, though the connections are complicated. The *acquisition view* has clear affinities to "traditional" epistemology, and to the tradition of analytic philosophy where the ideal of logically organized, conceptual knowledge is very prominent. This idea is nowadays often challenged, especially by those who support views representing the participation metaphor. The ideal of seeing human beings as logical reasoners is limited for understanding human activities more generally, although logical models can be developed so that they take the interaction with the environment more into account (see e.g., Hintikka 1999). So the basic challenge comes from those epistemologies that can be related to the *participation metaphor* of learning. These theories (inspired for example by Thomas Kuhn's and later Wittgenstein's theories) emphasize communal and social aspects in epistemology, rather than logic, or pure reason. Our contention in this paper is that the participation approach is not, however, the only challenger to the acquisition kind of an approach. The *knowledge-creation metaphor* has several historical roots although this position is not so much developed as the other two approaches. Vygotsky's conception of mediated activity has its roots in Hegelian (and Marxist) dialectical philosophy. A different and ideologically more neutral philosophical ground for mediation is American pragmatism (see Miettinen 2001), and especially Charles S. Peirce's pragmatism (see e.g., Peirce 1931-58). Peirce continually emphasized mediation, and his philosophy gives ample means to understand how human activity is mediated by sign-processes and practices. Bereiter's theory has its basis on Karl Popper's theory of three Worlds. Peter Skagestad (1993) has compared Popper's theory to Peirce's semiotic theory. We think that this Peircean/Popperian line could be one important step to better understand the mediated nature of human activity, in parallel with the Vygotskyan way of developing mediated activity (cf. Engeström 1987, pp. 37-73).

Educational Implications

Metaphors of learning not only help one to explain processes involved in learning, but they can also serve as tools to improve and understand the quality of learning and transforming the educational system. Thus, the metaphors of learning should also guide students, teachers, and researchers to develop new practices of learning and instruction to cope with all the cognitive, social, and motivational challenges of the emerging knowledge-based society. In brief, the acquisition view concentrates on how students would learn relevant knowledge structures most efficiently. It helps one to understand the development of individual conceptual structures, processes of conceptual change, and individual aspects of the development of expertise. The participation view concentrates on developing a rich cultural context for learning and identity development. It emphasizes the importance of embedding learning activities in authentic cultural contexts and tasks by breaking the boundaries between schools and the surrounding society. It is clear that these approaches are important in the educational domain; an critical question is whether the knowledge-creation approach provides something that cannot adequately be captured with these metaphors.

In the following, we briefly discuss some educational implications of the knowledge-creation metaphor for schools. Can there be schooling that focuses on processes by which shared objects of inquiry are developed collaboratively? What would such education look like? While summarizing some of the relevant aspects of such pedagogical practices, we acknowledge the preliminary and fragmented stage of our analysis. We will analyze briefly *some* ways schooling can represent the knowledge-creation metaphor by concentrating on issues investigated by our own research group. Many of these issues address, especially, science education, but appear also to be relevant across domains of knowledge. The metaphors of learning are so general that there are, of course, a large variety of ways that they could be implemented in schooling.

Bereiter and Scardamalia (1993; Bereiter 2002) talked about schools as knowledge-building communities in which both teachers and students work to build new knowledge and understanding. Together with their colleagues, they have reported a large number of case studies and design experiments that indicate that very young students are able to assume challenging knowledge-building tasks ands roles. Initially coming from the knowledge-building tradition, our

own research group has developed a pedagogical "*progressive-inquiry*" model that guides teachers and students in a process of advancing and creating knowledge (See Hakkarainen 2003b; in press; Hakkarainen & Sintonen 2002). Without going into detail, the progressive inquiry model is a variant of inquiry learning where explanation-seeking processes, and collaborative and social aspects of learning are emphasized. The model depicts a deepening question-explanation process where students collaboratively create the context, set up research questions, construct working theories, and critically evaluate the process (see Muukkonen, Hakkarainen, & Lakkala 2003; Hakkarainen, Palonen, Paavola, & Lehtinen, in press). This model involves elements of the acquisition metaphor (participants working for articulating the meaning of their conceptions) as well as participation metaphor (creating an extended learning community involving the teacher, students and external parties). Nevertheless, the specific characteristic of the model is to implement the knowledge-creation approach to learning. Hence, it is important to elicit in education practices that are similar to those that characterize scientific research communities (Bereiter & Scardamalia 1993). Accordingly, participants of a learning community engage in pursuing their own research questions, generating their intuitive working theories for explaining the questions and searching for scientific information (from literature, experts, and experiments) so as to solve their initial problems. Question generation and theory formation are not only conceptual processes, but social practices as well that guide participants to jointly articulate and advance preliminary problems and theories. We do not consider progressive inquiry as a specific method of team work; the defining character of it is to engage in sustained working for advancement of shared objects of inquiry across situations and contexts. Consequently, the object-orientedness of activity is the most fundamental aspect of such inquiry, which can, as such, be pursued either individually or collectively.

The knowledge-creation approach becomes practically relevant when there are available specific tools that help individuals and their communities to jointly work for advancement of their knowledge. Our contention is that practices of working innovatively with knowledge become accessible to school children when, for example, they are provided with advanced tools for creating and building knowledge based on the new information and communication technologies. From a psychological perspective, the most promising tools are ones that guide the participants themselves to engage in extensive working to produce knowledge through writing and visualization. Environments that provide a shared networked database, such as *Knowledge Forum* (see

http://www.learn.motion.com; Scardamalia & Bereiter 1993) or *Future Learning Environment* (see fle3.uiah.fi; Leinonen, Raami, Mielonen, Seitamaa-Hakkarainen, Muukkonen, & Hakkarainen 1999) are deliberately designed to facilitate collaborative knowledge building. These environments constitute a "collaborative notebook" that allows participating students to make their notes, pose their questions, explicate their conceptions, and share their reflections either during or between face-to-face meetings. If appropriately used, networked learning environments tend to move students' own ideas into the center rather than the periphery of discussion. Knowledge-building environments guide educators by scaffolding students in creation or elaboration of their shared ideas and thoughts within networked databases, thereby making these 'objects' available for others to work on and further articulate. An important aspect of the process is to locally "publish" results of students' inquiries so that these would not only serve their own learning, but become more widely available. Producing knowledge for an authentic audience rather than writing only for the teachers is likely to substantially change the nature of learning. In this regard, such environments appear to introduce a "trialogical" element into education in respect of organizing the learning community's activity around shared objects of inquiry.

The second author of the present study has conducted a series of studies at the elementary level education so as to facilitate progressive inquiry and practices of knowledge creation (Hakkarainen 2003b, in press; Hakkarainen & Sintonen 2002). Grade 5/6 students were working within a computer-supported classroom pursuing biological (Human Biology) and physical (Force, Electricity, Cosmology) study projects. Each project took 2-3 months to complete. The technical infrastructure of the project was provided by Knowledge Forum; there were approximately 10 networked computers within the class that allowed the participants to share all of their productions as soon as those were saved to the database. The students worked in small teams, each of which was responsible of pursuing a specific question as well as comment on the other study group's processes of inquiry. A qualitative analysis of the epistemology of the students' inquiry culture indicated that knowledge produced by the CSILE class in question was at a very high explanatory level in both biology and physics (Hakkarainen 2003b; Hakkarainen, in press).

We are currently working intensively on a project with one teacher and her grade 5 (11-year-old) students, entitled "Artifacts." The aim is to learn to understand the role of artifacts in the past, present and in the future. The project has continued approximately 18 months (Lahti, Iivonen, & Seitamaa-Hakkarainen in press). The students have kept an artifacts diary, i.e., re-

corded all artifacts that they had been using in a day. Teams of students each selected a particular artifact (e.g., lamp, clock, jewelry, ball) and investigated its history by visiting in a museum, doing literature research, designing and making experiment and observing and interviewing experts. The participants organized an artifact exhibition that was introduced by each student in turn, to the visiting adults and students from other classes. The project also involved science experiments designed by the participating students concerning electricity, light, heat, and lever. A central characteristic of this project is involvement of students in sustained work for generating knowledge of artifacts. All aspects of the investigations were recorded to the learning environments' shared database.

Characteristic of all models of knowledge creation is that the agent of knowledge creation is not an isolated individual but is either an individual embedded in a community or the community itself. Consequently, the projects reviewed above involved a great deal of student autonomy and self-regulation rather than external regulation, for learning processes: multivoicedness, and associated 'creative chaos' rather than pre-structured and strictly controlled instructional processes. The projects were based on an assumption that cognitive diversity and distribution of expertise promote knowledge advancement and cognitive growth (Dunbar 1995). In order to participate in knowledge advancement, learning communities were engaged in direct contacts with dynamic expert communities representing science or technology. Various forms of *student-expert partnership* and *student-scientist partnerships* have emerged that build bridges between schools and these dynamic communities, often relying on resources provided by the new technology (Cohen 1997; DePaula, Feldman, Konold, & Coulter 2000). Such partnerships that allow students peripherally participate in authentic research work, provide ample opportunities for knowledge creation; on the condition that students are given responsibility for all aspects of inquiry, not only engaged in data collection.

It appears to us that the above projects cannot genuinely be described as a process of knowledge acquisition because a major part of the information accumulated did not exist anywhere as such beforehand, but emerged through a long-standing process of inquiry. Further, while the projects involved a rich context of cultural participation, their process cannot be reduced to mere growing up to a social community. Activities of the participants were so strongly organized around the digital artifacts created by them that their process can best be considered to have genuinely involved trialogical elements. Whenever students started to investigate a topic,

they opened up corresponding shared views of the database and used those to guide and constrain their inquiry. Even classroom discussions were organized around a shared screen, representing knowledge artifacts being created by the participants. Thoughtful processes of learning occurring in this environment did not remain private; instead the participants' own mental efforts, continuous struggles to learn, understand and reach beyond information given became visible through the network (Muukkonen, Hakkarainen & Lakkala 2003). Genuine knowledge creation takes time and it is, therefore, very difficult to fit in a traditional educational context. The present projects involved an extended timescale (Lemke 2001) adequate for advancement of knowledge. Accordingly, it does not appear to be an overstatement to say that the processes are not best described in knowledge acquisition or participation approaches.

These investigations provide a kind of existence proof of sustained working for advancement of knowledge at the elementary-level education; in both of the cases there was an exceptionally skillful and committed teacher who had worked for several years to create classroom practices supporting creative working with knowledge (Hakkarainen 2003a). Nevertheless, we believe that ordinary teachers can benefit a great deal from exploring possibilities of involving students in genuine inquiry and thoughtful learning. This challenge concerns all levels of education. We have ourselves been involved in numerous attempts to engage university students in progressive inquiry using the Future Learning Environment and other educational groupware (see Muukkonen, Hakkarainen & Lakkala 2003); even university students have seldom experienced advanced processes of inquiry before starting to pursue their graduate studies.

Beyond the classroom level, it appears to be essential to apply the knowledge-creation metaphor at the level of school communities as whole so as to bring about changes that support progressive inquiry. One implication of the models of innovative knowledge communities is to analyze the overall functioning of schools in accord with the practices in knowledge-creating *organizations* rather than to focus on studying isolated teachers and classrooms. What are the central characteristics of these kinds of schools? David Hargreaves (1999) has talked about the "knowledge-creating school" when he has applied Nonaka and Takeuchi's theory to schools. His argument was that in order to answer the challenges of the knowledge society, schools, and especially teachers and headmasters, need themselves to become creators of professional knowledge. This entails teachers' deliberate effort to articulate their professional experiences into shareable knowledge within and between schools. The challenge of transforming schools toward dynamic

knowledge communities is systemic in nature. There are several factors that make the transformation of the school very difficult, such as social, spatial, and temporal structures embedded in classroom-based study practices (e.g., study of autonomous texts for exams and grading) and the teachers' tradition of working as individual professionals (Engeström, Engeström & Suntio in press). These fundamental constraints make it a great challenge for participants to communally reflect on their practices and engage in sustained expansive learning. School communities may, however, be guided to systematically explore possibilities of transformation through asking questions, generating visions and models of future pedagogy, and experimenting with new practices. Through such deliberate efforts to support transformations, educational communities may gradually come to resemble innovative knowledge communities.

Discussion

A central aim of the present paper is to propose a third metaphor of learning that conceptualizes learning in terms of communal knowledge advancement and as “trialogical” development of common object of inquiry. We have presented three models of innovative knowledge communities that appear to represent this kind of a view. It appears to us that the examination of the third metaphor of learning produces new conceptual means to analyze and understand learning. Epistemological processes in learning that create knowledge, and mediating artifacts and objects have many similarities to creative processes more generally; or, looking at it a little differently, processes of learning and processes of inquiry are inseparably intertwined. It is clear that several, already well-articulated approaches take these issues to be of a fundamental importance.

The knowledge creation metaphor appears to be a promising way to transcend the confrontation between the acquisition and the participation approaches to learning. The gap between these metaphors is evident in the debate between cognitive and situated perspectives on thinking and activity (see Anderson, Reder & Simon 1996; 1997; Greeno 1997). In recognizing the gap, there has been a tendency to try to combine, or to see connections between these two approaches (Anderson, Greeno, Reder & Simon 2000). Addressing processes of knowledge creation provides a means to move beyond the opposition between these approaches. In terms of Charles S. Peirce’s semiotics, we may assume that meanings are growing from iconic and indexical relationships towards symbolic and conceptual meanings (Prawat 1999). While the situational ap-

proach emphasizes indexicality and situatedness of human activity; and the cognitive approach, the symbolic nature of human knowledge, an approach that addresses processes of creating new knowledge and new artifacts collaboratively may simultaneously acknowledge situatedness of activity as well as the importance of mediating (conceptual and material) artifacts that are created in the process.

One limitation of the present discussion, thus far, is that the present authors have examined relations between the metaphors of learning and models of knowledge creation mainly in epistemological terms. Relations between these approaches, however, are much more complex than we have been able to indicate here, and that fact is relevant to educational applications. There are, beyond epistemological differences between the models, essential 'existential' differences, which the participation metaphor of learning has rightly emphasized (see Packer & Goicoechea 2000). If learning that focuses on knowledge-creation is to be taken seriously, these issues should also be addressed. The differing epistemological assumptions concern the nature of agents of knowing, conceptions of knowledge, and learning. *Existential* presuppositions, by contrast, are associated with issues related to one's identity, belonging, and reciprocal social recognition. Packer and Goicoechea (2000) call these "ontological assumptions" because they want to replace dualistic ontology (where there is a clear separation between a knowing subject and an object to be known) with an approach where participation in communal activities and identity of learners are emphasized. Becoming a student is an existential transformation. Although the present models of innovative knowledge communities are nondualist in spirit, school culture often appears to be inimical to them; it produces 'dualisms of mind and body, reason and emotion, and thought and action' (p. 236). In order to facilitate knowledge creation at school, a substantial change in students' identities must occur: it is essential to develop an identity of a prospective builder or creator of knowledge rather than just a 'student'.

We are starting to understand that a successful engagement in knowledge-creating efforts presupposes dealing with these existential challenges that are as important as epistemological ones. Progressive inquiry calls for a specific type of agency in deliberately pursuing collective epistemic goals (Muukkonen, Hakkarainen & Lakkala 2003); this may be called *epistemic agency* (Scardamalia 2002). Epistemic agency does not simply arise from the participants' individual characteristics, but emerges through participation in socio-cultural activities, and its manifestation is dependent on the nature of these collective activities (Holland, Lachicotte, Skinner, &

Cain 1998). Such agency entails that the students assume responsibility of the advancement of their collaborative inquiry and shared knowledge rather than merely pursue their own learning agendas (Scardamalia 2002). Consequently, they relate their personal ideas with one another, monitor advancement of collective activities, and overcome challenges emerging in the process. A critical condition for success appears to be that the *voices* (Bakhtin 1981) of participants of an inquiry community become socially recognized and respected. One may say that participants of progressive inquiry are not only working for knowledge advancement, but "authoring" their selves as well (cf., Holland, Lachicotte, Skinner, & Cain 1998, p. 169).

One question in the background of the knowledge-creation model is whether and to what extent students are able to *create* knowledge, and to what extent this is only a metaphorical way of emphasizing certain characteristics of learning. This depends, of course, on what we mean by 'creation' and what we mean by 'knowledge'. It appears that human activity is transformative in nature; people are very innovative in finding ways to achieve their desired goals and developing necessary means (Engeström 1987). If one takes an essential part of knowledge creation to involve transformation and change of social communities, then we may hypothesize that young persons are able to carry out such innovations. Empirical evidence concerning these issues, however, is still fragmentary. There are some indications that, if adequately supported, young students are able also to create artifacts that support their activities. These artifacts may not only be material in nature, but conceptual as well (Scardamalia & Bereiter 1993; 1994). In supporting environments, students are able to generate theories and explanations that help them to make sense of the issues being investigated (Hakkarainen 2003b; in press). They are also able to follow their research questions in depth and make substantial advancement in knowledge (Hakkarainen & Sintonen 2002).

We are not saying that students at schools should or could produce *historically* novel ideas or knowledge (Boden 2004). Because of the knowledge limitations of young students, they are not in a position to create knowledge in this more demanding sense, but only in relation to their initial position. Yet there are still a wide variety of valuable things that students can do to understand and explain the issues they are dealing with as well as transform their prevailing social practices and culture of working with knowledge. At the same time, they need to learn basic skills and practices related to knowledge advancement. These considerations suggest that educational practices are well worth restructuring on the basis of the knowledge-creation models.

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