Collaborative Knowledge Creation

Practices, Tools, Concepts

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This book presents perspectives on the knowledge creation metaphor of learning, and elaborates the trialogical approach to learning. The knowledge creation metaphor differs from both the acquisition and the participation metaphors. In a nutshell, trialogical approaches seek to engage learners in joint work with shared objects and artefacts mediated by collaboration technology. The theoretical underpinnings stem from different origins, including knowledge building and cultural historical activity theory. The authors in this collection introduce key concepts and techniques, explain tools designed and developed to support knowledge creation, and report results from case studies in specific contexts. The book chapters integrate theoretical, methodological, empirical and technological research, to elaborate the empirical findings and to explain the design of the knowledge creation tools.

The target audiences for this book are researchers, teachers and Human Resource developers interested in new perspectives on technology-enhanced learning, emphasizing collaborative learning, technology-mediated knowledge creation, and applications of this for higher education, teacher training and workplace learning.

The book is the result of joint efforts from many contributors who took part in the Knowledge-practices Laboratory (KP-Lab) project (2006–2011) supported by EU FP6.

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Collaborative Knowledge Creation
TECHNOLOGY ENHANCED LEARNING

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Scope
The rapid co-evolution of technology and learning is offering new ways to represent knowledge, new educational practices, and new global communities of learners. Yet the contribution of these changes to formal education is largely unexplored, along with possibilities for deepening our understanding of what and how to learn. Similarly, the convergence of personal technologies offers new opportunities for informal, conversational and situated learning. But this is widening the gulf between everyday learning and formal education, which is struggling to adapt pedagogies and curricula that were established in a pre-digital age.

This series, Technology Enhanced Learning, will explore learning futures that incorporate digital technologies in innovative and transformative ways. It will elaborate issues including the design of learning experiences that connect formal and informal contexts; the evolution of learning and technology; new social and cultural contexts for learning with technology; novel questions of design, computational expression, collaboration and intelligence; social exclusion and inclusion in an age of personal and mobile technology; and attempts to broaden practical and theoretical perspectives on cognition, community and epistemology.

The series will be of interest to researchers and students in education and computing, to educational policy makers, and to the general public with an interest in the future of learning with technology.
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PREFACE

The book is about collaborative knowledge creation, and more specifically about the *trialogical* approach to learning. Throughout the book, the authors explore collaborative work with shared knowledge artefacts and objects, and relate their contributions to tool development for and practices of technology-mediated learning. The contributions are concrete examples to explain how people create knowledge that is materialized in concrete objects, and transforms their knowledge practices by cross-fertilizing new and existing practices in educational and professional environments.

The book presents results from the Knowledge Practices Laboratory (KP-Lab) project (http://www.knowledgepractices.info), an EU-funded integrated project (2006–2011), to a broader audience. 22 partners from 14 countries joined to explore higher education courses, workplace learning and teacher training situations to help bridge practices in educational and professional institutions.

The book is aimed at readers interested in collaborative knowledge creation processes and technology-mediated learning. Compared to other contemporary European perspectives on technology-enhanced learning, the chapters in this book are framed within one overarching theoretical perspective, the trialogical approach, to explore knowledge creation processes.

As editors of this book, we are grateful to the authors’ commitment to contribute and present their work here. It has been a long journey, starting as a workshop in Oslo in 2007, followed by several iterations from initial conception to completion. Thank you all for persistence in a long process.

In addition to the authors of the chapters, we would like to express our great appreciations for the contributions by the KP-Lab senior researchers, and the KP-Lab expert panel members Carl Bereiter, Yrjö Engeström, Erno Lehtinen, Sten Ludvigsen, and Gerry Stahl. Without your participation, feedback and advice this book would not have been possible. Thank you very much!

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Oslo/Helsinki, March, 1st 2012,

Anne Moen, Anders I. Mørch, Sami Paavola (editors)
Understanding transformations of knowledge practices, both educational and professional, has been an overall goal in the explorations presented in this book. There is a need for new approaches to learning, especially for understanding and supporting practices where people are creating or developing useful and reusable things in collaboration. This assertion challenges several existing perspectives on learning: theoretically, pedagogically, when it comes to technology support, and when it comes to location (at school, at work, etc). Initial questions motivating our work included: What kind of knowledge practices, i.e. ways of working with knowledge, is needed in modern working life? How to teach and learn them? And what is the role of digital technology in these practices?

Collaborative knowledge creation seen in technology-mediated work with knowledge artefacts for practice transformations, and the trialogical approach to learning binds the chapters of this book together. The specific contribution of the trialogical approach is a combination of the conceptual aspects of the inquiry processes and idea-centred work with features adopted from the pragmatically- and ‘materially’ oriented approaches (Paavola & Hakkarainen, 2009).

Current approaches to learning emphasize issues like participation (Sfard, 1998), joint meaning making (Stahl et al., 2006), discourse and dialogue (Wegerif, 2006) as starting points for collaborative learning. As such, they also challenge individualistically oriented conceptualisations of learning. The same concerns technology and technology-mediated learning. ‘Information media’ has been challenged and supplemented with ‘communication media’, which are interfaces extending from human computer interaction to social interaction (or ‘dialogues’) (Enyedy & Hoadley, 2006). Furthermore, computer-supported collaborative learning environments complement and extend individual-oriented learning systems (Ludvigsen & Mørch, 2010). Notions like ‘Web 2.0’ are often used to point out new technology for harnessing participation, social networking and collective intelligence. We maintain that these perspectives’ suggestions to extend single user environments to collaborative interaction are not by themselves sufficient to understand and support modern knowledge work. Supplementary approaches are needed to take into account collaborative, long-term, iterative work with concrete things and issues.

The ‘objects’ and ‘artefacts’ play a crucial role throughout this book. This is one key to understanding the trialogical approach to learning. The practical and theoretical importance of ‘objects’ and ‘artefacts’, and their characterization as collaboratively developed becomes central. Although these directions in the
evolution of technology have existed for some time (Engelbart, 1962), the current opportunities are that the technology can try to ‘catch up’ with the early visions and conceptual frameworks. New kinds of object-oriented, or artefact-mediated approach carries a lot of unused potentiality, and should be further developed, harnessed, and applied, especially when it comes to technology mediated collaborative learning.

On one hand, and according to the cultural-historical approach, human activities are mediated by artefacts, used and modified by succeeding generations of humans and grounded in practical, everyday activities (Cole 1996; Miettinen & Virkkunen, 2005). Artefacts are seen more generally as the central means for cultural evolution (Wartofsky, 1979). On the other hand, the knowledge building approach maintains that collaboratively developed conceptual artefacts are the central epistemological means, contrasted to individualistically oriented learning (Bereiter, 2002). The object of activity is emphasized especially in activity theory as the starting point for understanding human activities (e.g. Engeström, 1987). The notion of ‘object’ is seen as increasingly important in other approaches as well (Engeström & Blacker, 2005 for various approaches related to objects).

Conceptually, elaborations of collaborative knowledge creation and the trialogical approach have been influenced by Knorr Cetina (2001) distinctions of epistemic objects and epistemic practices. According to Knorr Cetina, modern knowledge work cannot be described with the traditional notions of practices interpreted as recurrent routines or fixed commodities, but requires more dynamic notions of epistemic practices. Also other authors have combined ‘artefact-oriented’ or ‘object-oriented’ approaches to propose various forms of knowledge practices (Ewenstein & Whyte, 2009; Hakkarainen, 2009). The ‘Practice turn’ (Schatzki et al., 2001) in the social sciences and organizational learning carries implications for learning theories. Schön’s (1983) notions of reflective practice as reflection-in-action and reflection-on-action are relevant when studying learning integrated with other activities. However, Schön’s focus was on understanding human reflection during design activity contrasting the plan-based approach, in terms of how people modify their activity as they interact with the materials of a situation and in the dialogue with others. In this book, the authors address reflection in terms of collaborative processes, reflecting on practice transformation, and collaborative reflection aided by computer support.

‘Knowledge Practices Environment’ (KPE) is the technology platform investigated in many chapters of this book. KPE supports reflective and ‘object-centred’ knowledge creation practices. KPE provides virtual working spaces, called shared spaces, for the collaborative work. Working in a shared space enables viewing the knowledge artefacts and their relations from different perspectives and supports object-oriented development of all items. Basic tools and functionalities include, in addition to the common upload etc. functions, the following: note editor, commenting, context-based chat, semantic tagging, linking of items allowing also spatial organisation, and alternative process view for structuring the process, among others. Optional tools include Activity System Design Tool (ASDT), Visual Model Editor (VME), and mirroring tools (or analytic tools).
To understand the resources and processes involved when people transform their knowledge practices requires an integrative approach, since open-ended problem-solving processes cannot be completely planned in advance. This involves sensitive, flexible regulation, trying to tease out details of on-going activities and link them to the main goals and objectives, and openness to modifying plans and structures when a process asks for it. The unit of analysis in the knowledge creation in particular contexts require a multi-level methodology, which consists of interrelated levels of abstraction: micro, meso and macro, each of different temporal and spatial qualities. Micro-level data are data that represent actual, ‘in-situ’ interactions in knowledge-creation processes of what people actually do and contribute within the process. Meso-level data are data representing a series of interactions and productions as parts of evolving trajectories of participation in knowledge creation processes. Finally, macro-level data are data that record transformations, which involves broader historical and/or institutional perspectives. The three-tiered structure allows for in-depth analysis of moment-to-moment interaction to be combined with a perspective on evolving, object-oriented, open-ended inquiry.

Organization of the Book

The book seeks to integrate theoretical development, tool design and development, and empirical studies of the use and deployment of technological tools. Compared to other, contemporary European perspectives on technology-enhanced learning (e.g., Balacheff et al., 2009), the contributions in this book are framed within one, overarching theoretical perspective. Throughout the KP-Lab project, the trialogical approach to knowledge creation has been refined and operationalized through processes of technology design and empirical case studies of knowledge practices in higher education and professional practices. The first chapters in this book start by reflections on theoretical foundations and conceptual resources, followed by tools and design processes, and a selection of empirical studies on knowledge practices in higher education and professional practices including teacher training.

The Chapters

Paavola and colleagues (Chapter 1) introduce and explain the background for the trialogical approach to learning. It builds on classical approaches to mediation but aims at understanding novel practical and theoretical challenges of the knowledge society. The main theoretical development of the trialogical approach and different interpretations of the object-oriented knowledge work in the KP-Lab project are analysed in this contribution.

In Chapter 2, Batatia and colleagues consider tacit knowledge in knowledge creation activities. A variety of theories and models are surveyed in this chapter. This contribution attempts to elucidate relationships between trialogical learning and tacit knowledge for the purpose of theory-informed design of knowledge
creation tools. Examples are given from three of the KP-Lab tools. The chapter points out implications for further development of tools.

The chapter by Doerr and colleagues (Chapter 3) introduces the KP-Lab Reference Ontology as an extensible conceptual model useful to analyse knowledge creation processes when different types of actors, things, and events come into play. The aim of the Reference Ontology is to serve as common ground for interoperability of the tools, and to support data analysis across cases. It is proposed to meet the needs of the heterogeneous KP-Lab ecosystem, re-presenting and interpreting data produced in multiple knowledge practices. Special attention is given to the dynamics that occur during knowledge creation processes and transformation practices.

Bauters and colleagues (Chapter 4) introduce the web-based application system Knowledge Practices Environment (KPE). KPE aims to support continual processes and development of products through collaborative interaction. It provides affordances for work with shared objects, e.g., artefacts, processes or practices, and a database for persistent storage of these objects. The main design ideas and features of KPE are elaborated, and results from a user study with KPE are presented.

In Chapter 5, Richter and colleagues present the Visual Modelling Editor (VME) for computer-supported modelling of conceptual artefacts. This tool allows users to create, compare and update different visual models, and to design and revise the underlying modelling language. VME has been introduced in several courses at two technical universities and the first user experiences showed that it can be used to create, reflect on and develop visual models as shared knowledge objects, and how modelling could be understood as an epistemic activity.

Toiviainen and colleagues (Chapter 6) explain in depth the co-design process leading to the Activity System Design Tool (ASDT). ASDT is integrated in the KPE, and specifically supports activities in distributed, highly specialized teams of expert workers. The authors argue that work processes of this kind are best understood as co-production of material objects while being organized in different teams. Collaborative work is analysed as inter-layered communication and design actions. Different perspectives shape the collective learning process materialized in creation and maturation of a shared, material object: the ASDT.

In Chapter 7, Richter and co-authors describe two mirroring tools for collaborative analysis and reflection (Visual Analyser and Time Line Based Analyser). These tools allow users to depict, explore, and interpret the digital traces of collaborative knowledge creation activities. The contribution shows how heterogeneous user groups (students, teachers, and knowledge workers) can interactively visualize tasks and activities over time. Mirroring tools can provide the users with tools and methods to enable reflection on their knowledge practices as they are engaged in project work over longer periods of time.

In their chapter, Lakkala and colleagues (Chapter 8) report on the use of specially developed design principles for triological learning in two higher education courses. They claim that efforts to operationalize the rather abstract
design principles are useful because it helps to develop heuristic guidelines for educational practitioners and related tools. This requires that design principles are adapted to realities and challenges of each setting.

Karlgren (Chapter 9) introduces the triological approach to enrich medical simulation training in critical care. To portray the collaborative features, the cases’ were modified based on triological design principles. Analysing the empirical material, typical recurrent patterns are discerned, and a development trajectory is suggested. The contribution contributes to contextualizing and extending the KP-Lab design principles by comparing the design patterns in the unfolding trajectory of solving educational problems.

Kosonen and colleagues (Chapter 10) explore activities of students in a multidisciplinary course in which business ideas and media technology solutions were developed for customers. The contribution discusses how a course based on the cross-fertilization between educational institutions and professional contexts was used in training new product-development professionals. The analysis of instructors’ guidance and the subsequent changes made to students’ working documents was conducted.

Damşa and Andriessen (Chapter 11) present an empirical foundation for the notion of shared epistemic agency. Within the knowledge creation perspective of learning the capacity for shared epistemic agency is enabled by groups’ deliberate collaborative efforts to create shared knowledge objects. Epistemic and regulatory dimensions of the created knowledge object are elaborated and illustrated by actions during the collaborative creation of shared knowledge objects.

In Chapter 12, Kárpáti and Dorner apply knowledge building theory and the notion of epistemic agency to analyse teachers’ satisfaction during transition to a new teaching practice in Hungary aimed at educating reflective practitioners, and employing a model referred to as mentored innovation. A large-scale study using an instrument to collect satisfaction and communication preferences is conducted. The authors report on the teachers’ satisfaction, but also suggest an analysis to explore further strategies in teacher training that make knowledge creation processes more visible and accountable.

Sins and Andriessen (Chapter 13) report on a new kind of teacher-researcher collaboration at a secondary school where the goal was to collaboratively design a new learning module. The tensions among project team members became an object of analysis. The results are recommendations for a redesign of teaching practices, where the teachers themselves become targets for change. The authors propose a generic pattern of managing and resolving tensions for teachers as they reflect upon and constructively use tensions to transform practices. Aspects of activity theory are used in the conceptual framework for analysis and transformation.

Moen and Nes (Chapter 14) illustrate collaborative knowledge creation among professionals, where knowledge objects are (re)created based on interactions of persons and their material objects. The empirical example is a knowledge creation process where nurses’ negotiate and consolidate versions of local and
standardized procedures to co-create their knowledge object; a consolidated work description. This is discussed as a question-generating knowledge object, open to modification, change and evolution by the health care workers.

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1. THE TRIALOGICAL APPROACH AS A NEW FORM OF MEDIATION

INTRODUCTION

An emerging trend in theories about human learning and cognition is emphasizing collaboration, creative processes, and the use of new technology. Various changes in modern society form a basis for the change in learning theories, such as: 1) the rapid development of new technology which has formed and continues to form qualitatively new opportunities for distributed interaction and collaboration, 2) the pressure to create – and learn deliberately to create – new knowledge and transform existing practices in various areas of life, and 3) the complexity of modern society which means that people must combine their expertise to solve often unforeseen complex problems because individuals cannot solve problems alone. In order to underline this change and the emerging new phenomena related to collaborative creativity in theories of learning, the knowledge creation metaphor of learning has been proposed (Paavola, Lipponen, & Hakkarainen, 2002; 2004; Hakkarainen et al., 2004). This metaphor is a sequel to Anna Sfard’s well-known distinction between acquisition and participation metaphors of learning (Sfard, 1998). The knowledge creation metaphor has a central basis on the theories emphasizing collaborative creativity, such as Nonaka & Takeuchi’s theory of organizational knowledge creation (Nonaka & Takeuchi, 1995), and Bereiter’s theory of knowledge building (Bereiter, 2002); as well as activity theory, especially Engeström’s theory of expansive learning (Engeström 1987). The metaphor was developed and addressed first in the context of the computer-supported collaborative learning (CSCL) and is, accordingly, recognized mostly in the CSCL literature (e.g., Stahl, Koschmann & Suthers, 2006; van Aalst 2009) but also in relation to novel technologies more generally (e.g., McLoughlin & Lee, 2008), and when learning approaches have been reviewed (e.g., Tynjälä & Häkkinen, 2005).

The knowledge-creation metaphor of learning functioned as a foundation for the KP-Lab project (Knowledge Practices Laboratory), a five-year project (February 2006 – January 2011) representing various approaches to research and development of educational technology. A goal of the project was to develop theories, technology-enhanced tools, practical models, and research methods that elicit deliberate advancement and creation of knowledge as well as transformation of knowledge practices in higher education and in the workplaces. The partners in the project, who represented educational research, technology development, and various theoretical outlooks, focused on models and tools for higher education,
teacher training, and the workplace. The knowledge-creation metaphor of learning appeared to provide an apt theoretical background for this kind of project when it included partners with somewhat different theoretical starting points. Instead of starting from some specific theoretical outlook concerning learning or educational technology, it functioned more like an “umbrella” framework emphasizing commonalities between different forms of expertise and theoretical approaches which all seek to understand phenomena central to the project’s aims and research. As a co-design and integrated project, KP-Lab itself represented a knowledge-creation process in which objects are hard to specify or predict in advance because they shift and may emerge only towards the end of the process. Nowotny et al. (2001, 145) take the view that the process (in “Mode-2 objects”) is more one of groping towards an “object of negotiation”, which has yet to assume its scientific or technological “gestalt”, than of knowing from the beginning what its contours and content are likely to be.

To embody the knowledge creation metaphor in practice in relation to technology-enhanced learning and through a particular research approach, a trialogical approach was elaborated. One of the original aims of the KP-Lab project has been to apply the trialogical approach to learning by developing pedagogical practices, models and tools to support learning activity based on collaborative knowledge creation. In this paper, we elaborate how the trialogical approach has been determined. First we delineate the main starting points of the approach, taking influences from other approaches to mediated activities. We then elaborate how the trialogical approach has been developed in the KP-Lab project by framing tools and knowledge practices investigated there. Finally, we look briefly at the challenges of developing object-oriented knowledge practices further.

DEVELOPING FORMS OF MEDIATION

The trialogical approach builds on classic approaches emphasizing mediation as a basis for understanding human activities. Humans can control their behaviour from the outside, that is, culturally and socially, using signs and tools (Vygotsky, 1978). Signs, tools, and artefacts bring in “thirdnesses”, that is, mediated processes which are interpreted and developed in iterative, social processes (Peirce, CP 1.363; CP 5.138). To serve the knowledge creation metaphor, the focus on various forms of mediation has been used to overcome such dichotomies as the structural/processual, and individual/collective in studying human activities. In addition, mediation opens up new potentialities in technologically supported activities. Modern knowledge work supported by digital technology both requires new means for working with epistemic objects and knowledge artefacts and highlights their role for understanding learning differently. The trialogical approach emphasizes (knowledge) artefacts as things which mediate activities but are also taken themselves as objects to be created and developed by the actors. We argue that this triple nature (tool/concrete object/object to be developed) of situated artefacts forms the essence of novel knowledge practices, and puts the emphasis on how to organise actual processes of learning and working where mediating artefacts are
partly pre-existent, partly created, and partly modified in the activity whose constituents they ultimately are.

There are also other approaches which underline the new role and search for redefinition of epistemic objects and their artefacts. Karin Knorr Cetina (2001) has emphasized that the emergent phenomena of the modern knowledge society challenge traditional ways of understanding the meaning and nature of practices and objects as a part of human activities. Practices are often seen as recurrent processes and rule-based routines, but modern “epistemic practices” redefine this notion. Knowledge-centered work requires a more dynamic, creative, and reflective notion of practice. Knorr Cetina has also emphasised that the notions of object and especially epistemic object take on a new meaning in this situation. Epistemic objects or “epistemic things” (Rheinberger, 1997) are knowledge objects which are in the process of being defined, and more open-ended than traditional “objects”. Epistemic objects “appear to have the capacity to unfold indefinitely” (Knorr Cetina 2001, 181). The trialogical approach comes close to these ideas of epistemic practices and epistemic objects, especially when combined with the use and development of collaborative technology (the latter has not been the focus of Knorr Cetina’s concept of “epistemic objects”). The aim has been to develop technology to support work with “epistemic objects” and to organize this kind of work.

Within the KP-Lab project, various tools were developed intended to support collaboration on shared objects, and transforming and reflecting on knowledge practices, something which goes beyond “information genre” and “communication genre” (cf. Enyedy & Hoadley, 2006). A basic platform, the ‘Knowledge Practices Environment’, (KPE) was especially developed for supporting “object-centered” knowledge practices (planning, versioning, commenting, annotating, etc.) (more detail on KPE: Bauters et al., this volume; Lakkala et al., 2009; Markkanen et al., 2008). For developing the trialogical approach, important intermediate abstractions were the types of mediation (Rabardel & Bourmaud, 2003; see also Beguin & Rabardel, 2000) which emphasized new forms of mediated activity provided by technology. The KP-Lab project developed an interpretation of these types (Hakkarainen, 2008) in order to use them as guidelines for technology requirements. The result was a list of four main types of mediation that the technology was aimed at supporting:

- **epistemic mediation** is related to creating, organizing, linking and working with knowledge artefacts,
- **pragmatic mediation** is related to organizing, planning and coordinating knowledge-creation processes, and means for updating and revising the plans and coordinating them with other activities,
- **social (or collaborative) mediation** concerns building and managing networked communities and the social relations required for carrying out knowledge-advancement efforts, as well as cross-fertilization across different groups and communities, and
- **reflective mediation** is understood in terms of making knowledge practices visible, reflecting on, and transforming them.
The basic notion in the KP-Lab project was to support creating, drafting, versioning and organizing the work with knowledge artefacts, as well as support negotiation, commenting and reflecting on them. The aim was to enable participants to reflect on their ways of working and performing tasks, and take their own knowledge practices and processes as shared objects to be analysed and developed collaboratively. The KP-Lab technology was designed then to support multimediation (cf. Bodker & Andersen, 2005) by providing a shared knowledge space that facilitates all four types of mediation mentioned above and the flexible use of them together. There are, for example, technology-enhanced views in KPE which are in line with the types, that is, the Content View (cf. epistemic mediation), the Process View (as well as an Alternative Process View, cf. pragmatic mediation), and the Community View (cf. social mediation) (for more detail see Bauters et al., this volume). There are also special analytic tools developed to support reflective mediation (Richter et al., this volume). Technology then provided new applied ways of interpreting what it means that the activity is organized around shared objects in knowledge-intensive work. Nevertheless, the main understanding of multimediation required integrated tools for constructing epistemic, pragmatic, social, and reflective activities in any context of professional practices.

The trialogical approach comes close to many existing approaches to collaborative learning focusing on open-ended problem solving, like knowledge building, inquiry learning, project-based learning, the situated-interaction approach, or problem-based learning. In each of these learning approaches, there are many varieties and interpretations. The most distinctive feature of the trialogical approach is, however, that it emphasizes open-ended and challenging work on shared objects meant for subsequent use from a variety of perspectives. The trialogical approach combines features from approaches highlighting conceptual aspects of inquiry processes and idea-centered work (like knowledge building or inquiry learning) with features highlighted in pragmatically oriented approaches (like project-based learning). In modern knowledge work, epistemic issues are embedded in practical concerns, and are not alternatives. The trialogical approach aims to promote the work with knowledge artefacts by examining what these artefacts are, how they are created and modified for specific uses and how these processes are supported in practice. The outcome is constructed not only by the ideas that they inhere or by versions that are produced but how the artifacts are used and developed for maintaining new knowledge practices, which are both elements of and contextualized by a more long-standing object-oriented activity.

THE TRIALOGICAL APPROACH DEVELOPED WITHIN THE KP-LAB PROJECT

The technology developed in the KP-Lab project was originally defined as a virtual shared space with a set of tools enabling collaborative knowledge creation practices. According to the vision formulated early on in the project, the KP-lab project:
... aim[s] at understanding how people collaboratively, in long-term processes, develop novel epistemic things and transform their knowledge practices, and how students in higher education do the same by cross-fertilizing professional and educational practices and solve complex, authentic problems with the help of innovative knowledge practices and educational technology. The modern information and communication technology not only facilitates knowledge creation around shared objects but also puts forward the need to develop this kind of an approach about trialogical learning. (KP-Lab, 2007).

The focus was on collaborative processes for developing “epistemic things” and on transforming knowledge practices with the help of technology developed in the project. A specific focus was on higher education courses in which there is a close link to professional practice. Workplace research cases were also investigated where collaboration on “virtually constructed objects” was at the heart of new learning challenges.

DESIGN PRINCIPLES AS A FRAMEWORK FOR EMERGING KNOWLEDGE PRACTICES

Early on (in the first year of the project), new knowledge practices were defined by means of a set of design principles elaborated for complex learning settings (Bell et al., 2004; Kali, 2006). The trialogical design principles were meant to serve several purposes in the project, especially to function as a middle ground between theoretical ideas and practical aims, and to give broad guidelines and principles for the technology development and pedagogical emphases. There was a clear need to identify such basic characteristics of the trialogical approach in a project where there were several educational and technological partners involved with a variety of backgrounds with a new pedagogical emphasis. These design principles were not meant as a fixed set of normative rules but as providing outlines for evolving knowledge practices, supposed to be investigated and revised during the project.

The design principles had a background in analyses, done by the participants of the project, of theories representing the knowledge creation metaphor of learning. We had previously (before the KP-Lab project) analysed similarities in otherwise quite different theories representing the knowledge creation metaphor, and ended up with the following common characteristics (Paavola et al., 2004, 562) that may feed ICT-mediated knowledge creation and its tools and practices:

1. The pursuit of newness
2. Mediating elements to avoid Cartesian dualisms
3. Viewing knowledge creation as a social process
4. Emphasis on the role of individual subjects in knowledge creation
5. Going beyond propositional and conceptual knowledge
6. Recognizing conceptualizations and conceptual artefacts as important
7. Interaction around and through shared objects
The characteristics of the trialogical learning were discussed at the kick-off meeting of the KP-Lab project. The scientific coordinator of the project also drafted a paper listing first 12 and then 31 characteristics of trialogical learning and technology design (Hakkarainen, 2006). These characteristics were explicitly linked to knowledge building principles by Scardamalia (2002), but were also influenced by the activity theoretical research. Additional sources for defining the design principles were previous experiences of the KP-Lab partners in developing learning technology, and an explicit goal of the project was to develop courses in which students would be in close contact with real customers solving complex problems and developing specific end products for those customers.

The design principles of the trialogical approach were then formulated by the project partners on the basis of these various sources. The aim was to make a relatively short list of design principles which would cover the basic characteristics of the approach. At the end of the project, the trialogical design principles (DPs) were formulated as follows:

**DP1 - Organising Activities Around Shared Objects.**

The first DP explicates the central idea of the trialogical approach, emphasising practices through which participants organise their collaboration for developing shared “objects”. These shared objects are both various kinds of knowledge artefacts (documents, plans, models, prototypes, design artefacts, etc.) but also practices and processes (i.e., ways of working or organising the collaboration) that are developed together. One vital feature of the trialogical approach is that the work and versioning of external knowledge artefacts (made for some later use) are seen to structure human interaction essentially. These shared objects, and versioned knowledge artefacts provide a concrete common ground and mediating element. At the same time, participants are encouraged and supported in developing and reflecting their processes of organising their collaboration.

**DP2 - Supporting Integration of Personal and Collective Agency and Work (Through Developing Shared Objects).**

One point of the knowledge creation metaphor is that in order to understand and support knowledge creation processes properly the dichotomy between individualistic approaches to learning (often associated with the acquisition metaphor of learning) and purely social interaction (here associated with the participation metaphor of learning) must be transcended. This means that when people are involved in creative processes, the role of individual expertise is merged with fertile social and cultural processes (and vice versa). Participants are encouraged to take the agency of their own work, collaborative processes, and those objects that they are developing.
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**DP3 - Fostering Long-term Processes of Knowledge Advancement with Shared Objects (Artefacts and Practices).**

Processes of developing something new together or developing knowledge practices usually take a lot of time (from individuals, groups and social institutions). The focus is on practices and tools that support work with a longer time frame than is usually done in educational settings (within one course). This includes various aspects like doing things that are meant for some subsequent use, encouraging links between different courses, creative re-use of previous practices and knowledge artefacts, and providing enough time for the iterative cycles needed in knowledge creation processes.

**DP4 - Emphasising Development and Creativity on Shared Objects Through Transformations and Reflection.**

Theories and models belonging to the knowledge creation metaphor of learning emphasise development and knowledge creation through interaction between various forms of knowledge and between practices and conceptualizations. Interaction and transformation between such things as explicit knowledge, under-articulated (tacit) knowledge, knowledge practices, and conceptualizations are seen as driving forces in knowledge-creation processes. The processes of developing and formulating shared objects together provide mediating elements of knowledge creation.

**DP5 - Promoting Cross-fertilization of Various Knowledge Practices and Artefacts Across Communities and Institutions.**

One focus of the KP-Lab project courses was on learning settings in which students solve complex, “authentic” problems (meaning problems that have a relevance outside the educational setting in question) and were also producing objects for purposes outside educational institutions. This kind of “cross-fertilization” between different institutions and practices is an important motivation for students and teaches the competence needed in modern knowledge work.

**DP6 - Providing Flexible Tools for Developing Artefacts and Practices.**

Beside the first DP, this one is central to the trialogical approach. Trialogical processes can be undertaken without any special technology; people have developed knowledge artefacts and practices collaboratively for specific purposes without digital technology, but new digital technology provides clearly new means and affordances for these processes (for collaboration, sharing, reuse, reflection, modification, etc.). In the KP-Lab project, KPE was developed to support working with shared objects and artefacts by taking different forms of mediation defined in the project (epistemic, pragmatic, social, and reflective) into account.
As can be seen, these formulations of design principles are quite general and provide a perspective on knowledge practices central to trialogical processes (i.e., for collaborative work with shared objects meant for subsequent use). The basic idea is that collaboratively developed shared objects are put in the centre, and mediate the participants’ activities in several dimensions (see Figure 1.1).

*Figure 1.1. A figure on the trialogical approach depicting various dimensions of mediation with a focus on shared objects.*

The design principles themselves served different, overlapping purposes in the KP-Lab project (Paavola et al., 2011). They: 1) helped to explicate central characteristics and features of the theoretical approach which was also new for the developers (that is, to give outlines for an approach to be developed during the project), 2) helped to select, focus, and report research cases investigated in the project, 3) afford suggestions for practitioners for developing existing knowledge practices in line with the approach, 4) provided guidelines for technology development.

The meaning and interpretation of the design principles, used and revisited several times during the project, was specified in relation to the KP-lab project. Not all knowledge practices were emphasised as much during the project. The original aim, for example, was to investigate and promote longer-term changes in knowledge practices within some specific contexts, but this was not implemented to a large extent because of the revisions suggested by the project reviews of the cases investigated. From the point of view of research, it was also a challenge to investigate transformations across courses when higher education is organised mainly around quite separate courses. Similarly, there were plans to support the interaction between personal and collaborative working areas (see DP2) with the
help of the specific functions of the tools, but the functions were not actualized to
the extent planned. Not all plans could be implemented fully in one project and
choices needed to be made. What was somewhat surprising was that the design
principles themselves did not change much from their outer form during the project
(Paavola et al., 2011). They were re-evaluated and revised several times during the
project (on the basis of research cases). Beside various specifications, there were
not any major changes in them.
The design principles also provided guidelines for selecting research cases in the
project and reporting results from them, although their use was not unproblematic.
Especially at the start of the project, there was a tendency to interpret these design
principles so loosely that almost any kind of knowledge practice, or technology
supported projects could be included. This was problematic when the aim was to
find courses with trialogical elements which could be further supported by novel
tools designed in the KP-Lab project. Specifications were needed for formulations
of the design principles accompanied by discussions on trialogicality itself.
The design principles were also used as practical guidelines and hints for
developing and analysing courses (Lakkala et al., this volume; Karlsgren, this
volume). The trialogical design principles are very challenging if they are all
implemented in a strong sense. Often in courses in higher education there are just
not enough resources or time for taking all the aspects into account, which is why
they were used as “vehicles of innovation”, that is, providing ideas and directions
which can be implemented or used in various forms and with differing strength in
specific cases. The design principles were then used as tools for intervention,
although this interventionist way of using them was not as prominent as was the
framework for observing knowledge practices emphasised in research cases.
The influence of DPs on technology development turned out to be more indirect
than was originally planned. Early on in the project it became clear that DPs were
accounted by technology design as too abstract for directing the actual co-design of
the tools alone. They provided, however, a general theoretical and pedagogical
outline which was checked from time to time in the project in relation to the means
of collecting requirements for the technological development. The types of
mediation (see above) provided a basic framework for technology development
(Bauters et al., this volume). Technology was developed to support work with
shared objects from these different mediation perspectives.
As a summary of research with and on the design principles, we can delineate at
least three perspectives for further design of technology-enhanced learning:
1. Multimediation as a source of learning, in terms of deliberately creating,
sharing, and advancing knowledge, implies a complex combination of
qualitatively different processes, such as creating artefacts related to epistemic
objects and working with them, organizing interaction, linking and coordinating
knowledge-creation processes, managing and reflecting ongoing processes, etc.
The practices themselves have a complicated architecture in which they are
becoming more flexible and contextualized entities. They themselves start to
resemble an activity where “symbolic activity penetrates the process of tool
use” (Vygostky, 1978, 24). This penetration creates entirely new opportunities enabled by digital technology.

2. Novel knowledge practices can be identified with iterative processes in which the artefacts are produced for promoting and mediating object-oriented activities. As we have argued, the triple nature (tool/concrete object/object to be developed) of situated artefacts forms the essence of novel knowledge practices, and puts the emphasis on how to organise actual processes in which mediating artefacts are partly pre-existing, partly created, and partly modified in the activity whose constituents they ultimately are. The participants do not necessarily share the same meanings with regard to the ongoing activities, but they share the process of engagement and subjectively unique understandings on their participation (Engeström, 2009).

3. In creating technology-enhanced knowledge practices, co-design processes are uneasy, partly because the different disciplinary approaches and terminologies. On the other hand, “crossing boundaries involves encountering difference, entering onto territory in which we are unfamiliar and, to some significant extent therefore, unqualified” (Suchman, 1994, 25). To overcome such a deficiency, boundary crossing calls for a process-oriented theory of organising, such as a “dialogical mediated inquiry” (Lorino, Tricard & Clot, 2011) or trialogical learning which is collaborative and accommodated to the beginning and ending of co-design circumstances.

FUTURE CHALLENGES OF THE TRIALOGICAL APPROACH

One of the basic ideas of trialogical learning is that modern knowledge work should be seen more through unfolding and dynamic objects, or knowledge artefacts. In the trialogical approach, this “objectualization” builds on an epistemology where subjective, intersubjective, and objectual aspects are inseparably linked, not a stark opposite to individualistic or interactionist approaches to learning (cf. Davidson, 2001). In the KP-Lab project the focus on shared objects was a crucial challenge and a driving force theoretically. This challenge produced many discussions on the nature of “shared objects”. This reflects somewhat different theoretical outlooks which formed the background of the project. “Object” is a central theoretical concept in activity theory whereas in knowledge building the work on conceptual artefacts is emphasized. There are influences on both of these in the “shared objects” of the trialogical approach. On the other hand, this also reflects the complicated nature of knowledge work which includes working with various kinds of objects and artefacts, and there are different, partially overlapping conceptualizations aiming at understanding related knowledge processes and practices (e.g., Schmidt & Wagner, 2002; Ewenstein & Whyte, 2009).

In reviewing cases conducted in the KP-Lab project we can find three ways in which shared objects were constructed:

1. One emphasis was on collaborative and systematic work with knowledge artefacts, and how to organise the activities of participants for versioning and
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working iteratively on them. Alternatively, the focus could be on knowledge practices if the aim was to develop them concretely. This kind of iterative work on actual knowledge artefacts and their role in guiding the interaction was important, especially in theoretically oriented papers on trialogical learning. It has been emphasised that this kind of approach is an alternative to the “meaning-making” tradition often espoused in computer-supported collaborative learning (Paavola & Hakkarainen 2009). KP-Lab tools provided some support for this kind of versioning with knowledge artefacts. Additionally, not all tools were provided by the project but were loosely integrated into the environment (like the Google Docs, or a wiki). The KP-Lab courses showed that students are not used to working like this (versioning shared artefacts with many iterations) and short-term courses do not provide much time for learning these kinds of knowledge practices. Clearly such activities need more sustained practice.

2. In many pedagogical cases investigated in the project, a broader approach to “shared objects” was emphasised, however. These were mainly relatively short term projects (usually one semester) where the aim was to develop different kinds of project outcomes. The focus was then on organising the collaborative efforts around shared topics or project assignments. From the students’ point of view, the “shared object” might remain as a more abstract aim or phenomenon with which the group in question was working than just the knowledge artefacts which they were using. On the other hand, various kinds of activities and knowledge creation processes helped participants to work with these shared objects. KPE was supposed to provide a means of organising these knowledge creation processes (strengths and challenges of KPE are summarised in Bauters et al., this volume).

3. A third construction of shared object emphasised “object-bound” activities with an interplay of dialogical (with meaning-making, communication, and exchange of ideas) and trialogical (iteration of knowledge artefacts) activities. Different varieties of these object-bound activities were found, that is, activities in which commenting, chatting, or discussions referred to some specific artefacts or parts of artefacts instead of more general discussions. Varieties of object-bound activities were found to be especially important in workplace cases. KPE was used so that during face-to-face meetings (or sometimes in video meetings) the shared working area of KPE (a particular “shared space”) was projected onto the screen, and knowledge artefacts produced and modified as well as tasks and plans were discussed collaboratively. The aim was often to modify the knowledge artefacts, but the activity concentrated on discussions, and modifications were done later on by some of the participants.

These three constructions of shared objects are clearly overlapping in nature but with a different emphasis. The first one (“trialogues”) emphasises collaborative drafting and versioning of knowledge artefacts (or practices), the second one (broader knowledge creation processes) emphasises focused and targeted project work on common phenomena, and the third one (a variety of object-bound
activities) emphasises the combinations of working with knowledge artefacts and dialogical activities.

In the trialogical approach, objects alone are not so important, but rather form the driving force of the collaborative knowledge work as a part of those processes in which they are developed (Knorr Cetina 1997, 2001). However, as we have pointed out, knowledge creation processes with new technology challenge the notions of ‘object’ and ‘tool’ in a fundamental way. Knowledge-laden objects are worked on in the situated processes and produced as artefacts in order to use them iteratively as tools in the further ongoing processes. These intermediate processes provide knowledge practices with an epistemic frame of activity rather than narrow skills, competences, or contents (Brockmeier & Olson, 2009). The trialogical approach has shown its relevance for investigating these intermediate processes and their integrated, technology-enhanced tools. Pedagogically, the set of design principles (DPs) delineated knowledge practices employed in the project. DPs provided a horizon of potential ways of developing the trialogical processes further, and KP-Lab focused on certain aspects of them. One obvious challenge is to find ways of supporting and investigating longer-term changes in knowledge practices by individuals, groups and institutions embedded in practical concerns.

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INTRODUCTION

The concept of tacit knowledge has received a great deal of attention recently. From a knowledge creation point of view, much of the related discussion fails to provide any deep insights. Notwithstanding the superficial treatments commonly encountered, the concept embodies crucial aspects of learning that are critical for the success of KP-Lab. Indeed it became one of the core concepts of the project; capturing tacit knowledge within processes of learning and knowledge creation in higher education and workplaces has been one of the basic ideas which we identify according to three theoretical perspectives: The knowledge-creating company (Nonaka & Takeuchi, 1995), the cultural historical activity theory (Engeström, 1999a), and the knowledge-building communities (Bereiter, 2002).

Yu Zhenhua considered the different interpretations of tacit knowledge (TK) in his article (Zhenhua 2004). He took the work of Michael Polanyi as a starting point. He introduced the term “tacit knowing” or “tacit knowledge” into philosophy in his magnum opus “Personal Knowledge” (Polanyi, 1958). Since then, different philosophical traditions – e.g., phenomenological, hermeneutical, Wittgensteinian and Polanyian traditions – have pursued work on this notion and related interpretations, contributing to new research as the large body of secondary literature demonstrates. It is no exaggeration to talk about an ongoing discourse on tacit knowledge. The notion of “tacit knowledge” or “tacit knowing” is rich in its philosophical interpretations, with many theoretical dimensions.

Tacit knowledge means the range of conceptual and sensory information and images that can be brought to the fore in an attempt to make sense of something. It is based on the idea that such knowledge is not something expressed in symbolic or declarative means but by signs and structures embedded in visual representations, practices, concrete artefacts, diagrams. This is something different to propositional knowledge. The key to knowledge creation models is to understand how these “weaker” forms of knowledge are used and made explicit in a meaningful way in collaborative processes.

Michael Polanyi developed his version of the concept during the 1950s to emphasize that although knowledge is social, explicit and public (which is the
traditional understanding of knowledge as a noun) it also has a strong “tacit
dimension” (e.g. Polanyi 1958; 1966). Things like personal experiences, taste, and
involvement are central aspects of human knowledge, especially when something
new is created. According to Polanyi’s famous dictum “we can know more than we
can tell” (Polanyi 1966, p. 4) which means that discovery is not followed by
articulated rules or algorithms, but is aided by tacit elements of which we are not
aware. Tacit knowledge is not supposed to be something that could not in principle
be made “focal” or explicit, but the idea is that tacit knowledge is an atomic
element of all processes of knowing.

To Polanyi, knowledge is formulated/formal or unformulated/informal. The first
kind of knowledge is called explicit or articulated knowledge, whereas the second
is called unarticulated or tacit knowledge. To Polanyi, articulation means verbal
articulation even if he proposes a wide understanding of language, which includes
various symbolic forms like mathematical formulae, maps, and diagrams. The first
meaning of Polanyi’s concept of TK is that human beings have certain cognitive
powers, which in principle cannot be exhausted by linguistic means alone. Polanyi
claims that TK is the foundation of all explicit knowledge and concludes: “While
tacit knowledge can be possessed by itself, explicit knowledge must rely on being
tacitly understood and applied. The second meaning of Polanyi’s concept of TK is
that tacit knowledge is an activity that is better described as knowing, i.e. the
process or pre-logical phase of knowledge.

**Tacit Knowledge and Collaborative Knowledge-Creation Processes**

One central basis for the KP-Lab project has been the knowledge-creation
metaphor of learning, that is, such models and theories of learning and knowledge
advancement that emphasize dynamic and collaborative processes of transforming
prevailing knowledge artifacts and practices (Paavola, et al., 2004; Hakkarainen,
et al., 2004). Central representatives of this approach are Nonaka & Takeuchi’s
(1995) model of organizational knowledge creation, Engeström’s (1999a) model of
expansive learning, and Bereiter’s (2002) model of knowledge building. Tacit
knowledge can be seen as an important aspect of each of these three models
although its interpretation varies. Furthermore, it should be noted that both
Engeström and Bereiter are quite critical towards the concept itself, and are prone
to use related models and concepts.

In their book, *The Knowledge-Creating Company*, Ikujiro Nonaka and Hirotaka
Takeuchi (1995) presented a model of innovation processes, central to which is an
epistemological distinction between two sorts of knowledge, *tacit* and *explicit*.
Explicit knowledge is knowledge that is easy to articulate and express formally and in
clear terms. Tacit knowledge, which is more important in creating innovations, is
“personal knowledge embedded in individual experience and involves intangible
factors such as personal belief, perspective, and the value system” (viii). Another
starting point in their model is an “ontological” distinction between different levels of
“entities” that operate in knowledge creation; the individual, group, organizational,
and inter-organizational levels. According to Nonaka and Takeuchi, knowledge is
created and transformed spirally from the individual level to the organizational level, and finally between organizations. The dynamics of this model arise from the interaction between tacit knowledge and explicit knowledge. The knowledge creation spiral starts from socialization, sharing tacit knowledge and experiences at the group level. The next phase, externalization, is central in knowledge creation. In this phase, tacit knowledge is made explicit and conceptualized using metaphors, analogies, and concepts. In Nonaka and Takeuchi’s model, the basic source of innovation is tacit knowledge, which needs to be explicated in order to be transformed into knowledge that is useful at the levels of the group and of the whole organization. Combination holds that already existing explicit knowledge is combined and exchanged. Finally, in order to have real effects in organization, the explicit knowledge of the group or organization must be internalized by individuals and transformed into tacit knowledge and into action through “learning by doing”. After internalization, a new round of the knowledge spiral will start again.

Yrjö Engeström (1999b) studied and developed innovative learning cycles in work teams using Cultural-Historical Activity Theory (CHAT). Engeström’s model of expansive learning in work teams is based on a learning cycle with seven stages in its ideal form (Engeström 1999b, p. 383–384; cf. Engeström, 1987, p. 188–191, p. 321–336). The cycle starts with individual subjects questioning and criticizing some existing practices. This is followed by an analysis of the historical causes and empirical inner relations of the activity system in question. After that, participants engage in modelling a new solution to the problematic situation. Then, they examine the new model by experimenting and seeing whether it works and what potentialities and limitations it has. Next, the new model is implemented in order to explore practical actions and applications, and the process is evaluated during an activity of reflection. Finally, participants engage in consolidating this practice in its new form. Through this expansive cycle, in which the actors focus on reconceptualizing their own activity system in relation to their shared objects of activity, both the objects and the existing scripts are reconceptualized; the activity system transformed and new motives and objects for the activity system created. The model should be understood as an ideal or heuristic tool for analyzing elements of expansive learning, as the cycles of expansive learning do not necessarily follow any fixed order. The same cycle can be seen as a background for the change laboratory method (Engeström, Engeström, & Kärkkäinen 1995; Ahonen, Engeström, & Virkkunen 2000). Tacit knowledge is not explicitly emphasized in expansive learning, and more stress is placed on knowledge embedded in practices. Engeström has, however, given credit to Nonaka and Takeuchi’s circle for identifying various modes of knowledge, and discussing transitions between tacit knowledge and explicit knowledge (Engeström, 1999, p. 401). Engeström has also criticized Nonaka and Takeuchi for not taking into account the first two phases of the expansive cycle -- questioning and analyzing the situation -- and in doing so, neglecting the importance of controversies and conflicts in knowledge creation (Engeström, 1999b, p. 380).

Carl Bereiter (2002) argued that the emergence of a knowledge society has given rise to dealing with knowledge as a thing that can systematically be produced
and shared between members of a community. Scardamalia and Bereiter (1994) have proposed the concept of knowledge building, which refers to collective work for the advancement and elaboration of conceptual artefacts, the entities of the world of man-made, non-physical things (product plans, business strategies, marketing plans, theories, ideas, models, etc.). An important aspect of Bereiter’s theory is to make a conceptual distinction between learning, which operates in the realm of mental states (in Karl Popper’s World 2), and knowledge building, which is generated by human minds whilst operating in a socially shared realm (Popper’s World 3), which again makes use of material (World 1) objects for realization (e.g. paper, computer screens, ink). According to Bereiter, Nonaka and Takeuchi’s model of tacit knowledge (and explicit knowledge) is still rooted in a mentalistic “folk epistemology”: It is based on the externalization of tacit knowledge and appears to rely on a mentalistic assumption that knowledge resides and is created in an individual’s head. Bereiter feels that what is missing from this model is knowledge “in the world” considered as “conceptual artefacts,” and the idea of knowledge building. Tacit knowledge as such is, however, important in Bereiter’s model of expertise. Skills and know-how manifest themselves in performance, but tacit knowledge is much harder to recognize directly. Bereiter and Scardamalia 1993, p. 133–152; see also Bereiter, 2002) argue, for example, that knowledge of “promisingness,” which is for them one form of tacit knowledge, is an essential resource of creative experts. Having continuously solved problems in their own area of expertise, creative experts have some sort of sense about what is promising, and how to make progress in their field. They deal with uncertainty, and make ventures and risky efforts part of their innovative processes.

On the basis of the above three models concerning collaborative knowledge creation, it can be said that an important aspect of the knowledge creation metaphor of learning concerns mechanisms where non-explicit knowledge is conceptualized in collaborative processes. Different theories emphasize different kinds of non-explicit knowledge, often by using other concepts than “tacit knowledge”, or interpreting it slightly differently. Nonaka & Takeuchi emphasize personal hunches and insights that are rendered explicit for the use of the community, Engeström emphasizes practices and activities, which are reflected and transformed into collective processes, and Bereiter conceptual artefacts and ideas that are collaboratively developed. All of them come close to that aspect of Polanyi’s original idea that knowledge creation and discovery is not rule-governed or an algorithmic process based solely on explicit knowledge but involves non-explicit and iterative processes. In relation to Polanyi’s original ideas, they all seem to emphasize more communal and collaborative elements in making tacit knowledge more explicit than Polanyi did. In addition, Nonaka & Takeuchi’s model is the most individualistically centred.

TECHNOLOGIES FOR TACIT KNOWLEDGE

Technologically speaking, two disciplines have addressed knowledge processing: artificial intelligence (AI) and information systems. In their quest to capture, store,
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and make use of knowledge, both approaches have faced difficulties related to the specific nature of tacit knowledge (Harlow & Inam, 2006; Holthouse, 1998). Two contradictory directions evolved from AI research. The “mainstream” AI researchers developed expert and knowledge based systems as attempts to solve the problem. They have been criticized for ineffectiveness due to their systematic attempts to articulate all forms of knowledge into rules, procedures, frames, schemata, etc. The rigid aspect of these systems fails to fulfil the aim of knowledge-based systems (modelling the application of human knowledge). Despite related philosophical debates, limitations to knowledge codification have been misunderstood or ignored in the AI community (Grant & Qureshi, 2006; Luo et al., 2006). The other discipline is design research. Donald Schön became one of the main proponents. His critique of Simon’s notion of design as modelled by rule-based production systems drew on Polanyi (1966) and Wittgenstein. Schön (1992) suggested that computer support for tacit knowing in design should be about design assistance rather than design automation, and provided by computer based design environments rather than expert systems. Following on from this, Fischer (1999) developed prototypes of domain-oriented design environments to operationalize Schön’s notion of reflection-in-action (Schön, 1992). Knowledge management systems have been the approach adopted by Information systems to tackle the issue. Mainly based on Nonaka’s model, knowledge management systems proposed tools and techniques for socialisation, externalisation, combination, and internalisation.

Forsythe (1993), drawing on ethnographic material, explored epistemological perspectives of knowledge engineering, and showed that neglecting the complexity of social interactions leads to incomplete or irrelevant technology. She states that knowledge is social in nature and suggests that it can still be represented correctly by composing the set of agents’ knowledge representations. To Grant and Qureshi (2006), the failure of knowledge management systems is due to the attempt to represent and store tacit knowledge, overlooking the limitations of knowledge codification. The authors claim that implementation approaches must take into account the personal nature of knowledge and the importance of groups and communities. Along this line, emphasis has been placed more on practice-based theories of knowing and learning (Blackler et al., 2000), and the importance of taking into account context when designing and implementing knowledge management initiatives (Thompson & Walsham, 2004), including those involving information and communication technologies (Walsham, 2001). Tacit knowledge is revealed through personal interaction. Information and communication technologies can be used to foster interaction and provide a lateral medium enabling non-intrusive measure of tacit knowledge (Ritchie et al., 1999). The underlying principle is that although tacit knowledge cannot be codified, it is nevertheless a measurable phenomenon that enables the development of relationships and study effects (Harlow & Imam, 2006).

Abidi et al. (2005) presented a knowledge management methodology and its computational implementation. The described system allows the acquisition and representation of tacit knowledge in the form of clinical scenarios. The acquired
knowledge is used in health-care decision-support and medical education systems. Other studies have focused on knowledge management and learning in intensively knowledge-driven activities (French et al., 2007; Frade, 2004; Mansell & Curry, 2002; Masuzawa, 2001). Hagengruber & Riss (2005) argue that there exists no universal static knowledge valid for all contexts. Knowledge is described by means of relations between entities within specific contexts. The authors suggest that tacit knowledge can be expressed as shifts in context. Similarly, Cheah et al., (2003) use scenarios for the description of a healthcare situation. Instead of static knowledge representation, a collection of knowledge for different situations is preferred.

CONCEPTUAL FRAMEWORK

The role of tacit knowledge in trialogical learning is examined according to three KP-Lab background metaphors of learning, i.e., knowledge acquisition, participation, and knowledge-creation metaphors.

The knowledge acquisition perspective addresses individual knowledge structures and processes essential in learning to become expert. Tacit knowledge refers to forms of personal knowledge that are difficult to express linguistically.

The participation perspective considers tacit knowledge as a fundamental aspect of human activity. From this viewpoint, tacit knowledge relates to interactive processes involved in social participation as well as habitus transformation (Bourdieu, 1990, p. 24–5), a pre-requisite for transformative learning.

The knowledge-creation perspective, in turn, addresses tacit knowledge from the perspective of systematic, focused pursuit of novelty and innovation, and transformation of social practices. Here an important role is given to the tacit knowledge one develops in the pursuit of trialogical objects, while trying to go beyond the prevailing epistemic horizon. A significant tacit dimension is also indicated when producers with practical concerns seek deliberately to transform their knowledge practices toward more innovative ones.

All three levels of tacit knowledge have an important role in trialogical learning, and innovative knowledge practices must be based on deliberate capitalization on tacit knowledge. Various technologies may be used to assist participants in handling tacit knowledge in their educational and professional activities. The above three metaphors of learning structure KP-Lab’s approach to tacit knowledge. While the metaphors provide a useful way of examining various technologies for extracting and working with tacit knowledge, it is essential to bear in mind that boundaries between the metaphors are permeable and a given type of technology may be used for multiple purposes.

The knowledge acquisition perspective addresses tacit knowledge in terms of individual knowledge representations.
A1: Externalize ones’ ideas, thought, and fuzzy intuitions
A2: Identify, analyze, and model patterns of activity
A3: Record knowledge practices, reflect on activities, and follow experiences across contexts

The participation perspective addresses tacit knowledge embedded in interactive processes taking place within social communities as well as the transformation of the participants’ habitus.

P1: Constantly being aware of fellow inquirers’ activities
P2: Elicit interaction between users, and enable reflection on interactive episodes
P3: Become reflectively aware of own prevailing practices and habitus

The knowledge-creation perspective addresses sustained processes of working with shared artifacts and developing trialogical objects across long periods of time (product plans, business strategies, marketing plans, theories, ideas, models, etc.)

C1: Create, modify, structure, visually organize, and manage versions of knowledge artefacts
C2: Collaboratively map ideas, and make own ideas objects of collective reflection
C3: Facilitate the transformation of collective practices
C4: Capture disturbances and tensions in prevailing practices, collectively reflect on observed critical incidents and crucial episodes
C5: Facilitate the evolution of epistemic artefacts by eliciting collective conceptualization of past, present, and future activity around trialogical objects

KP-LAB TOOLS FOR TACIT KNOWLEDGE

Based on the previous framework, KP-Lab designed a set of software tools to support operationalizing tacit knowledge in trialogical learning, tools and practices. We briefly describe here three such tools: the so-called “knowledge practices environment”, the collaborative semantic modeler, the semantic annotation tool.

Knowledge Practices Environment – KPE

KPE is a virtual collaboration space that supports personalisation, temporal and faceted views to describe and visualise knowledge artefacts, their associations and state in different arrangements. KPE manages personal and collective spaces of knowledge artefacts allowing users to view knowledge artefacts in different ways and work according to different practices. A collective space is created for the knowledge community involved in a trialogical process. Users can browse and access content of a shared space through various views. A view is a graphical way of looking at the structure of information contained in a space. Three different views are possible: content view, process view and community view. The user is provided functionalities to handle the views and their contents, e.g., Fig. 2.1.
− Working with knowledge artefacts (creating, editing, storing, sharing, commenting, annotating semantically)
− Managing knowledge processes (creating, changing and executing process descriptions)
− Managing shared spaces (configuring access rights)
− Modifying the views of information

![Figure 2.1. KPE shared spaces view.](image)

Through these activities, the tool provides ways to capture and share tacit knowledge, especially by:

− Sequences of comments, authors of comments, timing of comments
− Nature of commented content items
− Concepts used when linking items
− Ways of positioning knowledge artefacts
− Tags used for particular content items
− Usage of knowledge views

To sum up, KPE has been designed on the basis of certain principles of tacit knowledge. In the knowledge acquisition perspective, KPE enables the externalization of ideas, the work on patterns of activities, and the recording of knowledge practices and their monitoring in different contexts. In the participation perspective, it supports awareness, reflection on interactions, and reflective awareness on ones’ own practices. In addition, KPE is well suited to working with epistemic artefacts, according to the knowledge creation perspective. Therefore KPE provides means for backing up tacit knowing related to knowledge acquisition, social participation and collaborative knowledge creation.
Collaborative Semantic Modelling

The collaborative semantic modelling tool permits the collaborative development and exploration of visual models as well as that of visual modelling languages (Richter, Allert et.al, this volume). The tool allows for a controlled evolution of a modelling language, preserving consistency in time. With this tool, the users, individually or collaboratively, can choose between different modelling languages and work with multiple models simultaneously. This makes it possible to approach a shared-object from different angles and create multiple representations for a given phenomenon. Furthermore, the tool assists users in creating a common ground by enabling the specification of visual models and the semantics of the modelling elements.

Typical scenarios include settings where users aim at describing their understanding of an object in the form of graph-like visual representations. As such, the modelling activity is rarely an end in itself, but instead embedded in more overarching activities like collaborative planning, design, inquiry or evaluation (i.e. trialogical activities). Accordingly, objects of interest might include, for example, diverse kind of processes, logical and causal relationships or organizational structures which can be represented for example as flow-charts, argument-graphs, organigrams, decision trees, or program logic models (Busch et al., 2003; 2001).

Even though collaborative semantic modelling provides first and foremost a means for the externalization and materialization of explicit knowledge, several authors have argued that the materialization of mental models (for example as texts or diagrams) is itself a productive process and goes beyond the mere replication of the mental model (cp. Hanke, 2006; Engeström, 1999b). For example Stylianou (2002) discusses the role of external representations in problem solving activities and conceptualizes model creation as a continuous process of visualization and analysis. Similarly, Hacker (2002) discussed the importance of external representations for constructive engineering tasks, pointing out that multiple representations, as well as failures in the attempt to externalize mental models, might trigger reflection and help to elicit otherwise tacit knowledge.

Against this background it seems plausible that collaborative semantic modelling can contribute to the discovery and collaborative materialization of otherwise tacit knowledge in various ways:

− The externalization and materialization of mental models allows the individual or group to inspect and scrutinize these models from the “outside” and hence might foster the detection of blind spots or hidden premises.
− The externalization of mental models requires the individual to translate his/her ideas into a more or less well-specified visual-language and thereby might open up new perspectives for the object of activity.
− Furthermore, the use of multiple visual models as well as different visual languages might foster the detection of otherwise unrealized interconnections or contradictions and might help to understand the different perspectives implied by different languages better.
The use of multiple visual modelling languages and related ontologies opens up an opportunity to explore various forms of tacit knowledge when used in the collaborative analysis of features and processes of videotaped activities which are otherwise beyond the reach of the analyzers' conscious reflection.

In summary, this tool implements principles of externalization and awareness at the first two levels of learning, whilst providing interesting means to support the tacit dimension at the level of knowledge creation. It particularly emphasizes work on epistemic artefacts and reflection on ideas considered as collaborative objects.

**Multimedia Annotation**

Various domains are characterized by knowledge intensive collaborative activities such as research, technological innovation, and medical diagnosis, among others. The analysis of such processes for the purpose of modelling or transformation is a difficult task. Video recording of collaborative activities provides a means to capture individual and group behaviour and simplifies the analysis of work activities (Suchman & Trigg, 1992). The resulting video records are rich media that incorporate various facets of knowledge. Among these, practices and dialogues (Tsoukas, 2009) are the most salient forms of tacit knowledge. Analyzing videos to extract knowledge has traditionally been reserved for highly specialized people. Providing agents with means to analyze video records of their own activity or others has a number of potential applications.

The semantic multimedia annotation tool has been designed according to the principles of our conceptual framework. A group of users is provided with a video record of a given activity. The latter might be the users’ own past activity, or that of others. The tool makes the use of free comments, formal domain discourse models, or other artefacts possible. Users can anchor comments or model items (concepts, events…) to specific fragments (or hot spots) of the video. The tool provides functionalities to manage media, participants, models and annotations. Technically, it is designed to import, store and export models and annotations using OWL (Ontology Web Language), RDF (Resource Description Framework) or plain XML formats. Processing tools implement various semantic inference methods to support activity analysis.

Two possible scenarios can be implemented. The first consists in asking the group to observe the video and to comment events, practices, singularities, or other aspects of interest. Users make use of annotations individually to share their findings. Group members are brought together to share their annotations and negotiate a common understanding. They are provided with annotation processing tools such as search, mining, comparing, and classifying. They create sets of agreed, disagreed and undecided annotations. This process is repeated to iteratively build a model of the underlying activity or design a knowledge artefact (e.g. a solution to a problem). This iterative and incremental cycle is a way of implementing a group dialogue where individuals become aware of their practices, by means of reflection, whilst working on a shared object. The knowledge artefact
(e.g. a model) created from an initial episode can be refined throughout episodes and reused for the analysis of future activities.

The second scenario consists in providing the group with a formal model of the underlying activity. The model can be the result of the previous process. They would be asked to map the model onto the actual activity depicted by the video. The members relate the concepts of the model to the video content, individually. The group shares the individual productions and makes use of annotation processing tools to negotiate a common understanding of the video content. They discover discrepancies between the activity and the model and suggest transformations of the practices and the model. The result would be a continuously evolving shared artefact.

Example applications of these two processes include: individuals becoming aware of their practices (Fig. 2.2), comparing own practices to those of peers (or experts); learners internalizing knowledge embedded in the media; analysts uncovering knowledge practices prevailing in a community of practice; groups collectively reflecting on their practices and becoming aware of their habits. As such, the tool has been designed to support tacit knowledge in the knowledge creation perspective of learning. It enables working with epistemic artefacts, collaborative objects of reflection, transformation of practices, and analysis of tensions and disturbances.

![Figure 2.2. The Semantic Multimedia Annotation Tool’s (SMAT) annotation view.](image)
To conclude on the analysis of these three KP-Lab tools, i.e., KPE, visual modelling and SMAT, the trialogical approach is based partially on the assumption that tacit knowledge plays an essential role in learning according to different perspectives. Various knowledge acquisition processes rely on personal knowledge that is difficult to make explicit without specific tools, instruments, and practices. Moreover, diverse processes of social participation involve a tacit dimension, the explication of which makes the interactive processes visible and subject to deliberate reflection. In addition, deliberate collaborative efforts of knowledge creation capitalize on tacit knowing that guide the construction of trialogical objects and assist in selecting productive lines of inquiry. The present investigators and their colleagues have developed technology-mediated tools and instruments that assist learners in utilizing their tacit knowing and facilitate their reflection-in-action. We consider the above tools merely as the first steps toward developing technologies for utilizing tacit knowing in collaborative learning processes. The KP-Lab project has also created other tools, such as the “Activity-System Design Tool” (ASDT), which are not addressed here, but open up interesting novel opportunities (Toiviainen et.al., this volume). While evaluating the above instruments, it is essential to remember that the tools do not work without supporting knowledge practices (i.e., social practices related to tool usage), which significantly transform learning processes. In order to take full advantage of tacit knowledge, it is essential to make active utilization of the present tools as an integrated aspect of participants’ everyday activity.

CONCLUSIONS

The aim of this chapter has been to position tacit knowledge within the KP-Lab learning paradigm. A short review of the origins of the concept and its interpretations focused on the seminal works by Polanyi and Nonaka. A link was then established from tacit knowledge as a concept, to collaborative knowledge creation processes, using Bereiter’s notion of conceptual artifacts.

The chapter has also provided a review of technologies for supporting aspects of tacit knowledge. Artificial intelligence and information systems approaches were analyzed. Emphasis was placed on recent approaches based on forms of knowledge other than traditional formal explicit knowledge.

The proposed conceptual framework for relating tacit knowledge to trialogical learning was then presented. This is based on tacit knowledge dimensions in the three perspectives of trialogical learning, namely knowledge acquisition, participation, and knowledge creation. Based on these principles, we described the capabilities of three KP-Lab tools to support tacit knowledge.

Further investigations will focus on the operational aspects of the proposed framework by more thorough analysis of KP-Lab tools. Taking into consideration the various forms of TK would be a way of improving the framework. Furthermore, it would also be interesting to study the feasibility of defining a lifecycle for tacit knowledge within trialogical learning.
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NOTE

1 The presentation of models of "innovative knowledge communities" are from Paavola et al., 2004.

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