TOWARD TRIALOGICAL APPROACH ON LEARNING

Kai Hakkarainen, Savonlinna Department of Teacher education, University of Joensuu

Sami Paavola, Centre for Research on Networked Learning and Knowledge Building, Department of Psychology, University of Helsinki

The purpose of present article is to examine a trialogical approach to learning that is the foundation of the Knowledge-Practices Laboratory project (see www.kp-lab.org). I will contrast the trialogical framework with prevailing monological (cognitive) and dialogical (situated cognition) approaches. Five characteristics of a trialogical approach to learning and cognition are distinguished: it 1) concentrates on processes which aim at developing shared objects; 2) takes place across long timescales, 3) involves interaction between individual and collective processes, 4) relies on cross-fertilization of knowledge practices, 5) relies on collaborative technologies designed to elicit object-oriented activities, and 6) develops through transformations and reflections across forms of knowledge. Three cases applying the trialogical approach will be presented in order to examine its empirical and practical dimensions.

1. INTRODUCTION

The purpose of the present article is to examine a novel approach to learning that we call *trialogical inquiry*. I will start this paper by contrasting monological, dialogical, and trialogical models of learning by introducing three metaphors of learning that we have examined in some of our previous articles (Paavola, Lipponen, & Hakkarainen, 2004; Paavola & Hakkarainen, 2005). Anna Sfard (1998; see also Lave & Wenger 1991; Rogoff, et al. 1996; Wenger 1998) has differentiated between two central metaphors of learning, the knowledge-acquisition metaphor and the participation metaphor. The division is very profound and considers there to be two fundamentally different approaches to learning. As we interpret them, the former emphasizes individual mental processes and the latter examines transmission of cultural knowledge and competence from one generation to the next.

The knowledge-acquisition metaphor examines knowledge as a property or characteristic of an individual mind. An individual is the basic unit of knowing, and learning a process in which information is transferred to the individual agent. The acquisition metaphor may be based on the traditional assumption of the linear transmission of knowledge to the student, or, as Sfard (1998) herself emphasizes, the active and "constructive" (but individual) process. This metaphor leads to an examination of learning from the perspective of a student's internal information processing and emphasizes the role of within-mind knowledge structures (e.g., schemata) in learning. Some versions of the knowledge acquisition metaphor are founded on the "folk" psychological assumption that a person's mind is a container for knowledge and learning is a process which fills this vessel, furnishing it with information (compare Bereiter, 2002).

An alternative approach, according to Sfard (1998), is *the participation metaphor* for learning, which examines learning as a process of growing up and socializing to a

community, and learning to function according to its socially negotiated norms (Lave 1988; Lave & Wenger 1991; Brown, Collins, & Duguid 1989). Participation in various cultural practices and shared learning activities structures and shapes cognitive activity in many ways. Cognition is distributed across individuals and their environments and learning is 'located' in the evolving networking relations. From the participatory perspective, learning is the process of growing to become a full member of a community, in which there gradually occurs a shift from peripheral to full participation. From this perspective, knowledge is not in the world itself or within the mind of an individual, it is simply an aspect of cultural practices (Brown, Collins, & Duguid, 1989; Lave, 1988; Lave & Wenger, 1991). The focus of the participation view is on activities and 'knowing', rather than on outcomes or products (i.e., on 'knowledge' in the traditional sense).

Neither one of these metaphors appears, however, to examine in full processes of knowledge creation and advancement that are essential to an advanced knowledge society. The knowledge acquisition metaphor presupposes pre-given structures of knowledge that an individual student is directed to assimilate or construct in the process of learning and expertise development. Although this process may include creative elements and support the formation of new meaning connections, the creation of knowledge is not central to this metaphor. The participatory metaphor, in turn, focuses its attention on controlling the deepening knowledge of a community without intentional aspirations to bring about conceptual or social change. Because the focus of the metaphor is on prevailing cultural practices, it does not pay particular attention to the creative change of these practices. Alternatively, it emphasizes discursive interaction but does not focus on how shared, concrete objects are developed collaboratively. The acquisition approach and the participation approach may both be developed so that they take innovative aspects into account, but it can be argued that this is not where these approaches are at their best (Paavola et al, 2004).

Based on these perspectives, Paavola and his colleagues (2005) postulate that a third, knowledge-creation metaphor of learning is necessary to overcome the dichotomy between the acquisition and participation approaches. From the perspective of knowledge creation, learning is seen as analogous to innovative inquiry through which new ideas, tools and practices to support intelligent action are created and the knowledge being developed is significantly enriched or changed during the process. The processes, practices and social structures examined under the knowledge creation metaphor, promote focused creation of new knowledge and innovation rather than adjust to the culture or discourse at large or the assimilation of existing knowledge. The acquisition view may be seen to represent a "monological" view of human cognition in focusing on within-mind processes. The participation view, in turn, appears to represent a "dialogical" view because it emphasizes the interaction with the culture, the surrounding (material) environment or among people, and. The knowledge-creation view, in contrast, represents a trialogical" approach to learning

because it focuses on collaborative development of mediating objects or artifacts rather than monologues within mind or dialogues between minds (see Figure 1.).

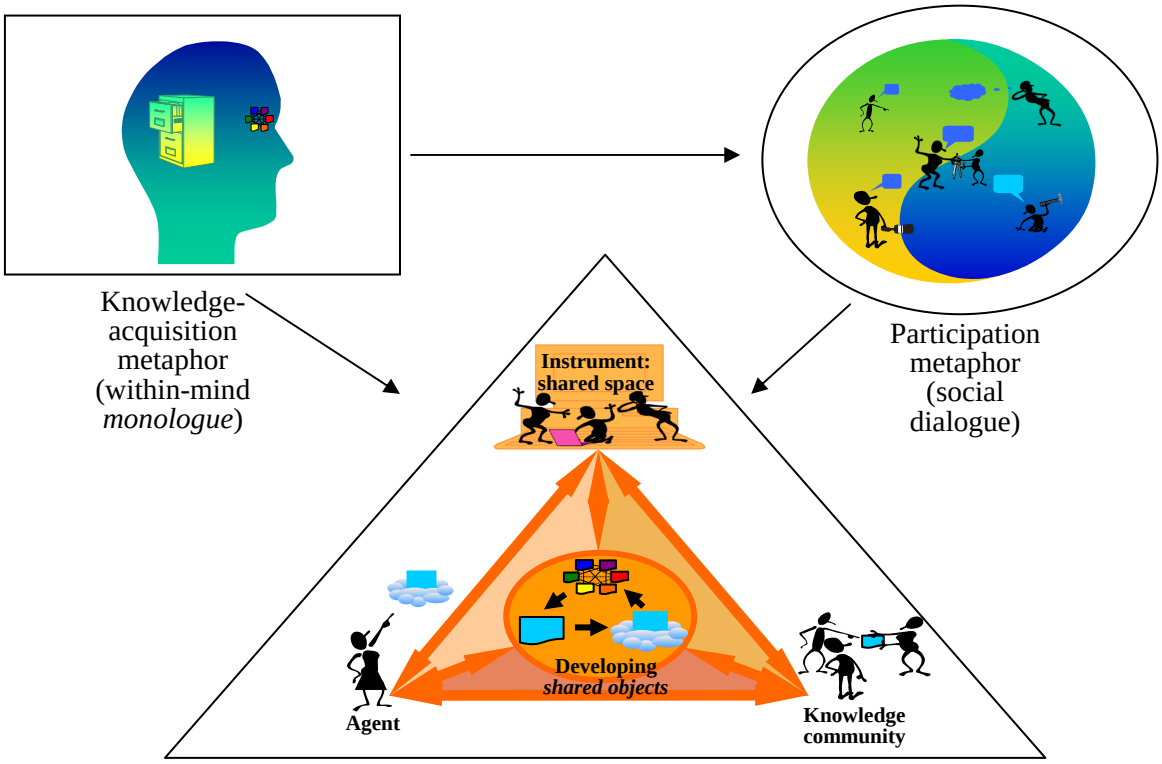

Figure 1. Three metaphors of learning

There are several models that examine learning and inquiry as a process of knowledge creation rather than just assimilating existing knowledge or adopting prevailing practices. These approximations to a trialogical approach guide the examination of learning as a process of innovative inquiry in which the aim is progressively to expand one's knowledge and skills by relying on the prevailing cultural fund of knowledge. We have distinguished three approaches that emphasize creative aspects in knowledge advancement and learning, i.e., Bereiter's (2002) theory of knowledge building, Nonaka and Takeuchi's (1995) theory of knowledge creation, and Engeström's (1987) theory of expansive learning. We have provided a detailed analysis of the basic characteristics of these models of *Innovative Knowledge Communities (IKCs)* elsewhere (Hakkarainen, Paavola, & Lipponen, 2004, and Hakkarainen et al., 2004). Table 1 (see the next page) presents an abstract description of some principal features of the three metaphors of learning.

2. SIX BASIC CHARACTERISTICS OF TRIALOGICAL LEARNING

While the acquisition and participation approaches provide valuable resources, respectively, for understanding individual and social aspects of learning, these metaphors do not appear to provide tools for understanding deliberate processes of advancing and creating knowledge typical of knowledge-intensive work in the present

age. The trialogical approach is intended to elicit innovative practices of working with knowledge within educational and professional communities. A central characteristic of such practices is their artifact-mediated nature; the participants are engaged in externalizing and objectifying their evolving knowledge and understanding in the form of shared artifacts, conceptual or material in nature, which they can utilize in their inquiries. These artifacts are 'objects,' according to the term already introduced. The knowledge creation framework, further, considers there to be a growing collective network of these artifacts of cognition or practice, which provides a basis for the participants' subsequent inquiry efforts.

Table 1. Typical Characteristics 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 collaboratively 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 ▪ Epistemology emphasizing dialogic interaction	▪ 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 objects and artifacts within cultural settings

We propose that the following, six, interrelated principal features characterize trialogical learning.

1. Focus on *shared objects of activity* which are developed collaboratively whether they are conceptual artifacts (e.g., ideas, plans, designs), concrete, material products (e.g., prototypes, design artifacts) or practices (e.g., standard procedures in a laboratory) taken as objects of inquiry. Knowledge creation takes place through collectively advancing shared knowledge objects.
2. *Sustained and longstanding pursuit of knowledge advancement.* Knowledge creation takes place across extended time scales and requires sustained, long-standing working for the advancement of the objects of inquiry. Because the process of knowledge creation is discontinuous and nonlinear in nature, it is full of sudden breakdowns, obstacles that appear insurmountable, accumulating and

resolving tensions and contradictions, as well as occasional leaps of inquiry. Consequently, it is essential to address both longitudinal transformation of knowledge as well as critical, short-term processes, stages and moments of trialogical activity.

3. Knowledge-creation processes taking place in mediated *interaction between individual and collective activities.* While the knowledge acquisition approach tends to reduce learning and cognition to individual mental processes and some versions of the participation approach examine only social practices and structures, the trialogical framework addresses reciprocal personal and collective transformation involved in knowledge advancement (Engeström, 1999).
4. *Cross-fertilization of knowledge practices* between educational, professional, and research communities. An essential aspect of trialogical learning is hybridization between schooling/studying and research cultures as promoted in various investigative learning practices, such as 'progressive inquiry'. It is essential to bring cultures of schooling in closer contact with professional cultures and to engage students in expert-like knowledge practices from the very beginning of their studies.
5. Technology mediation designed to scaffold long-standing collaborative creation, building, and sharing of knowledge. Trialogical activity cannot readily be engaged in without appropriate technologies that help the participants to create and share as well as elaborate and transform knowledge artifacts.
6. *Development through transformation and reflection.* Models and theories belonging to the trialogical approach emphasize development through interaction between various forms of knowledge and between practices and conceptualizations, etc., that is, an interaction and transformations between tacit knowledge, knowledge practices, and conceptualizations are a driving force in processes of knowledge creation.

3. THREE DOMAINS IN WHICH A TRIALOGICAL APPROACH HAS BEEN APPLIED

In order to be taken seriously as a research approach to learning and educational sciences, the trialogical approach needs to be grounded on empirical research in general, and research and development of technology-supported learning in particular. It appears to us that there are, indeed, empirical phenomena that are better understood in terms of trialogical rather than monological or dialogical processes. In what follows, we will briefly describe three such empirical cases. In order to link my presentation with the rest of the present workshop, we would like to present two cases regarding primary education; we have also pursued corresponding inquiries at the university level. The third, paradigmatic KP-Lab case, concerns universities and polytechnics.

Case 1: Progressive inquiry learning

Hakkarainen's research group has been developing so called the *Progressive Inquiry (PI) model* of learning over 10 years. By 'progressive inquiry,' the present investigators refer to the sustained processes of advancing and building of knowledge by pursuing the participants' own research questions and explanations (Hakkarainen, 1998; Hakkarainen & Sintonen, 2002). The PI model relied on Bereiter and Scardamalia's (1994) theory of knowledge building and was inspired by Hintikka's (1999; Hakkarainen & Sintonen, 2002) interrogative model of inquiry. Progressive inquiry is a trialogical process because it engages the participants in systematic collaborative efforts in advancing shared knowledge artifacts, such as questions, working theories, results of scientific experiments, scientific information, and so on. There external representations, jointly created or developed, usually consist of text, graphics, and photos.

Progressive inquiry represents several other characteristics of trialogical learning as well. These efforts take place in the context of larger study projects that engage students in pursuing collaborative inquiry across relatively long periods of time (from one to several semesters). The practice of progressive inquiry relies on hybridization of knowledge practices between educational and research communities through involving students in research-like practices of pursuing their own inquiries, corresponding questions and explanations. The technological infrastructure of these activities has been provided by knowledge-building technologies specifically designed to facilitate working with shared knowledge artifacts. Careful experiments indicate that successful progressive inquiry cultures cannot be created from scratch, but need to be cultivated interactively through sustained efforts involving expansive transformation of knowledge practices.

Case 2: Collaborative designing

Collaborative designing, we propose, is a trialogical process par excellence. Collaborative designing of products for everyday or business use focuses on creating a common design artefact (Seitamaa-Hakkarainen 2000; Seitamaa-Hakkarainen, Lahti & Hakkarainen, 2005), and it is in a very concrete sense emphasizing the development of shared objects. Designing has mental and material aspects: It is not only focused on developing the participants' ideas through taking part in knowledge-seeking inquiries, but also on creating design prototypes and concrete, material products. The efforts of the participants are organized toward developing shared design ideas (conceptual artifacts), embodying and explicating those ideas in visual sketches (graphic artifacts or inscriptions), and giving the ideas a material form as prototypes or end results (e.g., mass produced products). The process involves interaction with users whose needs and desires form constraints on the design process. Both conceptual and physically embodied design artifacts may be considered as trialogical objects around which the participants' efforts are organized. The design process appears from the beginning to the end to be mediated by the trialogical objects being designed.

A computer-supported study project concerning artifacts was organized at Laajasalo Elementary School, Helsinki, Finland. The Artifact Project – the Past, the Present, and the Future was organized in close collaboration between the class teacher and the researchers. In the project, 31 students from grades 4 and 5 participated. The aim of the project was to break boundaries of traditional schoolwork by supporting pupils' collaborative creation of knowledge with the help of various experts, such as museum staff, craftspeople, and designers. The technical infrastructure of the project was provided by Knowledge Forum, a networked learning environment, which provides sophisticated tools especially for building and visually organizing knowledge. In terms of timescale of the project (18 months), it represented a genuine trialogical process that takes place through sustained efforts across substantial periods of time (Bereiter, 2002; Hakkarainen et al., 2004).

In the first phase of the project (the Past), pupils explored their own environment of artifacts, analyzed the design and usability of artifacts, inquired into the historical development of selected artifacts, and built an exhibition of artifacts within a classroom. In the second phase (the Present), pupils investigated the physical phenomena of artifacts, such as mechanics (movement of a ball), light (electric circuits), and characteristics of metals. During the last phase (the Future), of the project pupils explored existing lamps and designed new lamps with the help of a professional designer. They also outlined and visualized artifacts of the future, as well as analyzed the needs of future consumers and utilization of future artifacts. The investigation of the lamp design led the students towards the last activities of the project focused on projecting what the design of their chosen artifacts would look like, in the year 2020. An innovative aspect of the project was a novel way of integrating working with material and conceptual artifacts in the context of trialogical inquiry. During the lamp design process, and the whole project, the pupils were both "hands on" and "minds on". By studying, investigating and designing material artifacts, tangible things that can be touched, they also created conceptual artifacts, such as ideas, explanations, and theories. Examining everyday artifacts from a design perspective assisted the pupils in going beyond mere appearances and digging to deeper levels of knowledge and understanding.

Case 3: Boundary-crossing KP-Lab course

A central idea of the Knowledge-Practices Laboratory project is to elicit cross-fertilization between educational institutions and professional communities through organizations courses in which the participants solve complex problems for real customers, whether the latter are enterprises, public organizations or research communities. This objective is based on actual practices for giving university courses developed by Göte Nyman and his colleagues. Nyman has organized a series of courses for students and teachers from the Helsinki University of Technology and Helsinki Business School in addition to those of the University of Helsinki. Each course is designed to answer a challenge with which one or several enterprises are struggling. Rather than lecturing about the emerging forms of mobile work, the

participants are guided to go to the field and collect data about mobile work by interviewing experts and observing their practices. The students work in teams with team leaders (i.e., senior students who have already completed similar courses). The team leaders constitute a coordination team that takes care of negotiations with customers. While other teams focus on fieldwork, the research team assists the coordination team in real-time management of the course.

The complex problem provided by the customer determines the trialogical objects with which the participants work. Activities of the course are mediated by technology-based learning environment that elicits creation, sharing, elaboration, and synthesis of digital knowledge artifacts. The ultimate trialogical object of the course is the final research report, jointly constructed for the customer. The boundary-crossing nature of this kind of process separates the activity from progressive inquiry or collaborative designing. The activity literally takes place at inter-organizational boundary surfaces.

The three kinds of courses presented above show how trialogical approach can be implemented in various ways (and these three are by no means supposed to give an exhaustive list of alternatives). There are different kinds of shared objects in these courses and those knowledge practices that they aim at developing varies a lot.

5. DISCUSSION

The present trialogical approach did not come out of the blue; it emerged through ten years of efforts to understand innovative learning processes. The research group at Helsinki has pursued research aimed at improving the quality of learning so as to answer the challenges emerging from the knowledge society in Finland, Europe, and North America. Investigations regarding the above metaphors have been undertaken in our efforts to resolve tensions or challenges emerging from our research work. In theoretical foundations and research methodologies, one may distinguish three overlapping "generations" of learning models on which our investigations have relied.

Generation 1: The first author's efforts to promote education by facilitating expert-like working with knowledge started in 1994 when he returned to Finland from doctoral studies at the University of Toronto. In his doctoral thesis, Hakkarainen had developed the progressive inquiry (PI) model that guided students in advancing their conceptual ideas through computer-supported collaborative learning (CSCL). Our research group ran, however, into various problems while trying to facilitate conceptual change in science education. Finnish students were initially posing mainly fact-seeking questions and gaining fragmentary knowledge. We were not able to convey the basic concepts of inquiry to the teachers, and the computer/software focus typically led to their becoming more interested in ICT technology than learning or understanding. We realized gradually that genuine inquiry cultures do not emerge without transforming the social practices prevailing at school (Säljö, 2001; Hakkarainen, Lonka, & Lipponen, 2004). The mature inquiry cultures investigated by Hakkarainen among students at selected sites in Canada have their own histories and

cannot simply be transferred from one country to another without going through corresponding developmental-historical pedagogical processes.

Generation 2: These challenges drew our interest to those participatory aspects of learning that had been invisible to many cognitive researchers. Learning takes place within *communities of practice* (Lave & Wegner, Werner, 1998; Brown & Duguid, 2002) that guide and constrain the participants' activities in multiple ways. In order to understand these processes better, we teamed up with innovative teachers, started videotaping classroom practices, and learned to do social network analysis (SNA, Hakkarainen & Palonen, 2003; Lipponen, Veermans, Lallimo, & Hakkarainen, 2003; Palonen, & Hakkarainen, 2000); this method allowed us to examine patterns of participation in our school projects and the "social infrastructures" needed to make computer-supported learning work. Cultural psychology and activity theory started to emerge as approaches that appeared to provide conceptual tools that allowed us to understand theoretically the complex relational processes involved. Something was, however, still missing, and the dynamics of knowledge-creation was only partially grasped. We were studying social networks and practices, but losing a relation to conceptual processes essential for in-depth understanding as well as advancement of knowledge. So we began to analyze and compare the most promising models of innovative knowledge communities (IKCs), i.e., Carl Bereiter's (2002) version of the knowledge-building approach, Nonaka and Takeuchi's (1995) knowledge-creation model for companies, and Engeström's (1987; 1999a) expansive-learning approach (Paavola & Hakkarainen, in press; Paavola, Hakkarainen, & Lipponen, 2004). These investigations indicated the need to articulate a more general theory of knowledge creation as well as to anchor the progressive-inquiry model more closely in social practices.

Emerging generation 3: Currently, we are struggling to understand learning as a form of trialogical activity focused on collaboratively advancing a shared object of inquiry, whether it is a research problem, theory, plan, product, practice (to be transformed), or project. This endeavor requires theoretical and conceptual development and corresponding improvements of research methods and methodologies. Our model of learning holds the promise of more general applicability in the investigation of the mediated nature of human activity. The "trialogical" account of inquiry, from which we draw, not only helps us to understand sign- and tool-mediated activity (Skagestad, 1993; Vygotsky, 1978; Engeström, 1987), but also examine, from also gives a unified framework for our research related to flow (Csikszentmihalyi, 1995), personal projects (Little, 1983; Salmela-Aro & Nurmi, 1999) and scientific creativity (Gruber, 1989, 1995; Gruber & Wallace, 1999) in a way that promises to give integration on epistemic, socioemotional, and social aspects of learning. Here dialogue with various cultural-psychological approaches, such as knowledge building, activity theory, distributed cognition, actor-network theory or situated cognition, will provide valuable guidance. Knowledge-creating learning can be seen as a self-organizing system (Resnick, 1994) that involves coevolution of

agents, artifacts, and dynamically evolving social communities and networks (Tuomi, 1999; 2002; Engeström, 1999a; Hakkarainen et al., 2004).

Participation aspects and knowledge-creation aspects of learning are not opposite, but support each other. *Technology enhances meaningful learning and instruction only through transformed social practices* (Hakkarainen et al., 2006). In order to genuinely elicit educational transformations, it is necessary to put social practices into the middle rather than periphery of discussion. Social and technical aspects of technology enhanced learning coevolve in terms of novel technological instruments providing new affordances for educational activity and evolving practices affecting directions of subsequent technology use. We propose that various forms of trialogical inquiry are not only about pedagogical processes but define certain social practices as well. Pursuit of question-driven inquiry, collaborative design or boundary breaking are social practices regarding creative working with knowledge. We call these *knowledge practices*. The technology as such does not automatically change educational practices; teachers' deliberate effort to cultivate new social practices are needed as well that channel the participants limited intellectual efforts in a way that elicit trialogical inquiry.

REFERENCES

Bereiter, C. (2002). Education and Mind in the Knowledge Age. Hillsdale, NJ: Erlbaum.

Brown, J. S., Collins, A. & Duquid, P. (1989). Situated cognition and the culture of learning. Educational Researcher, 18, 32-42.

Engeström, Y. (1987). Learning by expanding. Helsinki: Orienta-Konsultit.

Engeström, Y. (1999a). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R.-L. Punamäki (Eds.) Perspectives on activity theory (pp. 19-38). Cambridge: Cambridge University Press.

Engeström, Y. (1999b). Innovative learning in work teams: Analyzing cycles of knowledge creation in practice. In Y. Engeström, R. Miettinen, & R.-L-. Punamäki (Eds.), Perspectives on activity theory (pp. 377-404). Cambridge: Cambridge University Press.

Gruber, H. (1995) Insight and affect in the history of science. In R. Sternberg, R. & J. E. Davidson (Eds.) The nature of insight (pp. 397-431). Cambridge, MA: MIT.

Hakkarainen, K. (2003c) Progressive inquiry in computer-supported biology classroom. Journal of Research in Science Teaching, 40, 10, 1072-1088.

Hakkarainen, K. (2004) Pursuit of explanation within a computer-supported classroom. International Journal of Science Education, 979-996.

Hakkarainen, K., Muukkonen, H., Markkanen, H., & the KP-Lab Research Community (2006). Design principles for the Knowledge-Practices Laboratory

(KP-Lab) project. In S. Barab, K. Hay, & D. Hickey (Eds.) Proceedings of the International Conference of the Learning Sciences 2006 (pp. 934-935). Mahwah, NJ: Erlbaum.

Hakkarainen, K., Paavola, S., & Lipponen, L. (2004). From Communities of Practice to Innovative Knowledge Communities. LLine – Lifelong Learning in Europe, 9, 2/2004, 74-83.

Hakkarainen, K. & Palonen, T. (2003). Patterns of Female and Male Students' Participation in Peer Interaction in Computer-supported Learning. Computer & Education, 40, 4, 327-342.

Hakkarainen, K., Palonen, T., Paavola, S. & Lehtinen, E. (2004). Communities of networked expertise: Professional and educational perspectives. Amsterdam:Elsevier Science.

Hakkarainen, K. & Sintonen, M. (2002). Interrogative Model of Inquiry and Computer-Supported Collaborative Learning. Science & Education, 11, 25-43.

Hintikka, J. (1999). Inquiry as inquiry: A logic of scientific discovery. Selected papers of Jaakko Hintikka, Volume 5. Dordrecht: Kluwer.

Lave, J. & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge: Cambridge University Press.

Lemke, J. (2001). The long and the short of it: Comments on multiple timescale studies of human activity. The Journal of the Learning Sciences, 10, 17-26.

Lipponen, L. Veermans, M., Lallimo, J., & Hakkarainen, K. (2003). Patterns of participation and discourse in elementary students' computer-supported collaborative learning. Learning and Instruction, 13, 487-509.

Little, B. R. (1993). Personal projects and the distributed self: aspects of a conative psychology. In J. Suls (Ed.), Psychological perspectives on the self (pp. 157-185). Hillsdale, NJ: Erlbaum.

Paavola, S. & Hakkarainen, K. (2004) "Trialogical" processes of mediation through conceptual artefacts. A paper presented at the Scandinavian Summer Cruise at the Baltic Sea (theme: Motivation, Learning and Knowledge Building in the 21st Century), June 18-21, 2004 . (http://www.lime.ki.se/uploads/images/537/Baltic2004_Paavola_Hakkarainen.pdf)

Paavola, S & Hakkarainen, K. (2005). The knowledge creation metaphor – An emergent epistemological approach to learning. Science & Education 14, 537-557.

Paavola, S., Lipponen, L., & Hakkarainen, K. (2004). Modeling innovative knowledge communities: A knowledge-creation approach to learning. Review of Educational Research, 74, 557-576.

Paavola, S., Hakkarainen, K., & Sintonen, M. (2006). Abduction with Dialogical and Trialogical Means. Logic Journal of the IGPL 14(2), 137-150. Available online.

Resnick, M (1994) Turtles, termites, and traffic jams. Cambridge, MA: MIT.

Salmela-Aro, K. & Nurmi, J.-E. (1997). Goal contents, well-being and life context during transition to university: A longitudinal study. International Journal of Behavioral Development, 20, 471-491.

Scardamalia, M. & Bereiter, C. (1999) Schools as knowledge-building organizations. In D. Keating & C. Hertzman (Eds.), Today's children, tomorrow's society: The development of health and wealth of nations (pp. 274-289). New York: Guildford.

Seitamaa-Hakkarainen, P., Engeström, R., Kangas, K., Bollström-Huttunen, M., & Hakkarainen, K (2004) The Artifact Project: Hybrid Knowledge Building in a Networked Learning Environment. A paper to be presented the Scandinavian Summer Cruise at the Baltic Sea, June 18-21, 2004. (http://www.lime.ki.se/uploads/images/539/The_artifact_project_Seitamaa-Hakkarainen.pdf)

Seitamaa-Hakkarainen, P, Lahti, H. & Hakkarainen, K. (2005). Three Design Experiments for Computer Supported Collaborative Design. Art, Design and Communication in Higher Education, 4, 101-119.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. Educational Researcher 27(2), 4-13.

Skagestad, P. (1993). Thinking with machines: Intelligence Augmentation, Evolutionary Epistemology, and Semiotic. *The Journal of Social and Evolutionary Systems* 16(2), 157-180.

Vygotski, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.

Wenger, W. (1998). Communities of practice: Learning, meaning, and identity. Cambridge: Cambridge University Press.