

Perspectives on knowledge creating inquiry in higher education

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Abstract

Higher education is faced with the challenge of strengthening students' competencies for the constantly evolving technology-mediated practices of knowledge work. The knowledge creation approach to learning (Paavola et al., 2004; Hakkarainen et al., 2004) provides a theoretical tool to address learning and teaching organized around complex problems and the development of shared knowledge objects, such as reports, products, and new practices. As in professional work practices, it appears necessary to design sufficient open-endedness and complexity for students' teamwork in order to generate unpredictable and both practically and epistemologically challenging situations. The studies of the thesis examine what kinds of practices are observed when student teams engage in knowledge creating inquiry processes, how the students themselves perceive the process, and how to facilitate inquiry with technology-mediation, tutoring, and pedagogical models.

Overall, 20 student teams' collaboration processes and productions were investigated in detail. This collaboration took place in teams or small groups of 3-6 students from multiple domain backgrounds. Two pedagogical models were employed to provide heuristic guidance for the inquiry processes: the progressive inquiry model and the distributed project model. Design-based research methodology was employed in combination with case study as the research design. Database materials from the courses' virtual learning environment constituted the main body of data, with additional data from students' self-reflections and student and teacher interviews.

Study I examined the role of technology mediation and tutoring in directing students' knowledge production in a progressive inquiry process. The research investigated how the scale of scaffolding related to the nature of knowledge produced and the deepening of the question–explanation process. In Study II, the metaskills of knowledge-creating inquiry were explored as a challenge for higher education: 'metaskills' refers to the individual, collective, and object-centered aspects of monitoring collaborative inquiry. Study III examined the design of two courses and how the elaboration of shared objects unfolded based on the two pedagogical models. Study IV examined how the arranged concept-development project for external customers promoted practices of distributed, partially virtual, project work, and how the students coped with the knowledge creation challenge.

Overall, important indicators of knowledge creating inquiry were the following: new versions of knowledge objects and artifacts demonstrated a deepening inquiry process; and the various productions were co-created through iterations of negotiations, drafting, and versioning by the team members. Students faced challenges of establishing a collective commitment, devising practices to co-author and advance their reports, dealing with confusion, and managing culturally diverse teams. The progressive inquiry model, together with tutoring and technology, facilitated asking questions, generating explanations, and refocusing lines of inquiry. The involvement of the customers was observed to provide a strong motivation for the teams.

On the evidence, providing team-specific guidance, exposing students to models of scientific argumentation and expert work practices, and furnishing templates for the intended products appear to be fruitful ways to enhance inquiry processes. At the institutional level, educators do well to explore ways of developing collaboration with external customers, public organizations or companies, and between educational units in order to enhance educational practices of knowledge creating inquiry.

Tiivistelmä

Korkeakoulutuksen haastava tehtävä on valmistaa opiskelijoita tietotyön muuttuvien käytäntöjen osaajiksi. Työelämässä tietotyötä tehdään tyypillisesti tiimeinä moniammatillisissa työyhteisöissä ja -verkostoissa, joissa ratkaistaan monimutkaisia ongelmia ja kehitetään jaettuja kohteita kuten tuotteita, teorioita, työprosesseja tai suunnitelmia. Väitöskirjan neljässä osajulkaisussa on tarkasteltu sitä, miten yliopistokursseilla voi soveltaa tietotyön ja jaettujen tietokohteiden kehittämisen työskentelytapoja. Tällaista 'tietoa luovaa oppimista' on tutkituilla kursseilla mallinnettu kahdella tavalla: tutkivan oppimisen ja hajautetun virtuaalisen projektityön malleilla. Väitöskirjatyön tavoitteena oli selvittää millaisia tietokäytäntöjä tiimeissä syntyi, millaisia jaettuja kohteita he kehittivät ja mitkä olivat uusissa työtavoissa koettuja haasteita. Samalla tutkittiin myös miten ohjaajat tukivat työskentelyä ja millaista tukea verkko-oppimisympäristö tarjosi. Lisäksi on tarkasteltu niitä monitasoisia taitoja, joita yksilön työskentelyn, yhteisön sosiaalisten käytäntöjen ja jaetun kohteen edistämisen seuraaminen ja ohjaaminen näyttävät edellyttävän sekä opiskelijoilta että ohjaajilta eli metataitoja.

Osatutkimuksissa analysoitiin teknologiavälitteisiä yhteisöllisiä oppimisprosesseja neljällä kurssilla. Tutkimuksen lähestymistapana on ollut tapaustutkimus yhdistettynä suunnitteluperustaiseen tutkimukseen. Suunnittelu- ja tutkimuskierrosten perusteella tarkennettiin tutkimuskysymyksiä, aineistonkeräystä ja analyysitapoja. Keskeisen tutkimusaineiston muodostivat kursseilla käytettyjen virtuaalisten oppimisympäristöjen tietokantojen materiaalit, muuna aineistona olivat opiskelijoiden itsearvioinnit sekä tiimi- ja opettajahaastattelut. Kaikkiaan 20 tiimin käytäntöjä ja tuotoksia tutkittiin yksityiskohtaisesti laadullisen sisällönanalyysin menetelmällä.

Osatutkimus I tarkastelee tutkivan oppimisen etenemistä ja tuotetun tiedon luonnetta. Opiskelijaryhmien oppimisprosessit oli järjestetty eri tavoin: ilman teknologiaa, teknologian tai teknologian ja tutoroinnin tukemana. Osatutkimus II käsittelee yhteisöllisen työskentelyn metataitoja tietoa luovassa oppimisessa. Tutkimus kohdistuu jaettujen tietokohteiden edistämiseen ja käsitteellisen tietämyksen syventämiseen ryhmissä. Osatutkimus III vertailee kahta kurssia, joissa pienryhmät työstivät yhteisiä loppuraportteja tutkivan oppimisen tai hajautetun virtuaalisen projektityön mallin mukaisesti. Osatutkimus IV tarkastelee hajautetun projektityön mallin soveltamista yliopistokontekstissa, opiskelijoiden näkemyksiä tiedonluomisen haasteista sekä asiakkaan roolia. Asiakas antoi ryhmille haastavan konseptikehitystehtävän.

Jaettujen tietokohteiden työstäminen tiimeissä sisälsi tutkimuskysymysten, ideoiden, suunnitelmien ja raporttien tuottamista, käsitteiden tarkentamista ja vertaiskommentointia. Oppimisen teknologian sovellusten havaittiin edistävän kysymys-selitysprosessien ja ideoiden kehittämistä yhteistyössä. Tutorointi auttoi edelleen syventämään näitä prosesseja. Asiakkaiden osallistumisen prosessiin havaittiin kannustavan opiskelijoita tiiviimpään yhteiskehittämiseen. Opiskelijoiden esittämät haasteet liittyivät osallistumiseen ja sitoutumiseen, käytännön koordinoimiseen ja yhteisten tietokäytäntöjen kehittämiseen.

Keinoina tukea tietoa luovaa oppimista esitettiin tiimikohtainen ohjaus, tietotyön asiantuntijamallit, episteeminen, rakenteellinen ja käytännöllinen mallintaminen sekä erilaiset tuotospohjat. Institutionaalisella tasolla tulisi toimia yhteistyötä rajoittavien käytäntöjen tunnistamiseksi ja tehdä mahdolliseksi yliopiston, yritysten ja/tai julkisen sektorin yhteistyö tiedonluomisen kurssien keinoin.

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Helsinki, December 20th, 2010

Hanni Muukkonen-van der Meer

List of original publications

This thesis is based on the following four original publications, which are referred to in the text by their Roman numerals (Studies I-IV):

- I Muukkonen, H., Lakkala, M., & Hakkarainen, K. (2005). Technology-mediation and tutoring: how do they shape progressive inquiry discourse? *The Journal of the Learning Sciences*, 14(4), 527-565.
- II Muukkonen, H. & Lakkala, M. (2009). Exploring metaskills of knowledge-creating inquiry in higher education. *International Journal of Computer Supported Collaborative Learning*, 4(2), 187–211.
- III Muukkonen, H., Lakkala, M., & Paavola, S. (2011). Promoting knowledge creation and object-oriented inquiry in university courses. In S. Ludvigsen, A. Lund, I. Rasmussen, & R. Säljö (Eds.), *Learning across sites: New tools, infrastructures and practices* (pp. 172-189). New Perspectives on Learning and Instruction. Abingdon: Routledge.
- IV Muukkonen, H., Lakkala, M., Kaistinen, J., & Nyman, G. (2010). Knowledge creating inquiry in a distributed project management course. *Research and Practice in Technology Enhanced Learning*, 5(2), 1-24.

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1 Introduction

In the sociocultural approaches to learning, human activities are conceived as socially and culturally mediated: learning is part of social processes of knowledge construction, mediated by cultural tools and norms (Bruner, 1996; Vygotsky, 1978). In the last decades, higher education has been profoundly influenced by the development of cultural tools, such as educational technologies, electronic resources, and virtual communication. This influence is not merely a matter of technological innovations, but involves profound transformations of academic practices related to new forms of activities with these cultural tools. The research community has followed these transformations with an increased interest in the new practices of collaboration and working with knowledge.

Several educators and researchers in higher education (Bereiter, 2002; Mandl et al., 1996; Slotte & Tynjälä, 2003) have contrasted the practices of higher education and working life-organizations by pointing out that the majority of higher education learning still takes place around well-defined problems with known solutions. Conversely, in working life employees are expected “to develop new outcomes and products by finding solutions to problems that have not yet been defined, presumably for markets that have not yet been explored” (Slotte & Tynjälä, 2003, p. 452). This contrast offers intriguing questions for research investigation.

Encounters with real-world complexity are one way of bringing learning communities closer to the requirements of the surrounding society. Marton and Trigwell (2000) argued that that in order to facilitate transfer of learning, it is essential to engage students in collaboratively solving complex and varied problems; their efforts in the process of creating, comparing, and assessing various solutions to multi-faceted problems prepare the participants to solve unanticipated problems that they encounter in the future. The integration of theoretical and practical knowledge has been acknowledged as one mechanism with which to address the contrast. This address can, for instance, take the form of dealing with cases or authentic problems from professional contexts, as in problem-based learning. Another mechanism often employed relies on adopting work life practices, such as teamwork, customer assignments, project work, and multidisciplinary collaboration in pedagogical practices.

The objective of the present investigation is to examine how to engage students in

solving complex problems of professional life by bringing to them the professional practices of developing knowledge objects. The four studies of this thesis address iterations of designing and investigating collaborative inquiry processes in higher education. *Knowledge creating inquiry*, in the present contexts, is defined as higher education practices that seek to foster collaborative inquiry into complex problems and shared development of knowledge objects.

Two pedagogical models, sculpting practices of scientific communities and distributed project work, have been examined. The research on models and the social practices of collaboration has taken place in 5 contexts involving 20 student teams. The thesis examines the knowledge practices and objects in relation to the use of collaborative technology. It focuses on team processes and practices that can be traced in the database as well as students' reflections regarding learning and collaboration experiences in the courses.

The scope of this summary of the dissertation is to provide an overview of the four original studies of the dissertation. It aims to elaborate on the theoretical background of the studies and the key concepts used. Centrally, the summary has been written to tie together the studies in their empirical evidence as well as theoretical and methodological implications. References to the original publications (Studies I-IV) are made throughout the summary.

The following sections of the summary of the dissertation will address the theoretical background, the research objectives, methods, overview of the original studies, conclusions and implications of the studies as well as suggestions for future directions of development and research.

1.1 Theoretical framework

Two of the most frequently used concepts in this thesis are 'practices' and 'inquiry'. Schatzki has proposed that *practices* are "materially mediated arrays of human activity centrally organized around shared practical understanding" (2001, p. 2). These include executing everyday routines as well as carrying out learning tasks, solving problems, and creating knowledge artifacts, such as essays and research reports. Knowledge practices are the personal and social practices related to working with knowledge (Hakkarainen, 2010). More generally, social practices are assemblages of human

activity that involve goal-directed sequences of actions using particular technology and rely on a socio-historically developed system of knowledge (Schatzki, 2001; Scribner & Cole, 1981). Furthermore, various institutional settings may be labeled according to some prototypical conceptualizations of the routines and systems of knowledge: for instance, parameters such as work practices, professional practices, and educational practices are used. In our present society, these knowledge practices are increasingly technology-augmented, since technology has become such a fundamental mediator of our work with knowledge.

The research on practices is highlighted here because the present dissertation work is built on both professional and educational practices; it has been seeking to involve students in types of creative knowledge practices, similar to those that characterize knowledge-intensive work in professional settings. To make such an alteration of practices requires that the educational goals and the types of practices introduced during the courses by the designers and instructors be drawn from professional practices of working with knowledge: that is, work in teams to deal with complex problems and develop shared knowledge objects.

The other concept central to the presently reported investigations is *inquiry*. The original aspiration of the thesis work was to study and understand collaborative, technology-mediated inquiry learning. It was grounded in the expansion of research on collaborative inquiry learning taking place in the last two decades. The proliferation of web-based educational technologies is one of the main reasons, but also collaboration without technology has gained importance as an educational practice. In particular, the cognitive and motivational benefits of collaboration have been documented (e.g., Baker, 2003; Barron, 2003; Blumenfeld, Kempler, & Krajcik, 2006; Dillenbourg, 1999; Järvelä, Volet, & Järvenoja, 2010; Lahti, Seitamaa-Hakkarainen, & Hakkarainen, 2004; Muukkonen, Hakkarainen, & Lakkala, 2004). The approach of collaborative inquiry learning is a way of designing learning settings and activities which is based on giving students the main role as questioners, explainers, synthesizers, and evaluators of knowledge. Originally starting from epistemological considerations of collaborative inquiry learning, investigators focused on defining certain critical epistemic activities and associated practices involved in knowledge advancement. There are still many open questions related to the types of tasks, tools, agency, and practices that students should

be encouraged to develop to gain needed competencies and skills for work in the future knowledge society.

More recently, the research in this dissertation has been motivated by questions stemming from professional knowledge practices around development of epistemic objects. The term *epistemic object* has been used to refer to an entity or effect that is for the most part unknown and taken under study (Knorr-Cetina, 1999; Miettinen, 2005; Rheinberger, 1997), for instance the shortage of water or cancer and its treatment. Epistemic objects are of interest because they portray the types of uncertainty and incompleteness present in evolving work practices, where multiple interpretations of knowledge and practices co-exist and are being created. Epistemic objects, or “objects of knowledge” in Knorr-Cetina, are “*characteristically open, question generating and complex. They are processes and projections rather than definite things... Objects of knowledge appear to have the capacity to unfold infinitely. They are more like open drawers filled with folders extending infinitely into the depth of a dark closet. Since epistemic objects are always in the process of being materially defined, they continually acquire new properties and change the ones they have. But this also means that objects of knowledge can never be fully attained*” (2001, p. 181).

New formulations and explications are created as part of collective efforts to study the epistemic object. Explication of emerging knowledge takes place by creating epistemic entities or externalized and concrete *knowledge objects*, such as drafted theories, intervention programs, and reports. Knowledge work can be conceptualized as work that focuses on advancing and articulating knowledge objects by a community’s collective efforts and resources (Bereiter, 2002; Hakkarainen, Palonen, Paavola, & Lehtinen, 2004).

The nature of work and knowledge indicated by the terms ‘epistemic object’ or ‘knowledge object’ is at times overlooked by the educational practices of the institutions of higher education, although it is central in research practices of these organizations. This oversight may relate to the obligation to introduce each new generation of students to a comprehensive set of conceptual and procedural domain knowledge. The mainstream educational practice builds on solving relatively well-defined tasks for assimilating pre-selected entities of “autonomous texts” (Olson, 2003; also Bereiter, 2002; Mandl, Gruber, & Renkl, 1996). Therefore, in order to emphasize

work practices around knowledge objects in educational practice, it appears necessary to investigate ways of pedagogically designing projects with sufficient open-endedness and complexity, similar to professional work practices. Complexity is expected to generate unpredictable situations that are both practically and epistemologically challenging. These, in turn, bring into sight gaps, discrepancies, and breakdowns in current knowledge and practices (Engeström, 1987; Fischer, et al., 2005; Hatano & Inakagi, 1992; Perkins et al., 1995). Overcoming these gaps is foreseen to create prospects for novel solutions. The end results of inquiry processes are not only the artifacts, but also the transformed personal and collective practices (Hakkarainen, 2009) and the tacit and explicit conceptions of learning and knowledge related to the new practices.

1.1.1 Knowledge building

The original theoretical background for the studies comes from knowledge building theory and pedagogy. *Knowledge building* describes knowledge advancement as a collective affair rather than individual achievement (Scardamalia & Bereiter, 2006). Knowledge building can be defined as the production and continual improvement of ideas of value to a community (Scardamalia & Bereiter, 2003). Within the scope of more than three decades, the ideas of knowledge building have been very influential worldwide in fostering a pedagogical change based on the idea that authentic, creative knowledge work can take place in school classrooms. One might add, such work should also play a central role in undergraduate level education and beyond. Knowledge building places emphasis on ideas as conceptual artifacts that can be improved in community discourse (Bereiter, 2002). In *knowledge building communities*, members make progress not only by advancing their personal knowledge but principally by developing collective knowledge. In order to function as a knowledge building collective, a community must establish social practices which uphold collective cognitive responsibility (Scardamalia, 2002) for the pursuit of deeper understanding and development of ideas.

The classroom and workplace implementations of the knowledge building theory, pedagogy, and supporting technology have undergone extensive development. The first realization was the Computer Supported Intentional Learning Environment (CSILE,

Scardamalia & Bereiter, 1994) and later the Knowledge Forum (KF, Scardamalia & Bereiter, 2006). These environments generated impressive knowledge building discourses, but there were also cases of failure to establish a knowledge building community (Lipponen, 2000). These examples raised questions about the most appropriate ways to scaffold and model the practices of such communities. The Progressive Inquiry model (Hakkarainen, Lonka, Lipponen, 1999) and the Future Learning Environment (FLE) technology (Muukkonen, Hakkarainen, & Lakkala, 1999) developed by Kai Hakkarainen and colleagues are the results of efforts to realize and model the elements of knowledge-building communities' practices. They have modeled the deepening question-explanation processes, sharing of expertise, and focusing of inquiry questions as key elements in inquiry. This pedagogical model and the FLE-environment are described in detail in sections 1.7.1 and 3.5 of this summary.

1.1.2 Trialogical learning framework

The pedagogical investigations of progressive inquiry generated yet new questions on the role of the knowledge objects developed and the social practices of a learning community. These questions on the nature of the objects and their related knowledge practices were theoretically further developed in the trialogical learning framework as well as empirically in the studies in this dissertation (Studies I-IV).

The trialogical learning framework (Paavola, Lipponen, & Hakkarainen, 2004; Paavola & Hakkarainen, 2005; Hakkarainen, Palonen, et al., 2004), directs attention to those aspects of social interaction and artifact-mediated activities that are directed towards engagement in the development of shared objects and the pursuit of innovation. Roughly, the difference from the knowledge building approach can be formulated thus: the knowledge building approach focuses on understanding the processes related to idea-improvement in conceptual artifacts, whereas the trialogical approach takes a more specific focus on the knowledge objects, various ways to foster creation and revisions of tangible knowledge objects and the knowledge practices related to their development (Paavola, Engeström, & Hakkarainen, 2010). Knowledge creation is about setting up practices of working with knowledge and channeling the efforts of the participants around the epistemic objects in ways that educe knowledge advancement, where the development of ideas is one component (Hakkarainen, 2009), and collective practices

and products are others. At the outset of the present studies (Study I), the pedagogical design and analysis examined discourse progression in the database; the subsequent studies changed focus to the development of shared objects and artefacts.

In its early development, the triological learning framework was explicated to expand on the two metaphors of learning put forward by Sfard in 1998, the acquisition and the participation metaphors of learning, by adding a third, the knowledge creation metaphor (Paavola et al., 2004). The acquisition metaphor of learning addresses assimilation of prevailing knowledge and the individual's mental models and strategies of learning. Such practices are quite familiar to anyone taking part in traditional higher education courses, i.e., attending lectures, writing essays, and reading for exams. The participation approach highlights the adaptation to existing cultural and communal practices and the dialogical practices of learning (Lave & Wenger, 1991; Sfard, 1998). Such practices may be exemplified by the field-training period of studies, where students are scattered around into various institutions and under supervision become familiar with the practices, tools, and cultural knowledge of a particular working community.

The triological learning framework upholds the cognitive (individualistic) and social (participatory) forms of expertise and learning, but emphasizes the knowledge-creation (object-centered) approach to learning. The presence of these artifacts, practices, and products—objects—is the rationale for the term 'trialogic' as contrasted with 'dialogic'. The objects are seen to mediate knowledge advancement by structuring the efforts of the participants in the direction of working on these objects, negotiating meanings, expanding, and versioning them by collaborative efforts.

'Knowledge creation', as a more general term, is fairly frequently associated with work place practices, but tends to generate opposition or disbelief among educators when used in relation to educational practices. The doubt arises from the question whether students in undergraduate education are able to create truly new knowledge, because they do not have sufficient domain knowledge on which to base new ideas. The triologic approach to learning and the (predecessor) knowledge building theory are based on the premises (Bereiter 2002; Hakkarainen, Lonka, & Lipponen, 2004) that the underlying mechanism of knowledge advancement is the same whether one is in an undergraduate class or a top design team. A student team in undergraduate class strives for creation of locally novel knowledge, new conceptual understanding, practices, and

solutions, which go beyond their initial understanding. In a top design team or research community, the process intensively builds on existing cultural knowledge and aims at more unique solutions or substantial changes and impact at the societal level.

1.2 A view of knowledge objects in professional practices

To provide more background for knowledge creating inquiry, the present section visits some conceptualizations of knowledge work. However, it is important to emphasize that the studies in this dissertation have not examined workplace practices, i.e., workplace activity. The focus, here, is on higher education environments.

In current work practices, multi-professional collaboration is typically organized around long-term efforts for developing shared, tangible objects such as products, models, articles, or practices. These combined efforts take place in hybrid forms, for instance as global software development teams (e.g., Cummings, 2004; Faraj & Sproull, 2000; Malhotra & Majchrzak, 2004), research teams and networks (e.g., Akkerman, Admiraal, Simons, & Niessen, 2006; Latour & Biezunski, 1994) or organizational cross-functional development teams (e.g., Kerosuo & Engeström, 2003). An increasing part of these efforts takes place by virtual communication, since team members are not in the same location.

It is not my intention to claim here that all knowledge work is innovative or creating novelty. Knorr-Cetina (2001) has expressed it succinctly that expert communities rely on weakly determined, explorative, and problem-laden practices that are once in a while innovative. For the present work, whatever makes it ‘once in a while innovative’ is what makes it interesting and worthwhile to transfer to educational practices. The characterization of innovative knowledge communities (IKCs) (Hakkarainen, Palonen, et al., 2004) provides an example of the kinds of competencies valued in present professional work. The IKCs exemplify working within knowledge-rich domains, “dealing with very complex problems, the solving of which requires substantial depth of knowledge, and systematically working to create new knowledge and knowledge-laden artifacts” (Hakkarainen, Palonen, et al., 2004, p. 141). Two qualitatively distinct dynamics of innovation may be identified: one is based on increasing specialization and the other on combination of existing resources (Tuomi, 2002). Further, the cultural and material resources available for users are key components in an innovation process

(Bereiter, 2002; Tuomi, 2002).

The conceptualizations of IKCs and the knowledge creation process build on the works of Engeström, Bereiter, and Nonaka: collective objects have been shown to emerge by modeling new practices (Engeström, 1987; 2001), articulating conceptual artifacts (Bereiter, 2002) or developing ideas for knowledge-intensive products (Nonaka & Takeuchi, 1995; Nonaka & Toyama, 2003). Further, in knowledge creation, it is assumed that the epistemic objects are open-ended (Knorr-Cetina 1997; Miettinen & Virkkunen 2005), and they keep evolving while the particular project is carried out. Examples of such objects are theories, prototypes, and collective practices (Paavola & Hakkarainen, 2009).

The notion of *object of activity* has aroused fertile discussion especially within cultural-historical activity theory (Kaptelinin & Miettinen, 2005; Engeström & Blackler, 2005; Miettinen, 1998). Object-orientedness gives an important perspective on learning and the design of educational settings that is applicable beyond the framework of activity theory. According to activity theory, all activity is object-oriented (Leontiev, 1978): the objects have both an independent existence here and now transforming and interacting with the activity of the agents, and a future existence as an image of what could be. This object may take very different forms when examined at different levels of activity, from partially automated operations to goal-directed actions, and cultural forms of activity (Kaptelinin, 2005; Stetsenko, 2005). In its most general sense, the “object of activity” is a collective “motive” for the whole activity system (e.g., finishing a certain project within certain social and cultural settings) but it is also those concrete objects which are outcomes of that activity (e.g., end-products of that project). Individual students’ activities are focused on particular objects, e.g., writing an essay for a course. Collective activity systems have their own objects of activity, e.g., in an educational system to produce educated students for professional life.

The concept of *community* holds different implications depending on the setting addressed. In a workplace setting, a community of practice (Lave & Wenger, 1991; Wenger, 1998) designates participation in expert culture that provides cultural knowledge, tools, practices, and social norms. Learning has been understood as a process of becoming a member of that community, first peripherally and with time typically by varied forms of participation. This longer-term engagement (measured in

years or semesters, not weeks) is also characteristic of a learning community in a primary or lower secondary level classroom context. Examples of classroom learning community have been presented under such labels as *knowledge building community* (Scardamalia & Bereiter, 2006; Bielaczyk, 2006), *progressive-inquiry culture* (Hakkarainen, 2003; Lakkala, Ilomäki, & Palonen, 2007), and the framework of *guided discovery in a community of learners* (Brown & Campione, 1994). Although the notion of 'learning community' appears to provide productive possibilities by highlighting collaborative aspects of learning and engaging students into inquiry-oriented activities, it is important to consider the limitations of such an approach. The analysis of Roth and Lee (2007, see also Hakkarainen, 2010) indicated that educational researchers often used of the concept of 'community' in a very superficial way; they assumed that whenever a group of agents (e.g., students) was brought together for a short time, it was considered to constitute a community. Yet groups of learners under a teacher's guidance do not necessarily constitute genuine communities. Roth and Lee as well as Hakkarainen argued that in order to be considered as a learning community, a group of students needs *inter alia* to have a shared object of activity.

The settings addressed in the present dissertation work, higher education courses, cannot be defined as long-term communities. In fact they may be summoned and disengaged in a frame of 12 weeks, and teams hardly have time to develop any collective practices in a sense of a community of practice or a knowledge building community. Yet, it is argued that the members of a course do engage in building a learning community, and tutoring efforts should strongly facilitate it. Such a learning community in a course may be transient, but perhaps more transparent; on the part of the instructors there is a pressure to model and structure the activities around the development of shared objects; and on the part of the students, teams are expected to negotiate and establish practices for collaboration in a quick tempo.

1.3 Knowledge creating inquiry

Knowledge creating inquiry is a term employed in Studies II and IV of this dissertation to address higher education practices which seek to foster collaborative inquiry on open-ended problems and shared development of knowledge objects as set out in the triological framework. In Study I, progressive inquiry was the notion used, drawing on

the progressive inquiry model explicated in section 1.7.1 of this summary. In Study III, object-oriented inquiry was the broad notion used to explain the inquiry process. Its use was influenced by the research on object-oriented activity in the activity-theoretical approach.

Some explanations on the various characterizations of objects are still necessary. In the studies of this thesis, as well as the present summary, multiple ways to conceptualize an object have been used: epistemic object, shared object, knowledge object, and knowledge artifact among others. Presently, these terms are used with the following interpretations; however, the original publications hold alternative meanings of these concepts, in part due to an increasing awareness of the implications of object-centered activities. In research literature on professional knowledge practices, one also finds various terminology to describe the knowledge-laden nature of work.

An epistemic object appears to hold the most complexity and incompleteness to it, in a somewhat similar way as an object of activity understood as a collective motive for the whole activity system. Due to their functional complexity (Miettinen, 2005), such objects are addressed in multidisciplinary collaboration by externalizing and contrasting present understanding, and drafting, negotiating, designing, and testing new solutions. In terms of the temporal limitations of courses in education, it appears rather grand to assume that students could be arranged to collaboratively develop fuzzy epistemic objects. Therefore, in relation to the dialogical learning framework, the notion of *shared knowledge objects* has been central. It has been used to draw attention to the co-construction of objects and artifacts--design, plans, reports, software applications--as an important objective in educational practices. The term shared knowledge objects refers to concrete epistemic entities (Paavola et al., 2010), and is meant to include knowledge objects as well as knowledge artifacts and the knowledge practices undertaken during the development of objects. The terms *shared object*, *knowledge object*, and *shared knowledge object* have been used interchangeably in the summary. The knowledge artifacts are the most concrete end of this continuum, the digital and material artifacts that are manipulated.

The present research examines the development of objects from three points of view: first, how may the development of shared objects be employed as a guiding principle for pedagogical design of inquiry (particularly in Study III), second, what kinds of

knowledge practices are found in groups and teams asked to engage in knowledge creating inquiry (Studies I-IV), and, third, what kinds of novel skill-demands and challenges do students report, based on their experiences in open-ended collaborative inquiry (in Studies II-IV). Throughout the studies, students' collaboration was arranged to take place in teams or small groups of 3-6 students from multiple domain backgrounds. Students were scaffolded to collaboratively advance their understanding of open-ended research questions or to generate solutions on customers' assignment. Two pedagogical models were employed to provide heuristic guidance for the inquiry processes: the progressive inquiry model (in Studies I-III) and the distributed project model (in Studies III and IV). Progressive inquiry is a heuristic framework for structuring and modeling the sustained processes of advancing and building of knowledge characteristic of scientific inquiry (Hakkarainen, Lonka, & Lipponen, 1999; Muukkonen, Hakkarainen, & Lakkala, 2004). The distributed project model has been designed to exemplify distributed virtual project work tailored for educational settings (Marttiin, Nyman, Takatalo, & Lehto, 2004). It distinguishes communication structures, roles, responsibilities, and collaboration aims for teams taking part in a distributed, virtual project work.

1.4 Technology-mediated collaborative inquiry

A central principle of designing collaborative technology is to provide structures and activities that foster monitoring and reflection of one's own and the other students' comprehension and enable the construction of shared knowledge (e.g., Bereiter & Scardamalia, 1993; Brown & Campione, 1994; Roschelle & Teasley, 1995). Further, Scardamalia and Bereiter have proposed that networked learning environments, when properly designed, help to facilitate epistemic agency (Scardamalia, 2002) by moving students' own ideas into the center of educational practice and providing a forum to participate in socio-cultural activities of knowledge-building communities (Bereiter, 2002; Scardamalia, 2002). Advanced technology can facilitate students' collective inquiry efforts, but does not, by itself, provide sufficient support without appropriate pedagogical arrangements and scaffolding of the collaborative learning endeavor (Lehtinen et al., 1999; Lakkala et al, 2005; 2008; 2009; Lipponen & Lallimo, 2004).

The concept of mediation explicates the intermediary role of tools in a community's

knowledge creation activities (Vygotsky, 1978). *Mediation based on collaborative technologies* can be said to transform students' intangible ideas into digital entities that can be further articulated, shared, interlinked, and extended (Hakkarainen, 2010). As prolonged efforts of knowledge advancement tend to become messy and layered, instruments and methods that allow making visible, reflecting on, and transforming prevailing practices are needed. A flexible educational technology should provide varied types of mediation for team's collaboration, including pragmatic, social, epistemic, and reflective types of activities (Paavola & Hakkarainen, 2009; Rabardel & Bourmaud 2003; Lakkala et al., 2009). Epistemic mediation relates to creating, transforming, commenting, organizing and linking knowledge artifacts. Pragmatic mediation is needed for practices such as planning, organizing and coordinating tasks and work processes. Social mediation aims to foster managing social relations and interacting around shared objects. Reflective mediation intends to support making visible and reflecting on the work processes (Lakkala et al., 2009; Paavola et al., 2010). The integration of various types of mediation in one environment is one of the interesting design challenges of learning technologies, because the present day environments typically mediate only one type of practices, for instance pragmatic mediation is offered in many project work tools; similarly, applications of social media create forums for advanced types of social communication.

The present research examines the use of educational technology in a blended or hybrid form of instruction and collaboration (e.g., Graham, 2006; Garrison & Vaughan, 2008; So & Brush, 2008). Participants interact both face-to-face and virtually. The virtual interaction can be either synchronous, as in chat rooms or desktop audio/video conferencing, or asynchronous as in discussion forums, Wikis, blogs, or other collaborative authoring tools. Face-to-face and virtual collaboration environments have complementary characteristics, strengths and weaknesses that have an impact on the inquiry process (Graham, 2006). Graham names flexibility and access, activeness of participation, depth of reflection, spontaneity, procrastination, and human connection as characteristics present in diverse ways in face-to-face and virtual collaboration. The real question is how to design and implement fruitful combinations that gain the best out of each. For instance, prior research has suggested that virtual phases of instruction (with an eye for cost effectiveness) may be directed at mastering factual knowledge or

technical skills. Face-to-face phases are recommended for comparison of perspectives, critical evaluation, reflection, and decision making skills, which are not easily mastered by self-study (e.g., Garrison & Vaughan, 2008; Joutsenvirta & Myyry, 2010). In a study on collaborative designing, Lahti (2007) found that virtual design studios may provide a medium for sharing the central aspects of design thinking and constructing a design object. However, not all aspects of design collaboration can be computer-mediated, since, for instance the evaluation of certain material or functional aspects may be difficult to carry out, based solely on virtual representations. The present research examines these characteristics in relation to knowledge creating inquiry processes by making comparisons across technology-mediated and non-technology inquiry (Study I), as well as tutored and non-tutored technology-mediated collaboration (Studies I, II, and IV).

The types of regulation and coordination activities that need to be achieved by groups or teams have been extensively reported in research papers in CSCL. For instance, creating a common ground in shared problem solving (Mäkitalo, Häkkinen, Järvelä, & Leinonen, 2002), resolving differences in goals, expectations, communication styles as well as power dynamics among members (Arvaja, Salovaara, Häkkinen, & Järvelä, 2007) or the use of shared regulation in addition to self-regulation (Järvenoja & Järvelä, 2009). Järvelä and colleagues have concluded that many challenges to group members' productive participation appear to be socio-emotional in nature and emerge through interactions during the activity (Järvelä et al., 2010). Further, every group engaged in collaborative learning generates its own social dynamics through its members' interactions, engagement, and commitment (Järvenoja & Järvelä, 2009), which renders each collaboration process rather unique and unpredictable.

Recent papers by Meier, Spada, and Rummel (2007), Han and Hill (2007) and Damsa and colleagues (2010) have elaborated on several dimensions of computer-supported collaboration processes. Meier and colleagues (2007) particularly strived for developing a rating scheme for assessing the quality of computer-supported collaboration processes. They highlighted five aspects: communication, joint information processing, coordination, interpersonal relationships, and motivation. Han and Hill (2007) explored how asynchronous discussion in a virtual learning environment facilitated collaborative learning. They concluded that three main

categories were important in facilitating collaborative learning: context, community, and cognition. Further, Damsa and colleagues (2010) examined the emergence of collaborative actions indicating shared epistemic agency. Their investigation addressed the epistemic (knowledge related) and regulative (process related) dimensions of collaboration directed at advancing shared objects represented by intermediary and final versions of students' collective reports. It is intriguing that all three studies emphasize the epistemic and regulative dimensions of collaboration, while the roles of community formation, reflection, technical coordination and communication forms were given varying accent based on the foci of the investigations.

The work of Lakkala and colleagues (Lakkala et al., 2008; Lakkala, 2010) sheds further light on the dimension of scaffolding (Wood, Bruner, & Ross, 1976) of inquiry. Vygotsky introduced his famous concept of creating a Zone of Proximal Development (ZPD) (Vygotsky, 1978). This zone is understood as the distance between the actual developmental level that a learner (child) has, which is manifested in the kinds of problems that the learner is able to solve without support, and the potential development level, which is represented in what the learner can achieve with support of an adult or in collaboration with more capable peers. The notion of scaffolding (Wood et al., 1976) has been used to further extend this thinking: scaffolding originally indicated the guidance that a more competent adult provided to help an individual learner to solve problem otherwise out of reach for the learner. Gradual fading of the support ensured that the help was available as long as needed, but only until independent performance was achieved (Pea, 2004; Lakkala, 2010).

To examine the ways to extend the scaffolding metaphor to a learning community and progressive inquiry, Lakkala with colleagues introduced the notion of pedagogical infrastructure framework comprising four components: technical, social, epistemological, and cognitive. The *technical component of the pedagogical infrastructure* is shaped by tools provided, especially technology that enables and facilitates the co-construction of knowledge artifacts, and the organization of the use of technology and related guidance. The *social component* is shaped by such features as the explicit arrangements to advance social interaction and collaboration around knowledge objects. This includes the sharing of the process and outcomes, and the integration of face-to-face and technology-mediated activity. The *epistemological*

component is shaped by ways of operating with knowledge and knowledge-related things that the practices and tools reflect. It specifies participants' and knowledge artifacts' role in the process, and how (and sometimes which) knowledge sources are used. Further, the emphasis on object-centeredness in the tasks and assignments is critical. The *cognitive component* is shaped by features that support students' awareness, conscious effort of understanding and independent mastery of the critical aspects in the desirable practices. These are supported by explicit modelling of the strategies of inquiry and timely guidance of knowledge-laden inquiry for the students. The scaffolding functionalities embedded in technology exemplify the overlap of cognitive and technical components. Various instructional interventions or methods may be used to promote meta-level reflection of the inquiry process and object-oriented practices. These four components were investigated in Study III to reflect on the pedagogical design of two courses, interplay between the components and the context, as well as alignment with evaluation.

1.5 Teaching teamwork and multidisciplinary collaboration

The importance of cross-fertilization of knowledge practices between educational and professional practices (e.g., Derry & Fischer, 2005; Hakkarainen, Palonen et al., 2004; Tynjälä, 2008) has been considered to deserve increasing attention. The rationale of cross-fertilization of knowledge practices comes from the fact that educational and professional communities develop typically their own methods, means of communication, tools, languages, and practices, which may be difficult to understand or enact for someone coming from a different community. It is anticipated that setting up contexts, such as the course in Studies III and IV, that intentionally aim at engaging participants, students, teachers, experts from work life, in joint activities is likely to make one's disciplinary expertise and limitations explicit. The ability to transfer between contexts may be seen as a specific competence (Walker & Nocon, 2007; Tuomi-Gröhn & Engeström, 2003). Further, within the dialogical learning framework, it is argued that cross-fertilization between the practices of diverse knowledge intensive communities and settings is a factor that facilitates advancements in knowledge creation (Paavola & Hakkarainen, 2005); these authors have suggested engaging students in solving complex problems coming from outside of the educational institution and

organizing development of shared objects between students and experts as ways for achieving such cross-fertilization. Such projects with external stakeholders provide experiences of solving complex problems, and in combination with reflection, make all parties more aware of their knowledge practices (Roth & Barton, 2004; Virkkunen, 2006; Hakkarainen, 2010).

In a survey study asking university graduates to evaluate 2-5 years later how their education had serviced their needs in current work, Tynjälä and colleagues (2006) found that the professionals indicated satisfaction with their computer skills and general mastery of knowledge that university had provided them; however many of the graduates thought that they did not have enough practice in social skills and in interaction with clients during their university studies. Interestingly, most of the professional reported that they had only learnt at work the most important skills they needed in their job. Tynjälä and colleagues concluded that this is a challenge which calls for development of university pedagogy in a way that makes it possible to integrate studying domain-specific knowledge with learning generic skills, such as interpersonal skills, communication, presentation, and collaboration skills.

While engineering education is not the main domain in the present work, there is interesting recent discussion in this field on the importance of cross-fertilization and various types of competencies. Among others, Bucciarelli (2003) has claimed that a disjunction exists between the social practices of (engineering) design and the instrumental practices of educating engineers. He particularly criticized the latter for reducing knowledge to static, distributable entities (similarly to Olson, 2003), where problem-solving usually takes place in a linear, unambiguous, and de-contextualized process, not reflective of the nested and contextualized professional practices. Further, Shuman, Besterfield-Sacre and McGourty (2005) suggested that while educating engineers, the skills generally emphasized have related to the knowledge of content and understanding of engineering processes: ability to apply knowledge, design experimentation and analyze knowledge, ability to design systems, identify and solve engineering problems ('hard skills'). However, they explicate that the mastering of 'professional skills' has become a major concern: these they relate to interpersonal skills which include communication, teamwork, process organization skills, placing engineering in global and societal context, lifelong learning, and knowledge on

contemporary issues.

Prior findings have suggested that collaborative learning based on complex problems can be successful when students are advanced in their studies and wish to prepare for the challenges of future workplace practices (Carr-Chelman et al., 2000; McCune, 2009). Several papers have also approached the issue of creating opportunities for multidisciplinary collaboration in educational practices, but mostly as part of doctoral programs or post-graduate networking (Latucca, 2002; Manathunga, Lant, & Mellick, 2006; Derry & Fischer, 2005). They, however, pointed to the importance of creating spaces for interdisciplinary and transdisciplinary collaboration; projects, meetings, workshops. Drawing on the expertise of participants from multiple disciplines and their theoretical backgrounds, tools, and practices gives access to new cultural tools and mediational means. The result of such interdisciplinary, “synthetic efforts is the capacity to imagine new ideas, new projects, and new futures” (Latucca, 2002, p.734). However, it has also been noted that cultural diversity tends to create additional challenges due to language and communication style differences, as well as culture-bound prior educational practices (e.g., Volet & Ang, 1998). In the present work, the term *multidisciplinary* is used to characterize the multiple domain backgrounds of students, teachers, and customers. The present studies take place in undergraduate education, thus they examine practices that involve multidisciplinary collaboration already from the beginning of studies.

Carrying out customer projects in higher education is a long-standing tradition, especially prominent in business, engineering, and design studies (e.g., Denton & McDonagh 2005; Marttiin et al. 2004; Nance, 2000; Seitamaa-Hakkarainen et al. 2005; Stankovic, 2009). Nance (2000) reported a case, similar to the one in Study IV, of combining a term project with cross-course collaborative activities, where the older students acted as project leaders. The students agreed that taking part in a hands-on experience of teamwork was invaluable because it provided them with a better understanding of what it takes to operate successfully in a group and a taste of real world project management activities. Concurrently, this real-world-like quality had its drawbacks: the students expressed significant frustration over the frequent confusion, miscommunications, and mid-project adjustments. Nance reflected: “the requirement that students take personal responsibility for their own time management, work

organization, and self-discipline, while forced to meet rigid weekly project deadlines, seemed to be an extremely foreign concept to many students” (p. 303). In light of the present work, one might add that perhaps it was not only a foreign concept but uncustomary knowledge practice, which would have required a new epistemological approach and strategies for collaborative inquiry from the part of the students.

These reflections point to the distinct features of a highly challenging situation for students: they need to manage and generate their own activities in teams, which may be especially difficult for students with little working experience. In Stankovic’s study (2009), students experienced that accountability and time management are important, and that effective project communication and learning also depend on documentation that must be correct, meaningful, and up to date. Furthermore, undertaking a complex process of collaborative design is likely to be accompanied with the feelings of ambiguity and uncertainty amongst the participants (Dym et al. 2005).

1.6 Agency and competencies for knowledge creating inquiry

One of the possible benefits of collaborative inquiry is the value that lies in students learning to understand the cognitive value of social collaboration and gaining the capacity to utilize socially distributed cognitive resources (Jost et al., 1998; Salomon & Perkins, 1998; Salonen, Vauras, & Efklides, 2005). Järvelä and colleagues (2010) suggested that in collaborative learning, individual members represent interdependent self-regulating agents who at the same time constitute a social entity, which creates affordances and constraints for engagement in the activity. The subjective and intersubjective aspects of collaborative inquiry are inextricably intertwined. The knowledge creation approach to learning further posits that the mediated, object-centered activities should take the main focus of those individual and collaborative activities.

The concept of agency is useful in order to shed light on this interdependency. A member of a community may take a proactive role, which is to say, exhibit agency. Bandura (2001) has emphasized intentionality and individual and collective efficacy in the regulation of actions; Edwards (2005) has highlighted the need for relational agency as a capacity for working with others; and Virkkunen (2006) has stressed the hybrid quality of transformative agency as agents are involved in long-term collaboration in

different activity systems with partially overlapping objects of activity. Further, the notion of epistemic agency was introduced by Scardamalia (2002) and Bereiter (2002) in their investigations of the advancement of conceptual knowledge in a knowledge-building community. Epistemic agency becomes overt in situations where a student starts to consider how to advance her own knowledge by reflecting, with others, on ideas and cultural knowledge on everyday phenomena. Furthermore, Damsa and colleagues (2010) have examined shared epistemic agency, which they depict as a capacity that enables groups to deliberately carry out collaborative, knowledge-driven activities with the aim of creating shared knowledge objects. In their work, they particularly examined the epistemic and regulative dimensions of creation of shared knowledge objects. In educational context, what makes agency a hard-to-specify competence relates to that shared epistemic agency is an emerging, recursive, and gradual process. The process is triggered and influenced by individual input, interaction with peers, and the object of activity, and, furthermore, guided by feedback (Damsa et al., 2010; Schwarz & Okita, 2004).

In the studies of this dissertation, the importance of students' agency in multiple forms is emphasized. However, it has not been operationalized, largely due to this very emergent and gradual quality, which necessitates examining the micro-level interactions within student collaboration, something that did not appear possible. Addressed at the meso-level of analysis, the metaskills of knowledge creating inquiry have been introduced by the present research in Study II. The metaskills are defined as dealing with the three areas of monitoring inquiry, individual, collective, and object-oriented. This division suggests that activities of students as agents should maintain multiple foci: personal engagement and inquiry goals; participation in social interaction and dialogue; and monitoring the object-oriented aspects of inquiry by engaging in collective idea generation, versioning, and refinement. Metaskills can be seen as involving how a group of students takes deliberate steps to make co-inquirers' activities more transparent and coordinated, and to reflect on the past and ongoing practices. Problematization of present knowledge and asking and responding to explanation seeking questions are interpreted as indications of evolving metaskills. These inquiry processes advance the explication of the shared object.

An intriguing question is what constitutes an appropriate time-span for assessing the

development of competencies for solving complex problems? Using only the few weeks reserved for one course in a semester appears debatable. Findings from the research on epistemological assumptions suggest that development of complex reasoning is indeed a long-term process (e.g., King & Kitchener, 2004; Kuhn, 1991). Similarly, developmental research within the activity theoretical approach depicts processes of several years for communities developing new practices (e.g., Engeström, Pasanen, Toiviainen, & Haavisto, 2005; Miettinen, 2005). Nevertheless, a worthwhile question appears to be that how could intentionally set up learning experiences trigger development of such skills and competencies even with a relatively short time frame, for instance, of 3 months?

1.7 Two pedagogical models

Several methods based on problems as definers of collaborative inquiry learning have been developed and refined by pedagogical research in the learning sciences. Two models, in particular, have been widely adopted and investigated: problem-based learning (Norman & Schmidt, 1992; Boud & Feletti, 1997) and project-based learning (Krajcik & Blumenfeld, 2006).

Problem-based learning has been widely adopted both as a method and a curriculum level approach in the medical and nursing education. It emphasizes the merging of practice and theory in teaching, as well as the use of patient cases already at the beginning of studies. The process of problem-based learning can be structured in the following way: a design team for the educational unit selects a problem and an event which can be used to represent the problem; student groups typically go through a seven steps process (Schmidt, 1983) which involves defining the problem based on the event and expressing the problem as a set of questions they use to define resources needed, collecting and applying them to the problem. A number of problems defined by the design team would be employed in a problem-based curriculum to cover a whole unit (Ross, 1997). The function of PBL process may be seen as one of activating questions and problems that guide the participants' further studies, which serves to bridge knowledge from the discipline studies to patient cases (Dolmans & Schmidt, 1996). A meta-analysis comparing problem-based learning with traditional methods indicated that the facts and basic knowledge of medical science were learned as well with both

methods, but the students who used problem-based learning were better at clinical deduction (Dochy et al., 2003).

The project-based learning is a model based on situated cognition that has been developed by Krajcik and Blumenfeld (2006) and their colleagues since the beginning of 1990s. The idea is to engage students in pursuing projects that involve complex real-world activities of experts, including questions, hypotheses, and explanations. It is assumed that students achieve a deeper understanding of material when they actively construct their understanding by participating in project-based learning. It highlights importance of learners' own questions, designing investigations, analyzing data, reporting results, and publishing results. It emphasizes students' active engagement and processes of developing artifacts.

Two pedagogical models have been employed in the courses examined, the progressive inquiry model (in Studies I-III) and the distributed (virtual) project model (in Studies III and IV). While the progressive inquiry model may be understood to model epistemic practices of scientific research groups, the distributed project model identifies social structures of virtual and distributed team work in companies and organizations.

Comparison of the problem-based and project-based learning models to the progressive inquiry and the distributed projects work reveals many similarities, especially in using questions and accentuating student teams' self-directed activities. Differences can be found: the progressive inquiry, in particular, does not frame the context in the way done by the problem and the event predefined by the teachers in problem-based learning. In the same manner, the distributed project model appears to rely more on engaging the students in knowledge practices in distributed teams by using the motivating assignments of the customers to initiate a process of inquiry manifested in the knowledge objects developed.

1.7.1 The Progressive inquiry model

In progressive inquiry, students' own, genuine questions and their previous knowledge of the phenomena in question are a starting point for the process, and attention is drawn to the main concepts and deep principles of the domain (Hakkarainen, Lonka, & Lipponen, 1999; Hakkarainen, 2003; Muukkonen, Hakkarainen, & Lakkala, 1999;

2004). From a cognitive point of view, inquiry can be characterized as a question-driven process of understanding; without research questions, there cannot be a genuine process of inquiry, although in education, information is frequently conveyed or compiled without any guiding questions. The model is primarily based on theories of knowledge building (Bereiter & Scardamalia, 1993), the interrogative model of scientific inquiry (Hintikka, 1999; Hakkarainen & Sintonen, 2002), and concepts of distributed expertise in a community of learners (Brown & Campione, 1994). The aim of inquiry is to explain the phenomena in a deepening question-explanation process, in which students and teachers share their expertise and build new knowledge collaboratively with the support of information sources and technology. Original, often vague questions are based on students' initial understanding of the issues. As summarized by Otero and Graesser (2001), research in question-asking has provided evidence that generation of questions is triggered by clashes between world knowledge and the materials or stimulus at hand, such as contradictions, anomalous information, obstacles to goals, uncertainty, or obvious gaps in knowledge. In the progressive inquiry process, the initial questions are generally found, during the process, to consist of several subordinate questions, which, in turn, become the focus of students' inquiry as in the Interrogative model of inquiry (Hintikka, 1999; Hakkarainen & Sintonen, 2002).

The progressive inquiry model specifies certain epistemologically essential processes that a learning community needs to go through, although the relative importance of these elements, their order, and actual contents may involve a great deal of variation from one setting to another. As depicted in Figure 1, the following elements have been placed in a cyclic, but not step-wise succession to describe the progressive inquiry process.

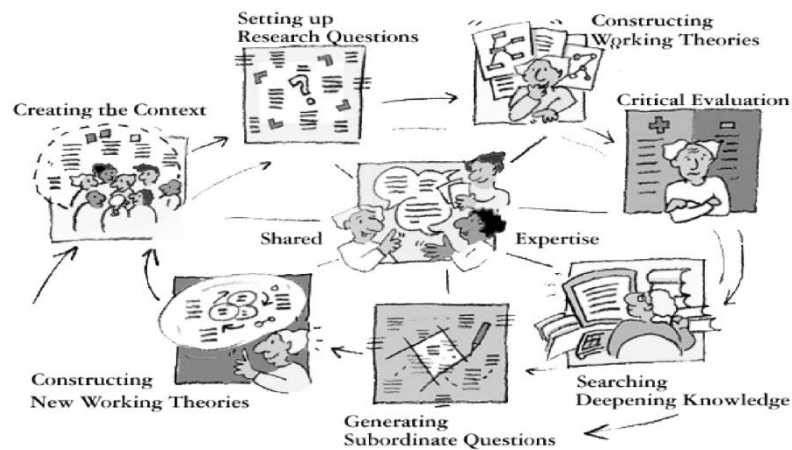


Figure 1. Elements of the progressive inquiry model

a. Distributed expertise is a central concept in the model. Progressive inquiry intends to engage the community in a shared process of knowledge advancement, and to convey, simultaneously, the cognitive goals for collaboration. Diversity in expertise among participants, and interaction with expert cultures, promote knowledge advancement (Brown et al., 1993; Dunbar, 1995). Acting as a member of the community includes sharing cognitive responsibility for the success of its inquiry. This responsibility essentially involves not only completing tasks or delivering productions on time, but also learners' taking responsibility for discovering what needs to be known, goal-setting, planning, and monitoring the inquiry process (Scardamalia, 2002).

b. The process begins by creating the context to anchor the inquiry to central conceptual principles of the domain or complex real world problems. The learning community is established by joint planning and setting up common goals. It is important to create a social culture that supports collaborative sharing of knowledge and ideas that are in the process of being formulated and improved.

c. An essential element of progressive inquiry is setting up research questions generated by students themselves to direct the inquiry. Explanation-seeking questions (Why? How? What?) are especially valuable (Hintikka, 1999; Hakkarainen & Sintonen, 2002). The learning community should be encouraged to focus on questions that are knowledge-driven and based on results of students' own cognitive efforts and the need to understand (Bereiter, 2002; Scardamalia & Bereiter, 1994). It is crucial that students come to treat studying as a problem-solving process that includes addressing problems

in understanding the theoretical constructs, methods, and practices of scientific culture.

d. It is also important that students explain phenomena under study with their own existing background knowledge by constructing working theories before using information sources. This serves a number of goals: first, to make visible the prior (intuitive) conceptions of the issues at hand; second, in trying to explain to others, students effectively test the coherence of their own understanding, and make the gaps and contradictions in their own knowledge more apparent (e.g., Hatano & Inakagi, 1992; Perkins et al., 1995); third, it serves to create a culture in which knowledge is treated as essentially evolving objects and artifacts (Bereiter, 2002). Thoughts and ideas presented are not final and unchangeable, but rather utterances in an ongoing discourse (Wells, 1999).

e. Critical evaluation addresses the need to assess strengths and weaknesses of theories and explanations that are produced, in order to direct and regulate the community's joint cognitive efforts. In part, it focuses on the inquiry process itself, placing the process as the center of evaluation, not only the end result. Rather than focusing on individual students' productions, it is more fruitful to evaluate the community's productions and efforts, and give the student participants a main role in this evaluation process. Critical evaluation is a way of helping the community to rise above its earlier achievements, creating a higher-level synthesis of the results of inquiry processes.

f. Students are also guided to engage in searching deepening knowledge in order to find answers to their questions. Looking for and working with explanatory scientific knowledge is necessary for deepening one's understanding (Chi et al., 1989). A comparison between intuitive working theories produced and well established scientific theories tends to show up the weaknesses and limitations of the community's conceptions (Scardamalia & Bereiter, 1994). Questions stemming from true wonderment on the part of the students can easily extend the scope of materials beyond what a teacher can foresee or suggest. Furthermore, searching for relevant materials provides an excellent opportunity for self-directed inquiry and hands-on practice in struggling to grasp the differences between various concepts and theories.

g. Generating subordinate questions is part of the process of advancing inquiry; learners transform the initial big and unspecified questions into subordinate and more

specific questions, based on their evaluation of produced new knowledge. This transformation helps to refocus the inquiry (Hakkarainen & Sintonen, 2002; Hintikka 1999). Directing students to return to previously stated problems, to make more subordinate questions, and answer them are ways to scaffold the inquiry.

h. Developing new working theories arises out of the fresh questions and knowledge that the participants attain. The process includes publication of the summaries and conclusions of the community's inquiry. If all productions to the shared database in a collaborative environment have been meaningfully organized, participants should have an easy access to prior productions and theories, making the development of conceptions and artifacts a visible process.

The progressive inquiry model played an important role in the first three studies in this dissertation. It was presented as heuristic guidance for the elements in the inquiry process. In Study I, it was elaborately addressed theoretically during the weekly lectures and students were guided to initiate the collaboration with the guidance from the model. In Studies II and III the model was theoretically introduced, although more briefly. In addition, it was used to structure the activities for each seminar session and taken up regularly during the sessions to reflect on knowledge advancement and collaborative activities.

1.7.2 The distributed project model

The distributed project model has been created to provide communication structures and collaboration aims for teams taking part in a distributed, virtual project work (Marttiin et al., 2004) simulating professional virtual teamwork. The model's emphases are drawn from issues that research on global, virtual teams at work have found challenging: coordination of work between team members, keeping the customer satisfied, and use of tools for virtual communication and collaboration (e.g., Ahuja & Galvin, 2003; Holton, 200; Prasad, & Akhiles, 2002)

To plan and design the pedagogical set-up for such a course involves four phases. First the teachers negotiate with potential customers to find a match between customers that could benefit from a brainstorming type of concept development and a motivating assignment for the students. This takes place typically several months before the actual onset of the course period. Next, with the students, the course build-up is an intense

phase directed at introducing the customer's assignment, theoretical grounding for distributed virtual work, setting up the teams and their working themes and practices. The themes are based on an assignment from customers: for example, determine the future possibilities and challenges of a broadcasting company in offering digital-TV services for people as workers, learners, citizens, and consumers. The activity phase is for creating solutions in teams, as will be detailed in the next paragraph. The last phase is the outcomes phase: based on the created solutions and usage of knowledge sources, each team constructs a presentation to the clients and a more extensive paper report. It is anticipated that the outcomes can provide fresh and out-of-the-box ideas for the customers and provide them with the reports as reference materials for their internal work.

Activity management refers to the self-directed and -organized collaboration in teams. The distributed project model (see Figure 2) provided the structure for the collaboration. Students are furnished with templates for each type of product, such as a team flyer, team diary, and a project plan. This is intended to provide scaffolding in the form of models and templates for engaging in various productions central in professional practices. A coordination team, composed of more advanced students, is given charge of the whole process of combining work in separate teams. The coordination team is responsible for communicating with the teachers and the customers; all communication from project teams towards these entities needs to go through them. In all teams, the team management responsibility is rotating; in turn, each student is the manager in his or her team for 1-2 weeks. In addition to the coordination and project teams, another separate student group was a research team, which was responsible for studying and reflecting on the other groups' experiences. A central weight is given to producing high-quality solutions on the customers' assignment (the future possibilities and challenges of a broadcasting company in offering digital-TV services), and to report and present the outcomes in front of the customer representatives. Throughout the phases, the coordination team supervises the teams, and the research team follows the process by questionnaires and interviews to study and report on team interaction and project management issues.

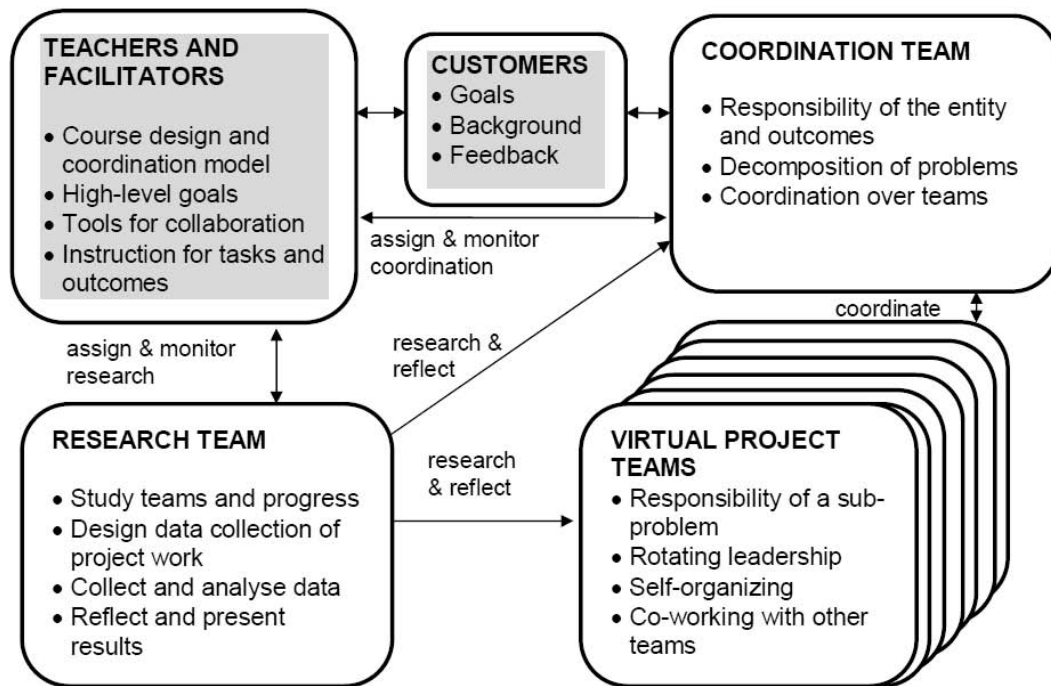


Figure 2. The distributed project model

The distributed project model introduces the customer in the process and it presents student teams with various functions. It draws attention to the roles, tasks, and responsibilities of the various participants of the process. Further, it defines communication structures, for instance by confining the communication with the customers only to the teachers and the coordination team, because of the limited possibilities of the customers to engage in interaction with every team. Similarly, project teams are expected to principally coordinate their processes with the aid of the coordination team. The coordination team and the research team interact directly with the teachers to plan and monitor team activities. In addition, the teachers provided all teams with templates from professional practices of the expected types of knowledge objects to be produced (e.g., final reports and plans).

2 Aims of the study

The aim of the present research is to address inquiry practices in higher education, with a focus on collaborative and technology-mediated knowledge creation around student generated research questions and assignments from customers. This focus has entailed a number of choices regarding the selection of the units of analysis: the principle unit of analysis is the process and knowledge creation that takes place in teams or small groups. The selection of the unit of analysis was deliberately made to take a small group level rather than the individual level, because it was deemed important to understand the collective processes of advancing shared objects. A similar argument in favor of using small group level as the unit of analysis has been made by Stahl (2006). Analogously, even when students' self-reflections are by nature individual perspectives on the process, they were not used to explain individual processes but the collective ones.

The reconstruction of the learning processes is attempted by drawing on, first, the database sources and interviews that record the activities in inquiry, and second, the self-reflections of the participants and their accounts of the process. Three principal research questions were posed:

1. How does collaborative knowledge creating inquiry take place in the examined courses?

In the examined educational practices, the designing and modeling of the collaboration processes was framed by the teachers with the utilization of the two pedagogical models and the introduction of the particular types of knowledge practices and aims promoted by the models. However, part of the organization of the collaboration process was left explicitly to the groups and teams with the expectation of self-organization around the knowledge objects. The first principal research question can be divided into the following sub-questions:

- What kinds of collaborative practices do student teams set up for complex and open-ended inquiry?
- How does the collaboration take place in the virtual learning environment?
- What kinds of shared knowledge objects were the students creating?

The knowledge practices promoted by the two models were taken as the reference point in comparing the kinds of collaboration processes encountered in teams.

2. How do the participating students reflect on their inquiry practices?

The sub-questions drawn from the second principal question include:

- How do students themselves perceive their commitment and ability to take part in collaborative inquiry (Studies II-IV)?
- What kinds of challenges do students report, based on the experience of engaging in knowledge creating inquiry (Studies II-IV)?

Here the approach is to address the learning processes from the viewpoint of the people involved. The use their explanation of the process aims to enrich the understanding of the observed processes with perspectives on agency and intent (Schwartz, 1999; Scardamalia & Bereiter, 2005).

3. How does one facilitate knowledge creation and technology-mediated inquiry?

The third principal research question examines the elements of the pedagogical setup of knowledge creating inquiry. Particularly:

- What is the role of pedagogical models?
- What is the role of tutoring?
- What roles could the technology be assigned?

The research addressed the kinds of choices in pedagogical design that appeared critical and what kinds of tutoring was offered in the various contexts. Finally, the type of facilitation offered by the virtual learning environments was examined.

3 Methods

3.1 Design-based research

Design-based research (DBR) is an approach and methodology in development since the early 1990's when Ann Brown (1992) and Allan Collins (1992) first introduced the term 'design experiment'. This approach focused on examining educational practices by iteratively designing interventions or pilots, examining what works and identifying constraints and limitations, and re-designing the field experiment at the subsequent iterative cycle. This approach involved educational researchers going to the field to make exploratory educational experiments rather than analyzing relations between variables in laboratory. In essence, the approach is considered to present a methodology which focuses on studying and designing of learning settings which are presumed effective but not very well understood and often overlooked if only summative effects of an intervention are examined (Design-based Research Community, DBRC, 2003; Wang & Hannafin, 2005). This approach has since then been advanced by researchers and designers in the learning sciences under several terms including *design-based research*, *design research*, and *design experiments*. The approach grew out of dissatisfaction with learning research carried out in laboratory settings, because of the inability of laboratory research to breed generalizable results and tools for natural pedagogical settings. Further, research carried out in the field was considered more able to carry out formative research based on theoretical principles (Collins, Joseph, & Bielaczyc, 2004). The core idea of this approach is iteration, and the capacity and knowledge to modify the intervention when it appears not to work or require improvement (Kelly, Baek, Lesh, & Bannan-Ritland, 2008).

Design-based research is, by nature, hypothesis generating and cultivating, rather than testing (Kelly, 2006). The goals of the DBR methodology are explicated by Barab and Squire (2004):

“The goal of design-based research is to lay open and problematize the complete design and resultant implementation in a way that provides insights into the local dynamics. This involves not simply sharing the designed artifact, but providing rich descriptions of context, guiding and emerging theory, design features of the intervention, and the impact of these features on participation and learning. [...] Our

goal, as applied researchers engaged in doing design work, is to directly impact practice while advancing theory that will be of use to others.” (p. 8)

The DBR approach has based on the “progressive refinement in design” which involves trying out the first version of the design to examine it in practice, and “then the design is constantly revised based on experience, until all bugs are worked out” (Collins et al., 2004, p. 18). This last quotation perhaps still echoes the background of many of the researchers in cognitive research, as it is very difficult to imagine a ‘bugless’ educational design except in laboratory settings because naturalistic conditions are always more prone to obstacles of all types that need to be dealt with on the run. Moreover, educational design is a prime example of an epistemic object continuously generating new questions. In addition, technology keeps evolving at such a speed that as one gets to the point of getting the bugs out of software, one may realize that the technology is already obsolete. Reaching an ideal situation and the preference for summative evaluation have been some of the main criticism from the traditions of workplace research towards design-based research, while experimental researchers question the generalizability of findings across contexts from such studies. Therefore, there exists an inherent tension between the desire for locally applicable knowledge and designs on the hand, and scientifically sound, generalizable findings and theories on the other (Sandoval & Bell, 2004).

The central role of theory development as the key outcome of DBR is increasingly emphasized. However, there are apparent differences of interpretation as to what the theories created should specify: for instance, Edelson (2002) appeared to focus on the role of design theories, which go beyond the specific context to explicate domain theories, design frameworks, and design methodologies. Concurrently, Gravemeijer and Cobb (2006) emphasized the development of applicable theories of learning and teaching. For the research in this dissertation, the focus was on the application of models for collaborative inquiry based on the sociocultural learning theories. Gravemeijer and Cobb explicated two routes for theory development; first, by developing local instructional theories by means of iterative micro- and macro-design cycles, or second, by placing the investigated events and designs in a broader context by framing them as instances, or paradigm cases, of a class of phenomena. The first route requires the possibility to iterate the design in a certain context and come to a deep

understanding of that local learning ecology. The second route entails that the particular characteristics of an investigated learning ecology are examined and translated into theoretical models and tools, vehicles of innovation, that make it possible to identify relations to phenomenon in other learning ecologies. In the present studies, one may argue that the development carried out on the progressive inquiry model and the FLE environment took place in rather similar contexts, which nevertheless, cannot be described as presenting one local ecology, but several, because settings and participating students changed (Studies I and II). Overall, the various settings of the courses studied may be understood as instances of the knowledge-creation approach to learning (Paavola et al., 2004), because the pedagogical models utilized intend to engage students in knowledge creation.

The overall approach has been evolving from initially examining the implementation of progressive inquiry model in three settings (Study I) and later in another setting (Study II) in order to understand elements involved in pedagogical design of progressive inquiry as well as the technological mediation by the FLE environment. In Study I the author was herself also involved in the first iteration as a tutor in the technology-mediated condition (Ic) and as one of the three tutor-teachers in Study II.

After working with the progressive inquiry model, a course on distributed project management arranged together by the Department of Psychology, Helsinki School of Economics and Business Administration, and the Helsinki University of Technology caught our attention because it provided another solution to modeling and structuring collaborative inquiry and a very intriguing set-up for multi-disciplinary teams and cross-fertilization of practices between universities and organization. A possibility to carry out a study in this setting was arranged; this time the author was in the role of the principal researcher. In Study III, the data were used to make a case comparison to the data in Study II. Study IV was carried out to further examine this learning ecology and to expand on themes related to distributed work practices.

Research on a complex phenomenon is not an activity that an individual researcher can conduct in isolation (e.g., Kelly, 2006; Reeves, 2006). The researcher is very dependent on the motivation and engagement of teachers, students, experts and possible customers as well as co-researchers and technology designers and programmers in the design, implementation, reflection, and analysis of the process. Acting simultaneously

as a tutor and a researcher provides a dual role of addressing the data-collection procedures and the tutoring and scaffolding concurrently, which calls for careful prior planning. On one hand, being oneself an active participant in the process naturally enables tracing the pedagogical decision making, interventions, and reflection in detail. On the other hand, the documentation of the process may suffer, due to time pressures and false trust in one's memory. In the role of the researcher, it is possible to contribute particularly to the ongoing educational practices by a) identification and explication of problems facing teachers and participants, b) the creation of prototype solutions based on existing design principles, technologies, and institutional contexts, as well as c) the writing of research-based evaluations of targeted pedagogical and technological interventions.

3.2 Case study

The iterations were carried out as case studies examining a certain learning ecology by employing the methodological practices of such studies. Whereas the research approach of design-based research can describe how the progressive refinement of pedagogical design and theory development took place in iterations, the case studies or multiple case studies research design can explain how the data collection and data analysis have been arranged in each study. The case studies were designed to understand the emerging inquiry practices and to contribute to theory development; as such they exemplify instrumental case studies (Eisenhardt, 1999; Yin, 2003). The case studies, pedagogical models, research questions, and analysis methods are summarized in Table 1.

It is possible to distinguish between a single case designs and multiple case designs. Here the single case study is used to refer to one context, a course, which may nevertheless include investigation of multiple teams, as in Studies II and IV. A multiple case study is here distinguished by the presence of two or three distinct conditions or contexts, which are contrasted in the analysis (respectively in Studies I and III). Therefore, all of the studies may be described as involving embedded designs (Yin, 2003), meaning that the investigation involves contrasting teams and cases within both single case and multiple case study. The theoretical background and prior findings guided the design of the later cases.

Table 1. Studies, pedagogical models, research questions, and analysis methods.

Study	Pedagogical model	Research questions	Analysis methods
I	Progressive inquiry	1. Scale of scaffolding and the nature of knowledge produced 2. Technology-mediation 3. Tutoring	Theory-guided qualitative content analysis; quantifying qualitative data; non-parametric tests; descriptive statistics; descriptive comparisons
II	Progressive inquiry	1. Students' engagement in collaborative inquiry on an authentic task 2. Students' self-evaluations 3. Relationship of observed activities and self-reflections 4. Indications of developing skills for engaging in object-oriented inquiry	Theory-guided qualitative content analysis; quantifying qualitative data; non-parametric tests; descriptive statistics; descriptive comparisons
III	Progressive inquiry Distributed project model	1. Pedagogical design (pedagogical infrastructures) and object-oriented inquiry practices 2. Shared objects 3. Students' self-evaluations	Descriptive statistics; theory-guided qualitative content analysis; descriptive comparisons
IV	Distributed project model	1. Students' learning expectations and outcomes 2. Students' expectations and reports of challenges of virtual and multi-professional teamwork 3. Teams' productions 4. Teams' practices 5. Dealing with open-ended assignment	Data-grounded qualitative content analysis; quantifying qualitative data; descriptive statistics; descriptive comparisons

3.3 Overview of iterations

The methodology in this thesis is design-based research (DBR), also known as design research (cf. Brown, 1992; DBRC, 2003) combined with case study research designs (Yin, 2003). Sandoval and Bell (2003) have suggested that DBR simultaneously pursues the goals of developing effective learning environments and using such environments as natural laboratories to study learning and teaching. This is very descriptive of the process which took place in the cases in Studies I and II: The FLE-environment with the embedded progressive inquiry model was being developed and tried out, analyzed, and the pedagogical practices and technology refined, based on feedback and findings during iterative design cycles and courses (Muukkonen et al., 1999; 2001; Seitamaa-Hakkarainen et al., 2001). The motivation to carry out Studies III and IV stemmed from a desire to understand the implementation of another course which appeared to value similar learning aims, but operated with theories, practices, and tools from distributed virtual work. The relationship of the datasets, number of groups, pedagogical models, and studies is visualized in Figure 3. The two dashed boxes indicate the use of progressive inquiry model as one pedagogical model and the distributed project model as another. The dark dots indicate the number of groups investigated in each data-set. Each of these studies has been run and analyzed as a multiple case study (Studies I and III) or self-standing case (Studies II and IV), but informed by the prior iterations.

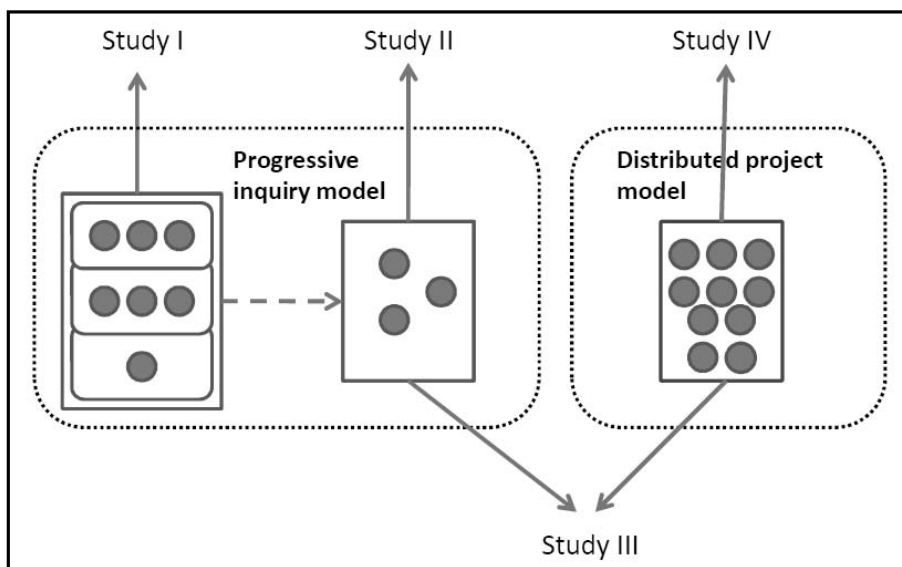


Figure 3. The relationship of datasets, number of groups, pedagogical models, and studies

3.4 Settings and participants

An overview of settings and participants is presented in Table 2.

Table 2. Overview of course settings and participants

Study	Course title	Duration weeks/ hours teaching	N students	N teachers	N tutors	Student study field(s)	N of teams	Virtual tutoring
I a	Psych. of learning and thinking II	15/24	17	1	0	multiple	3	-
I b	Psychology of learning and thinking II	15/24	17	1	3	multiple	3	yes
I c	Perspectives on cognitive psychology in media education	9/24	13	1	0	media education	1	no
II+III	Psychology of modern learning environments	11/24	13	0	3	multiple	3	yes
IV+III	Distributed project management	12/24	47	3	3	technology, engineering, and psychology	10	no

Study I involved three different settings or conditions. In conditions a and b, students took part in the same course; a set of students volunteered to use the Future Learning Environment, FLE, as their collaboration tool (I b technology with tutoring groups) while the rest of the course participants did not use any collaborative technology. A subset of 3 teams was included in the analysis from the latter (I a nontechnology groups). In condition c, students were enrolled to another course given by the same

teacher. Here they also worked in the FLE, but did not get any online tutoring to facilitate their inquiry (I c technology without tutoring group).

Study II involved 3 teams of students collaborating in the FLE environment with tutoring. Study III included the participants from Studies II and IV. Study IV involved 10 teams collaborating in the Optima environment, which did not get team-tailored online tutoring to facilitate their inquiry, but did interact with teachers and facilitators virtually on coordination issues.

Typical of the teams was that they consisted of students with multiple study fields, hence generating a multidisciplinary team environment. Only in condition c of Study I were the students taking part in one study program, media education, but nevertheless they had quite varied backgrounds and work experience. For all other teams, students initially arrived at their courses from multiple study programs.

3.5 Virtual learning environments

The virtual learning environment used in Studies I to III was The Future Learning Environment (FLE). It is an asynchronous groupware system developed by the Media Laboratory, University of Art and Design Helsinki, in collaboration with the Centre for Research on Networked Learning and Knowledge Building at the Department of Psychology, University of Helsinki. It is designed for supporting collaborative knowledge building and progressive inquiry in educational settings. The FLE is an open-source collaborative tool (<http://fle3.uiah.fi>; Leinonen et al., 2003; Muukkonen et al., 1999). The pedagogical model of progressive inquiry is embedded in the FLE design and functionality (Muukkonen et al., 1999). The basic modules of the environment used here were the user's Webtop (virtual desktop) and the Knowledge Building (KB) module. The KB provided a threaded discussion forum and a personal but open space for storing files on the Webtop. Progressive inquiry was promoted by asking a user posting a message to categorize the message by choosing a knowledge type scaffold. These scaffolds correspond to the basic elements of the progressive inquiry model (Problem, Own explanation, Deepening knowledge, Comment, Metacomment, or Summary), in a similar way as in the Knowledge Forum (Scardamalia & Bereiter, 2006).

In Studies III and IV, the main collaboration tool used was a virtual learning

environment called Discendum Optima (see <http://www.discendum.com> and the administrator website <http://www.discendum.com/doc/learning/admininstructions.html>), which is also used in work settings for project work. The Optima environment offers a virtual workspace where it is possible to add editable webpages accessible by the members of the course or project, create hierarchical folder structures, upload files, and use a discussion board. Teachers and facilitators used the system for delivering general instructions and materials of the course and for monitoring teams' progress. The project teams used the system for storing documents, project manager diaries and status reports, and for intra- as well as inter-team communication (e.g., between coordination and project team), and communication with the teachers. The working areas of the teams in Optima were structured according to four categories of project activity: definition, planning, execution, and delivery.

3.6 Data collection

To address the criteria for validity of research, several authors have emphasized the need for multiple data sources, accumulation of evidence and triangulation of data sources and analysis to assess whether the information obtained by the data collection and analysis is trustworthy (e.g., Creswell & Plano Clark, 2007; McKenney, Nieveen, & van den Akker, 2006; Yin, 2003). Designing a data-collection process in a way that captures the variation within actual pedagogical practices is a challenging affair. Some researchers even suggest that it is not possible to specify the details of data collection a priori, because of the emergent nature of complex processes and the importance of observation and interpretation in context (Hoepfl, 1997; Patton, 1990; Engeström, 2008). Furthermore, in DBR, one is tempted to iteratively widen the scope of sources of evidence in order to better capture the various aspects of the learning and teaching processes and interventions taking place. However, McKenney and colleagues (2006) caution that “triangulation of data sources, data collection settings, instruments, or even researchers can be quite robust, but should not be driven by the misconception that more is better” (p. 86).

The data collection sources employed in the four studies are summarized in Table 3. The summary shows that data sources progressively multiplied with each successive study. Study I was based on the comparison of database materials and the learning-logs

and essays. In Studies II and III, the database materials were complemented with the final reports and the self-reflective post course evaluations. In Study IV, pre-course self-reflections and the interviews with students teams and teachers, video-recording of lectures, and team end-scores with justifications were additionally collected. Each successive study was informed by the outcomes of the previous studies and the addition of data sources speaks for the identification of more specific research questions and an aspiration for more in-depth examination of the process from the various viewpoints of the participants. However, it is important to point out that the data-collection was intended to address educational practices at the meso-level, such as the circa 12-week courses from their onset till the end. The focus was not on data-collection at the micro level, e.g., team face-to-face discussion, or at the macro level, e.g., description of institutional practices. However, as Lemke (2001) has pointed out, zooming in and out of the analytical focus and multiple timescales is important in order to reflect on the more systemic and multilayered aspects of practices and learning ecologies.

Table 3. Overview of data collection sources

Study	VLE data base	Learning- logs and essays	Final reports	Self- reflective open questionnaire		Interviews		Video- recorded lectures	Team end- scores
				pre	post	team	teachers		
I a		x							
I b	x								
I c	x								
II+ III	x		x		x				
IV+III	x		x	x	x	x	x	x	x

3.6.1 Database content and documents

The main body of data in each study was collected from the virtual learning environment (VLE) database. This includes the messages posted in the forums of the Future Learning Environment (version 1 in Study Ib and Ic and version 3 in Study II), the messages posted in the Optima environment in Study IV, as well as all the files uploaded in the VLEs by the participants.

3.6.2 Learning-logs and essays

In Study 1, the nontechnology groups (Study Ia) wrote weekly learning-logs and individual essays. These groups were arranged to read and comment on each others' learning-logs. Each student delivered to the teacher 4-5 learning logs and written comments on the learning-logs of two peers. Individual essays were written at the end of the course.

3.6.3 Self-reflective open questionnaires

The students in Study II were asked to answer, by email, an open-ended questionnaire at the end of the course; all students responded to these self-reflections. The questions asked were intended to promote self-reflection on the respondents' participation and the challenges of the knowledge building process, their opinions of the tutoring provided, and their views of this type of course, compared to other seminars they had attended. Last, other comments were prompted.

Study III utilized the data in Studies II and IV.

Students in Study IV were asked to answer open-ended reflective questions after the first two weeks of the course (pre-questionnaire) and after the last session of the course (post-questionnaire). The questions and responses included in the analysis were on personal learning objectives and how they were met as well as their conceptualizations of the central content of the course; i.e., virtual teamwork and multi-professional teamwork. Again, other comments were prompted. In all, 43 students out of 47 students responded to the pre-questionnaire and 44 to the post-questionnaire by e-mail.

3.6.4 Interviews

In Study IV, half-hour team interviews were conducted with teams. The interviews took place mid-way in the course, and 2-4 members were present in each team session. These structured interviews consisted of 7 questions on team functioning and 7 questions on the course content and problem solving process. At the end of the course, an interview with three teachers was conducted. The teachers were asked to describe the construction of the course activity processes and to reflect on critical phases, roles of the participants, content, and the experiences gained from the course.

3.6.5 Video-recorded lectures

In Study IV, about two-thirds of the lectures and technology tutoring sessions of the course were video-recorded to create a record of the types of activities and teaching that took place during the face-to-face sessions.

3.6.6 Team end-scores

Teachers in Study IV evaluated teams' productions and collaboration and gave a score (0-60 points) to each team. These scores and their written justifications were collected.

3.7 Data analysis

3.7.1 Qualitative content analysis

The content analysis in each study was performed with the ATLAS.ti software. In Study I, the purpose of the content analysis (see Chi, 1997) was to examine the type and quality of knowledge produced by the students according to a plausible operationalization of the progressive inquiry model. As a first step, the messages were segmented into propositions, which were considered to address only one idea. In the content analysis, each segment or idea was classified into one of the six developed categories, which were set up as mutually exclusive. Furthermore, to analyze the inter-rater agreement of classification, an independent rater classified 5-30% of ideas produced. The Kappa coefficient for rater agreement (Cohen's Kappa) was calculated.

In Study II, the content analysis of the data was carried out in two discrete processes. First, the database discourse materials were examined to construct a process view of the inquiry regarding the discourse evolution and the knowledge advancement. For the purpose of depicting the discourse evolution, a message was considered a suitably large unit of analysis. To address knowledge advancement, concept definitions and report versions were counted in each of the threads in the FLE environment. Second, the self-reflections were categorized to examine the students' perspectives on the monitoring of individual, collective, and object-oriented aspects of inquiry as well as the tools and course design.

In Study III, first, the pedagogical design of the courses was examined using multiple

data sources, partially reconstructed from the teachers' descriptions, the database structures and materials, and observations. Three researchers analyzed the data together in an explorative way to identify the infrastructures (Lakkala et al., 2008) and to describe the actual implementation of technical, social, epistemological, and cognitive components of the pedagogical infrastructure in the course designs. Second, the number of different types of objects were counted and the role of the objects was examined: the revisions made to different documents and the versioning of reports, presentations, and conceptualizations. Third, the self-reflections were addressed: how the teachers saw the inquiry process and its value, and what the students articulated on commitment to shared efforts, challenges of inquiry, coordination of teamwork, and the development of shared objects.

In Study IV, first data analysis focused on students' self-reflective pre and post questionnaires: they were segmented into ideas. Each idea would address only one category regarding learning expectations and outcomes, and challenges of virtual and multidisciplinary teamwork; the categories were set-up as mutually exclusive. To analyze the inter-rater agreement of classification, an independent rater classified approximately 25% of self-reflection responses. Second, the database materials were sorted into sub-types of assignments, e.g., project proposal or discussion note. Third, team and teacher interviews were transcribed and thematically reviewed.

3.7.2 Non-parametric tests and descriptive statistics

In Study I, the coded ideas were analyzed to obtain a comparative measure of the content of written productions. Cell-specific exact tests (Bergman & El-Khoury, 1987) were performed to examine whether the observed frequencies in each cell (or group) deviated from what could be expected by chance alone. Cell-specific exact tests assume that the observed frequency of a cell in a two-way contingency table follows a hypergeometric distribution. The test utilizes the total sample size to represent the population size, the row total to represent the sample size, and the column total to represent the number of objects in the population of this type. The cell-specific analysis will indicate whether a specific cell frequency is larger or smaller than what could be expected according to an independence model.

4.8 Criteria for quality of research and limitations of the studies

Based on Yin's (2003) work, four criteria for quality of research in social sciences and particularly for case studies can be synthesized: reliability, internal validity, construct validity, and external validity. Yin (2003) relates reliability to demonstrating that the operations of a study can be repeated with the same outcomes, and construct validity to establishing correct operational measures for the concepts being measured. Anfara and colleagues (2002) define internal validity as how trustworthy the conclusions are that are drawn from the data and how well they match with reality. External validity refers to how well conclusions can be generalized to a larger population. Furthermore, Barab and Squire (2004) have argued that usefulness or consequentiality is an essential criterion in determining the significance of the DBR efforts.

Several recurring problematic aspects regarding these criteria have been highlighted in educational literature (e.g., Creswell & Plano Clark, 2007; Burkhardt, 2006; Anfara et al., 2002) and by practical experience. To address reliability, the challenge lies in creating complete documentation of the data, to check for biases in data analysis and in the development of themes and categories. To increase internal validity, prior researchers have urged one to look for convergence of evidence and more robust explication of basis of inference. Construct validity is dependent on the appropriate operationalization of measures, an explicit relationship of research questions and data, a specification of the types of expected changes, and sensitivity to subjective judgments. External validity is enforced by clarity of theoretical propositions, generalizability of findings beyond the context at hand, and replicability of results in the same context. Finally, consequentiality of research has been argued to relate to that research outcomes are made available and meaningful to the decision making in educational practices and policies. However, it has been noted that it is extremely demanding to spell out implications or achieve scalability across various layers of educational practices.

The present studies have examined educational practices in their full complexity in educational settings, but have simultaneously been framed by a limiting set of questions regarding these practices. Reliability of data collection and analysis practices was addressed in the present studies: this included the documentation of data collection procedures and calculation of inter-rater reliability for each data set and categorization separately. In Study I, the reliability of the segmentation was also examined, but for

later studies it was not considered vital because we were using a larger unit of analysis in Study II (a message) and because the volume of the segmented ideas was not used for drawing conclusions on differences between teams in Study IV. Further efforts could have been taken to document the multiple phases of the categorization process.

A central limitation of the present studies from the learning sciences perspective is the lack of specification of types of expected changes; for instance, measures of learning gains as pre and post scores on a certain set of knowledge content. This puts any arguments on achieved learning gains on feeble ground, which has been acknowledged throughout the studies. The nature of the intended creative activities makes the research more explorative and focused on the processes and the practices around development of objects.

The analysis of Study I only addressed the written productions of students, which narrows the perspective of the entire process rather tightly, but allows tracing object-centered inquiry processes. The subsequent studies (II-IV) similarly employed the database as the principal data source, but also included additional data sources: students' self-reports, team and teacher interviews, video materials, and teachers' team evaluations and end scores to gain a thicker description of the knowledge practices investigated. These reflect the methodological challenge of construct validity: which sources and types of evidence to select, and how to construct a chain of evidence regarding the advancement of collaborative inquiry. As the student teams were not followed in their face-to-face meetings, the studies cannot provide evidence on the micro-level dimensions of knowledge-creating inquiry practices. However, the types, nature, and evolution of the shared objects as they were portrayed by the database discourses were evidenced and the corroboration of evidence from different participants, types of data, and methods of data collection was realized (cf. Creswell & Plano Clark, 2007).

Regarding the internal and external validity of the studies, it is noticeable that being able to rely of the theoretical postulations of the progressive inquiry model has aided the methodological decision making. It has provided a model to test for patterns in discourse, reiteration of version of inquiry practices, and cumulative explanation building on object-centered activities. The use of the distributed project model, on the other hand, generated alternative explanations and complementary patterns of activities

stemming from a distinctly different type of knowledge creating inquiry practices.

The question of consequentiality is perhaps the most difficult: the studies have attempted to document course design and pedagogical decision-making, as well as to address implications also beyond the meso level of analysis adopted here. Discussions with the involved teachers and researchers have been a standard practice, but this consultation has not included checking with the students after the courses, due to practical limitations. The concluding sections will further elaborate on the issues of consequentiality.

4 Results

4.1 Study I

The objective of Study I was to explore pedagogical practices defined by the progressive inquiry model, tutoring and technology mediation. We investigated their influence in directing students' efforts into taking responsibility for self-regulative processes that enhance commitment to inquiry and facilitate deepening their inquiry processes. The analysis was carried out on the written productions (learning-logs and essays) of the nontechnology groups and messages in the virtual learning environment (Future Learning Environment, FLE version 1) of the technology groups.

First, a qualitative content analysis was conducted to find out how the scale of scaffolding (none, technology, technology and tutoring) related to the nature of knowledge produced by students. It was expected that the discourse profiles of the conditions would reflect the scale of scaffolding provided and that more support would result in more versatile discourse with attention to all aspects of the inquiry model.

Reviewing the results (Table 4), the scale of scaffolding was found partly to relate to the nature of knowledge produced; scaffolding by technology appears to have supported the practices of problem-setting and metareflection. The learning-logs condition (LLog groups) was set apart particularly by a lower proportion of problems, a higher proportion of own explanations, and a lower proportion of metacomments and quotes/references. Overall, we had expected to discover more focus on presenting and debating the theoretical content of the courses in an academic style.

Examination of the results of the content analysis revealed that the profiles of the two technology-mediated conditions, tutored (FLE1-3) and nontutored (FLE-4), were surprisingly similar. Immersion in the data, however, had led us to suspect that the level of analysis may not have reached qualities related to the process and its depth. Therefore, a more descriptive examination of the progression of discourses was carried out with two comparisons, which addressed, first, the role of technology-mediation, and second, the role of tutoring in fostering practices of deepening the question–explanation process, developing ideas collectively, and self-reflection.

Table 4. Frequencies for categories of ideas and results of cell-specific tests

Group	Idea Category					Total
	Problem	Own Explanation	Source-Based Explanation	Metacomment	Quote/Reference	
LLog-1	51 ^a	417 ^b	53	82	18 ^a	621
LLog-2	110 ^a	534 ^b	134 ^b	62 ^a	45 ^a	885
LLog-3	51	264 ^b	33	26 ^a	13 ^a	387
FLE-1	64	123 ^a	78 ^b	55	14	334
FLE-2	139 ^b	267 ^a	51	89	63	609
FLE-3	85	167 ^a	11 ^a	79 ^b	68 ^b	410
FLE-4	126 ^b	192 ^a	31 ^a	66	80 ^b	495
Total	626	1,964	391	459	301	3,741

Note. Significance tests are based on hypergeometric probability estimates (see Bergman & El-Khoury, 1987). LLog = learning-log; FLE = Future Learning Environment.

^aObserved frequency smaller than expected ($p < .001$). ^bObserved frequency larger than expected ($p < .001$).

To investigate how technology-mediation influences inquiry processes, a descriptive comparison between the nontechnology and tutored-technology conditions was conducted; here students were in the same course. It suggested that technology-mediation with tutoring had supported the practices of stating research problems, evaluating the progression of inquiry, metareflection, and developing ideas in collaboration. By contrast, in the inquiry processes of the learning-log (nontechnology) groups that we examined, no evidence for the practice of building on each other's ideas was found, despite the commenting process carried out. On the other hand, the nontechnology groups concentrated relatively more on understanding and presenting the theoretical content of the course. The technology-mediation was interpreted to provide affordances for turning attention to collective efforts by enabling to establish practices of monitoring joint advancement and building on each other's ideas available in the web-based environment.

Finally, the role of tutoring in the progression of technology-mediated inquiry was examined. A comparison between tutored-technology groups and the nontutored-technology group was carried out to gain an understanding whether and how tutors did promote knowledge creating inquiry and reflection in the FLE. In practice, tutors were guiding the students to return to earlier questions, ideas, and theories and to readdress them. As evidence for the tutors' role, the process analysis recovered a more focused problem-setting tendency in tutored groups: instead of opening up new lines of

questions, the tutored groups were more likely to present subordinate questions to previous ones.

In light of assessing the Progressive Inquiry model and its applicability, the model appears to have provided a heuristic framework for the students to engage in a predominantly self-directed question–explanation process. There was an intriguing difference between the conditions in respect of mediated, object-oriented inquiry. Students of the non-technology groups who commented on their fellow students’ learning-logs appeared to evaluate, from an external perspective, the quality of the other student’s inquiry as a whole—without engaging in dialogue with the ideas articulated. They commented on ready-made contributions without extending the ideas involved or continuing the line of inquiry in question. The participants of the two technology conditions, in contrast, appeared to have engaged in discourse with ideas developed by their fellow students. Thus, the implementation of the progressive inquiry model together with corresponding technological support apparently helped to bring about a process involving extended discussion on shared ideas. In terms of lessons learned for a next iteration, it appeared important to attempt to further strengthen this mechanism by introducing a formal shared outcome of the process, such as a final report, which would direct the student groups’ inquiry efforts towards summarizing and reflecting on their knowledge advancement. Further emphasis should be given to scaffolding practices of academic literacy, including exploitation and evaluation of knowledge sources to support working with theoretical knowledge and concepts. In addition, the tutors were never face to face with the students, nor did they follow the lectures. In hindsight, it would likely have been easier to provide guidance had the tutors been more aware of what took place during the lectures; perhaps they could have better facilitated the social aspects of collaboration.

4.2 Study II

This Study reports a course in cognitive psychology that was designed according to the pedagogical model of progressive inquiry. This course was designed following experiences from the prior courses presented in Study I (see details in Lakkala et al., 2008). Changes in design, in particular, were that teams were able to view each others’ forums, they produced final reports in teams and lecturing was minimized and

substituted by face-to-face and virtual tutoring. Students' work was organized with the aim of promoting a deepening process of creating challenging research questions collaboratively, formulating initial explanations, and producing elaborated explanations with the support of knowledge sources. Their inquiry process was represented in the final reports. Three tutors provided support and guidance for the process. Progressive inquiry was modeled in the activities taking place during the weekly seminar meetings and embedded also in the virtual learning environment used: the Future Learning Environment, versio 3 (FLE3).

The first goal of the research related to exploring collective inquiry practices and their monitoring. The database materials were used to gain a description of working practices on shared knowledge objects and artifacts. A further goal was to consider what kinds of skills such collaboration on complex questions and practices required, pertaining, simultaneously, to the individual, collective, and object-oriented aspects of monitoring inquiry. A great majority of studies on regulation of inquiry have taken place in controlled settings within short time spans (see Lin, Schwarz, & Hatano, 2005), because otherwise it is extremely difficult to capture the elusive and relational executive processes regarding collective inquiry. In this study, the aim was not to examine the executive processes as such, but to seek for their traces in students' written productions, especially what kinds of inquiry practices the teams developed, how they coordinated their collaboration, and what kinds of issues they raised as central or challenging in the post-course self-reflections. The traces were expected to inform us about how student groups negotiated and reflected on the challenges of co-orchestrating their work, collective knowledge advancement, and co-authoring their final reports. Further, the study asked how students themselves perceive their commitment and ability to take part in collaborative knowledge creation, as evidenced in the students' responses to a post-course open questionnaire. The expectation was that it would involve perceiving the value in committing to work on shared objects and engaging in building on each other's ideas. Therefore, two complementary angles to the inquiry process were taken: how the database materials portray the inquiry practices and how the participating students reflect on them.

First, analysis of the discourse evolution and knowledge advancement provided evidence on varying practices of inquiry. In Group A, the seminar report was

constructed with very little collaborative interaction and could be described as a product of three individual inquiries. In Group B, the members did collaborate significantly more in order to advance their understanding of the research questions they had produced. However, in Group C, this collaboration was equally observed, but it had a distinct quality: students produced more conceptual definitions, debated their conceptual understanding, and also, importantly, versioned their work more than did the other groups.

Second, students' self-reflections yielded evidence that, in every group, students emphasized the importance of their own efforts, that this was a new way of studying for them, which required more initiative and responsibility, and that they would need more practice to get better at it. In general, the students portrayed the collective and object-oriented aspects of inquiry as both rewarding and demanding. A number of students wrote that scientific argumentation was difficult, but that the model provided by older students and tutors was valuable since it had provided concrete examples and strategies for scientific presentation of one's arguments.

Third, the observed activity of student-groups and their self-reflections were addressed in parallel. It revealed that when the analysis suggested that the students did not engage in a collective process or iterate the shared object, the students wrote about issues of commitment and only individual aspects of inquiry (in Group A). Further, when the database analysis suggested that the group did engage in discussing and explication of ideas but not in a further revision or elaboration, the students reflected on the coordination challenge and only secondarily on the knowledge creation challenge (in Group B). With the third group (Group C), when the database analysis suggested a collaborative knowledge-creation process, the students reflected comparatively less on the individual aspects of monitoring inquiry. Although they concentrated on the collective and object-oriented aspects of inquiry, they were also relatively self-critical about the process.

The activities of Group C provided indications of developing skills which deal particularly with engagement in object-oriented aspects of inquiry. This evidence is indirect and not based on assessment of any particular skills, but nevertheless appears relevant for the present argument. Group C actively monitored and took charge of insuring that the discourse was directed at addressing the research questions, asked for

more explanations on unclear issues from each other and the tutors, and evaluated the obstacles in their questions-explanation process. Further, they introduced procedures to increase awareness of each others' activities and practices for coauthoring the report.

The findings suggested that, particularly for younger students, knowledge-creating inquiry was a novel experience and required competencies not previously called for in their undergraduate studies. Especially in Groups A and B, we encountered difficulties in finding ways to direct the inquiry toward advancing the shared object. Apparently, there was not robust enough scaffolding to support engagement in the new practices: providing templates and models of expected outcomes might have provided additional facilitation. The examination of course from Study II was further pursued in Study III.

4.3 Study III

The aim of the study was to undertake a multiple case study to reflect on how object-oriented inquiry is implemented in educational practice. In comparison to the other studies, Study III was oriented to the investigation of the pedagogical design of the two educational practices examined, whereas the other studies focus more on the collaboration processes. The research was carried on two cases assumed to foster object-oriented collaborative inquiry. The research questions focused on how the implementation of the pedagogical design of the courses represented object-oriented inquiry practices, what kinds of knowledge objects the students were creating in the virtual learning environments, and how the students evaluated their experience of participation in the inquiry processes. Both cases presented the students with open-ended tasks, a small group composition (teams of 3-5 students) for collaboration with student having multiple domain backgrounds, and a final report student groups were to create together in a timeframe of 3 months. Although these aspects of pedagogical design were similar, there were a number of aspects that made the courses different, and therefore interesting to compare. In the first case we tried to model research practices which rely on deepening question-explanation processes, whereas the second case was focusing on modeling distributed, virtual work, and involved customers.

The first case was an undergraduate course in cognitive psychology (introduced in Study II) that was designed according to the pedagogical model of progressive inquiry. The students were guided to form their own questions about the phenomena and create

their intuitive working theories as initial explanations to answer their questions. These stages were undertaken before using authoritative information sources, to challenge the students' own thinking. The students obtained new information by exploiting various information sources after having together evaluated the ideas and explanations. The tutors facilitated the process by explicitly structuring the activities of the course with the model of progressive inquiry and by scaffolding deepening cycles of formulating subordinate study questions and more elaborated theories and knowledge products.

The second case was an undergraduate course on distributed project management (a prior year has been reported in Marttiin et al., 2004). As further detailed in Study IV, the whole study process was organized as a virtual project management process aiming at creating, in expert teams, innovative problem solutions for a genuine client. The goal of the course was to get students acquainted with the theories, methods, and practices of organizing distributed work by participating themselves in a virtual teamwork process and conducting a study for the customer organizations. These teachers had several years of experience in iterating the design of their course and making changes based on feedback.

The examination of the two cases provided evidence for two different ways of facilitating object-oriented inquiry, examined in terms of the technical, social, epistemological, and cognitive components of a pedagogical infrastructure (Lakkala et al., 2008). In the first case, the goal was to model the knowledge practices of scientific inquiry resembling the work of a research group. The shared object the groups worked on were particularly the research problems, explication of theoretical concepts, process reflections, and partially the reports. In the second case, the goal was to simulate the activities and challenges of virtual project management work, with authentic clients participating. The shared objects for the teams were the team flyers, project proposals and plans, and final reports with presentations. The analysis of the development of objects showed considerable variation between teams in both cases in regard of the revisions made to different documents and the versioning of reports, presentations, and conceptualizations. It is important to note that the amount of revisions as such is not an indicator of a more productive collaboration, because the versions may involve only very minor revisions. It can, however, tell roughly about the extent of participation and the intent of elaborating more advanced objects. The way that second case was

organized appears to have promoted a more concrete focus on creating versions of their documents as the students mainly collaborated virtually, together with the pressure of producing outcomes for the clients. Further, the facilitation provided by the teachers in the two cases had differing roles: in the first case the tutors focused on scaffolding the deepening of the inquiry process, in the second case, the teachers' scaffolding was evidenced in the documentation templates provided, which were stemming from professional practices of virtual teamwork.

The evidence suggests that the teachers had taken a number of steps to provide structure and to model the advancement of the inquiry process or project, and the overall pedagogical designs were considered aligned with the goals of each course. However, the analysis of the two cases suggested that being taken to a motivating course with new practices and models for collaboration was indeed a challenging situation for most students. It appears to have created a contradiction in terms of their expectations about a learning situation in higher education course; student teams were asked to define themselves a large part of the content to study, to manage the teamwork in collaboration, and to produce solutions to complex problems, each presenting practices that they were not accustomed to in their prior studies. The students perceived it as confusing and conflictual to work in the new manner, initially, but generally acknowledged the importance of such experience towards the end of the course.

4.4 Study IV

A course on virtual project management was organized as a distributed project management process aiming at creating, in expert teams, innovative problem solutions for two customers. In light of the entirety of the thesis work, the involvement of the customers as well as the multidisciplinary team work opened the possibility to examine knowledge practices of distributed project work in addition to those of scientific communities addressed previously. The teachers emphasized that the engine of the entire process lay in the introduction of the customers' problem: determine the future possibilities and challenges of a broadcasting company in offering digital-TV services for people as workers, learners, citizens, and consumers or "Digi-human". The customers hoped to see 100 ideas not published before nationally with a 2-year and a 10-year outlook. The teachers explained that in a best case scenario, the authenticity of

the problem feeds into motivation, own interpretations, passion for solving the problem as a team, agency and ownership of generated solutions, responsibility over carrying out the project, and enculturation to professional practices.

The outcome of each of the project team's work was a report and a presentation to the customer, which together described the team's solution; for example, "The future of music business – challenges and opportunities" in team 5. One team was the coordination team and another the research team with different responsibilities. Three teachers and 3 tutors took part in the course as facilitators of students' work; metaphorically they were introduced as the board of directors, not directly involved in the execution of tasks.

The design of the four activity processes of the course consisted of customer activation taking place prior to course onset, course build-up involving the introduction of customers' assignment and team formation, activity management and team work, and the presentation of outcomes to the customers. Each process was based on sub-processes, management control, and a common communication infrastructure. The model was intended to offer the teams explicit structural support for the work process but to leave intra-team communication and knowledge-related activities floating, thus requiring genuine commitment and self-organization.

The first research objective was to examine whether the course could simulate the professional practices of members of distributed virtual team on development of knowledge objects. The results revealed that the concrete experience expanded students' conceptions about various aspects of managing collective activities: communication skills and means, planning and organizing activities, and the importance of participation and trust. Similar aspects have been identified in literature characterizing distributed teamwork relating particularly to team processes (reviewed by Bosch-Sijtsema, Ruohomäki, & Vartiainen, 2009), which suggests that a high degree of authenticity of teamwork practices –and challenges– was achieved by the course design. Other aspects mentioned by Bosch-Sijtsema and colleagues, such as time on tasks, team structure, workspaces, and organizational context were addressed to a lesser degree, presumably because they were predefined by the course design itself (relating to team structure and time on task) or they were not applicable to the tasks at hand in educational context (relating to the particulars of an organizational context).

The second research objective was to examine the knowledge creation challenge: the customers' assignment, together with the course design, presented a strong challenge for the teams to find solutions in a self-organized manner. We witnessed in the pre-questionnaire and the mid-course team interviews that students were quite confused and anxious about how they should proceed. In the post-questionnaires, the students regarded the course as instructive on project management and many of the positive ratings reflected satisfaction with pulling through a very challenging project in teams and devising practices for intra-team communication. Many of the negative or mixed ratings pointed to a lack of guidance and unclarity of the learning goals, which the students attributed to the course design. Importantly, the teams produced solutions that the teachers considered above satisfactory and also gained the full attention of the customers.

Overall, the students mentioned challenges: overcoming a sense of frustration and confusion; trusting a project that they could not understand fully in the beginning; managing a culturally-diversified team; and devising practices for co-authoring and advancing their reports. It can be hypothesized that finding a common understanding about the form of the presentation and report (the shared object) led to some decrease in confusion. Another explanation is that the course work was constructed so that there were, at regular intervals, small deadlines for project deliverables (e.g., project plans and team flyers), and the teams could feel to progress by accomplishing these. Contrary to findings from Study II, younger students were not observed to experience any additional problems with the inquiry process.

A comparison of how the teachers described the course objective and how the students approached it, generated a discrepancy worthy of note. The teachers addressed the objective as a distributed virtual project work, which was the content of the course and which they supported through the project model, templates, explicit phases, and deadlines to facilitate focusing of inquiry. It appears, however, that for the students, the primary objective was to meet the knowledge creation challenge, that is, to create innovative ideas and present them to the customers. While it is easy to acknowledge that these practices are intertwined, it is suggested that their facilitation may be offered by various means: the first predominantly pragmatic or structural (how to coordinate activities, how to manage teamwork, how to present outcomes of team work?) and the

latter epistemic (how the generate questions, how to explore knowledge sources, how to collaboratively advance ideas?). The lower level of epistemic support could partially explain the strong confusion that the students experienced facing the knowledge-creation challenge. This type of epistemic support for collaborative knowledge advancement is not very commonly available at workplaces either, although various types of idea generation techniques and company templates are widely used. In future, the course design could be enriched by explicitly modeling and scaffolding the epistemological advancement and concrete strategies of inquiry.

5 Discussion

5.1 Collaborative practices for knowledge creating inquiry

The present dissertation examined, first, *how collaborative knowledge creating inquiry took place in the examined courses*. Counted together, the processes and productions of 20 teams were analyzed in detail. The studies provided evidence for various practices in collaborative inquiry. One way to prototypically summarize them is that the teams showed three types of engagement. In the first type, within the frames of the collaboration assignment, the students would nevertheless pursue individual inquiries and only superficially construct shared products (parallel individual inquiry). Second, teams would engage in collaboration by dialogical interaction, debate, and as well as creation of written explanations, questions, and solutions as they were initially proposed and after being enriched by the dialogues (discourse-centered inquiry). The third type of engagement would further advance these outcomes—revisions of questions, tentative solutions—and re-iterate them, by means of building on ideas of peers, written and oral comments, revisions, and new versions, and hence, clearly undertake a triologic or object-centered approach to advancing their understanding (object-centered inquiry). The second type of engagement appears to have been most frequent, although in each study, the first and the third type of engagement were also found.

Several explanations for the common lack of deeper types of engagement have been advanced by previous investigators, to which the author adds her own reflections. First, although their research addresses preparation for exams, the conclusions from Broekkamp and van Hout-Wolters (2007) hold value for all types of education: as long as students are able to perform successfully with routine strategies, they are unlikely to experiment with new types of strategies or approaches to learning or do so in very superficial ways. Naturally, a further question to ask is, What were the routine strategies for students prior to the examined courses; this matter is a concern for further research, since it was not measured in the present studies. That said, students' self-reflections in Studies II-IV and summaries in Study I provided evidence that, in all studies, students were clearly taken out of their comfort zone by asking them to engage in collaborative inquiry around complex problems and tasks. Few teams appear to have failed in creating a functioning collaboration or persisted in giving priority to individual forms of

engagement. In prior research, reasons for failure have been attributed to social and motivational challenges of collaboration, such as conflicting goals, lack of commitment, problems in time management and coordination, not reaching reciprocal understanding, or personal conflicts (e.g., Damsa et al., 2010; Järvenoja & Järvelä, 2009; Mäkitalo et al., 2002). Study II of the present work suggested that the younger students had more difficulties in engagement in knowledge creating inquiry, but the findings from Study IV did not corroborate this position. Yet, it appears that prior experience in the knowledge practices of complex inquiry may nevertheless be an important factor, one deserving further investigation.

The second type of engagement, discourse-centered inquiry, appears to have been most familiar to students; this type of dialogic inquiry takes place in all types of interaction, including school and informal collaboration. Naturally, there are highly important skills of communication, argumentation, and explication to be mastered as part of the discourse-centered inquiry. Making a clear distinction here between technology-mediated discourse-centered practices and object-centered practices of collaborative inquiry is not always straightforward. However, the findings from Study II on the importance of emphasizing collective commitment and goals beyond individual commitment and advancement, appear to provide one basis for a distinction between the two. The latter practices focus on the versioning and elaboration of the central knowledge objects (as examined in Studies II-IV). In assessing these two levels of inquiry process one asks, do teams show efforts to explain central concepts, ideas, plans, and designs; do they comment on each others' ideas and writings; and does the commenting process generate new versions of objects. Overall, important indicators of the object-centered inquiry appear to be whether new versions of knowledge objects and artifacts demonstrate a deepening inquiry process and whether the various productions contain a significant, cumulative and intentional contribution from team members.

The types of shared objects the students created were to a high degree related to the course designs and instructors' choices. In Study 1 the shared objects were the discussions forum discourses, whereas in the other studies, instructions to create a team's final report laid out the objectives for collaboration. Students who were scaffolded by the progressive inquiry model clearly employed the elements of the model to specify both their own and prior research -grounded research questions and

explanations. Human tutoring was associated with more versatile use of the elements of the progressive inquiry model as evidenced in Study I. Study III examined two types of educational practices that were designed, with an emphasis on producing final reports representing teams' outcomes. Both were concluded to have concretely set the focus of collaboration on creating and improving these knowledge objects. In Study IV, scaffolding the authoring of team productions took the form of providing templates for written productions. All teams used these templates and modified and extended them by their own inquiry.

In Study I, the comparison of the technology-mediated and non-technology groups provided evidence for the influence of technology mediation. Problem-setting, meta-reflection, and collaborative development of ideas were encountered comparatively more often in the technology groups. The non-technology groups were mostly conducting individual inquiries; these, however, at times reached depths not attained by the technology-mediated groups. These findings appear to highlight the need to further define how to plan, phase, and scaffold overlapping individual and collaborative activities in technology-mediated collaborative inquiry in order to facilitate deepening of inquiry.

The second research question of the dissertation asked *how the participating students reflected on their inquiry practices*. Study II approached this question by examining students' post-course self-reflections. Novel challenges were evoked by the inquiry process: collective commitment, involvement in the development of knowledge objects (e.g., which concepts to explain, how to deepen inquiry into certain questions, how to engage all members in the efforts, and how to maintain awareness on progress), dealing with the confusion of having to frame the groups own research questions, how and where to find reference materials and resources, and the iterative nature of improving the report by versioning and commenting.

Study IV examined students' perceptions of the knowledge creating inquiry process. The experience of taking part in the teamwork was observed to relate to a change in the direction of emphasizing the interpersonal and mediated aspects of collaboration in place of individual skills and time management, as well as the need to create common working practices and goals. Apparently, the push for collaborative inquiry had worked in the sense that students reported being faced by the intersubjective and object-centered

challenges of inquiry: overcoming a sense of frustration and confusion; trusting a project that they could not understand fully in the beginning; managing a culturally diverse team; and devising practices for co-authoring and advancing their reports.

To summarize, on the evidence, the challenges encountered in students' self-reflections relate to various aims of knowledge creating inquiry. First, they related to emotional, motivational and pragmatic aims of founding a collective commitment, practically initiating and upholding collaboration, (re)negotiating the goals of collaboration, and agreeing on what to produce concretely. Further, they related to epistemic and reflective aims: defining and working with complex problems, searching for resources, experimenting with strategies for iterative knowledge advancement, and collectively examining the steps taken, resources, and obstacles encountered in the inquiry process. Mahn and John-Steiner (2002) as well as Packer and Goicoechea (2000), consistent with our findings, have suggested similarly that collective creativity is not just an intellectual or epistemic matter but a socio-emotional and existential achievement as well. The existential achievement relates to taking part in a process not understood initially, learning to cope with feelings of uncertainty and dealing with complexity.

The third question asked *how does one facilitate knowledge creation and technology-mediated inquiry*. The two pedagogical models, progressive inquiry and distributed virtual project, were shown in Study III to have a strong influence in both cases on how the teachers set up the collaboration environments and which types of activities were central for the learning collective in the database. The involvement of the customers in Studies III and IV was observed to provide a strong incentive for teams. The progressive inquiry model together with the tutoring and technology appeared to provide robust support for focusing on the practices embedded in the elements, i.e., setting up research questions, explaining initial understanding, and searching for deepening knowledge, and refocusing inquiry. The distributed project model did not explicate such epistemic strategies for engaging collaboratively in an inquiry process but focused on the communication structures, roles of the participants, aims of collaboration, and setting phases for tasks more explicitly. An important role was also played by the templates and reading materials the teachers provided for the development of team introductions, project plans, reports, and presentations for the customers. To be

precise, neither model specified the role of shared knowledge objects, although the pedagogical design of both courses clearly set up that task, and tutors facilitated its development either by guidance or by templates. Otherwise, the models seem to complement each other in the types of epistemic and structural support they offered. Specification of the role of the shared knowledge objects, and the various dimensions of support deserves further attention in pedagogical modeling of knowledge creating inquiry.

As evidence for the tutors' role, Study I suggested that the virtual tutoring had some role in scaffolding the students in moving toward an iterative and deepening inquiry process. The data analysis recovered a more focused problem-setting tendency in tutored groups. Instead of opening up new lines of questions, the tutored groups were more likely to present subordinate questions to previous ones (cf. Hintikka, 1999). In Study II, the face-to-face tutoring had a central role in the scaffolding of the progressive inquiry process. The students valued the engagement of three tutors because it provided an example of expert argumentation with complementary and even contesting views. They also expressed a wish for more explicit structures of inquiry process and templates for reports. In Study IV, the scaffolding was provided principally in the form of the templates for team productions. These students also expressed a need for more guidance on defining the goals of collaboration. It appears that providing team-specific guidance, expert models of scientific and professional argumentation and work practices, and templates for the intended products are ways of enhancing inquiry processes.

In the initial steps of the dissertation work, the role of technology itself was more prominent. The present view may be synthesized by proposing that a meaningful appropriation of collaborative technology entails development of knowledge practices which guide and channel participants particularly around the development of knowledge objects and related practices. The FLE environment supported the sharing of the inquiry discourse and knowledge artefacts throughout the course, both during meetings and distance periods. In the course using the Optima environment, technology tools were in a crucial role in sharing all activities and artefacts because the student teams worked, in large part, virtually. From the point of view of object-oriented inquiry, however, these tools did not concretely enable the co-authoring of common digital artefacts, nor the visualizing, monitoring, and reflecting on the advancements in inquiry due to the

threaded or hierarchical structuring of the environment.

The appropriation of a technology into a team's or a course's collective practices is not a straightforward implementation process, but rather a reciprocally interactive process in which tools provide more or less targeted facilitation for intended practices and innovative practices are created in order to make better use of novel possibilities provided by technologies (cf., Tuomi, 2002; Hakkarainen, 2009). It is the types of social practices that a targeted educational experience calls for that render specific tools valuable (or not) for that purpose. It is, however, possible to distinguish between a tool that provides specialized affordances for a particular activity, for instance social interaction, web-publishing, concept mapping, or co-authoring, and a modular set of tools and functionality that can be customized and integrated within one platform (e.g., Knowledge Practices Environment, KPE, Lakkala et al, 2009).

5.2 Methodological implications

The methodologies for design-based research have been criticized for a lack of methodological rigor, vague units of analysis, predefined interventions, and a variable-centered data analysis overemphasizing causality (Engeström, 2008). The solution adopted here of combining case study and DBR approach, although not promising more rigor, nevertheless suggests one way of combining intensive case study with a focus on iterative improvement of practices and designs in relation to learning theories. Iteration offers a way of specifying design challenges, new research questions, and exploring alternative solutions. However, iterations may take such novel focus, due to context or practices examined, that it is difficult to apply prior questionnaires or data analysis schemes. This introduces the risk of losing a connection between the iterations because one is not able to compare observations at the level of raw or categorized data. Nonetheless, a pronounced revision of research objectives and search for alternative explanations is justified as long as the logic of revisions in relation to a learning theory is explicated.

Consequentiality is an important issue to be upheld: further efforts are needed to involve key informants and colleagues in review of results and inferences, and further develop and apply models of knowledge creating inquiry. Overall, interaction between research, educational professionals, and policymaking instances ought to be intensified.

It is needed to ensure translation of research findings to societal implications and to facilitate further elaboration of research questions and programs based on central questions in education practices and policymaking.

Further accumulation of case studies, as well as meta-analysis aggregating findings from current research publications, appears crucial to address the strength of the conclusions. Evidently, any meta-analysis based on effect sizes is not able to address findings from qualitative research. As argued in the methods section, generalization to theory can be employed as an alternative route. However, an abundance of theoretical frameworks is available alone on collaborative inquiry learning (see for instance Säljö, 2009 and Alexander, Schallert, and Reynolds 2009 for related discussion on fragmentation of theoretical perspectives on learning). Therefore, in addition to generalization to theory, ideas for ways to aggregate findings from qualitative studies employing various frameworks are called for. One possible solution lies in developing ‘indicators of inquiry’, which draw on the qualitative and quantitative aspects of inquiry processes and embrace context-generic aspects of advancing collaborative inquiry in addition to the content-related aspects. Examining the deepening of inquiry based on a manual analysis of content knowledge is, however, very laborious, because of the non-predefined nature of the inquiry outcomes within such knowledge creating inquiry settings. Another solution may be offered by novel technological solutions, i.e., developing analytical tools that are able to offer visualizations or statistics of database contents related to key steps in inquiry processes and knowledge advancement (cf. de Laat et al., 2007; Nurmela et al., 2003; Markauskaite & Reimann, 2008; Richter et al, 2010). These can be used to examine, for example, participants’ contributions to the production of knowledge objects, use of key concepts and their relationships to other concepts, and versioning and commenting processes.

5.3 Pedagogical implications

Perhaps the strongest argument of this dissertation having pedagogical implications is that collective creativity is something that can be learned and taught by engagement in social practices designed to structure collaboration around the development of knowledge objects. However, as Scardamalia & Bereiter (2005) have pointed out, there is still “a long way to go, from simulating an emergent process to designing ways to

supporting, improving, or trouble-shooting the process” (p. 25). The analytic framework of the studies has enabled, principally, observation of the emergent processes, although the pedagogical modeling and tutoring have been used to provide support for the processes. Besides advancing pedagogical design for knowledge creating inquiry, it is also worthwhile to ask to What are the realistic expectations that any single course can accomplish through an intervention to promote knowledge creation competencies. What would be a sufficient number of courses during a master’s program? These questions could be addressed at the curriculum-level pedagogical design and empirically by following students with various educational experiences longitudinally across their studies and into professional practices. However, the author would recommend that one introduce inquiry on complex problems from the first year on and include a minimum of two multidisciplinary inquiry processes in any given degree program. Processes could base on the work of students from prior year courses, for example by continuing in the same database, having older students involved in tutoring or coordination, or extending issues examined in prior iterations of courses.

Some more practical pedagogical implications of the present studies are discussed, next, very specifically from the point of view of advancing shared knowledge objects and related knowledge practices. The first issue deals with how the learning community comes to define its knowledge objects. The present work has argued that an explicit emphasis should be placed on that efforts are directed at advancing shared objects, rather than just individually carried-out tasks or discussions. The foundation is set by a collective incentive, a motivation to engage in an inquiry that cannot be pulled together without the input from each participant. A form of structural modeling is needed to scaffold team collaboration practices: such modeling should explain, for instance, how does interaction take place, who is expected to do what, and how is responsibility distributed. A form of epistemic modeling is needed to explicate intended practices for knowledge advancement, for instance, what are we creating and what kinds of inquiry steps are involved. The overall challenge is to set up social practices which spell out collaborative orchestration of individual efforts in relation to joint practices. Initiation of teamwork may be facilitated by face-to-face sessions. Sufficient time and possibly organized activities can support teams in their initial brainstorming sessions. A set of smaller deadlines throughout the process is useful for teams’ productions, so as not to

leave time for procrastination in the beginning phases and to trigger team interaction.

The second issue relates to epistemic advancement: Scardamalia and Bereiter (2005) have pointed out that a challenge for teacher is to prevent a premature settling of ideas and to promote a self-organizing process where idea improvement is central. The role of questions in guiding a self-directed inquiry is highlighted by the progressive inquiry model: it presents the elements of a deepening question-explanation process. The practices observed in relation to distributed project emphasized the importance of well-timed expert explanations, templates from professional practices, and reference materials to model expert practice and thinking.

The third issue addresses collaborative monitoring of inquiry. Monitoring the individual, collective and object-oriented aspects of collaboration and knowledge advancement calls for multilayered skills. Monitoring and awareness may be modeled and supported by multiple forms of facilitation, such as technological, conceptual, or practical. Examples of technological facilitation are various awareness features depicting participants' activities and development of artifacts. Conceptual facilitation may be provided by explicitly modeling elements in inquiry, engaging participants in discussion which involve reflection on these elements, thus inviting explication of experiences and understanding, and providing further reference materials. Practical facilitation may involve asking participants to examine their collaboration means and practices, and jointly consider possible improvements: deepening of inquiry, understanding of the central concepts and theories, and managing and coordinating a collaboration process warrant equal importance in regulation.

Fourth, in knowledge creating inquiry, reflection on learning – as well as evaluation of learning – is intended to focus on the examination of artifacts, social practices, and processes (i.e. shared objects) representing advancements in knowledge, rather than just the improvement of personal understanding or social interaction as such. Self-evaluation and reflection throughout the process benefit from expert modeling and structuring to focus on collective knowledge advancement.

Finally, the integration of new software applications and tools in pedagogical practice presents, currently, a major dilemma: all types of new tools are available, but they are rarely supported by the university administration. On the one hand, it is motivating to try out new applications, but on the other hand, without sufficient

technical support, the problems of access, compatibility, licensing, and security are left to the instructor. It is easy to predict preference for institutionally supported tools, even with limited functionality. A longer-term engagement in knowledge creating inquiry would also necessitate finding better ways to exchange complex networks of digital artifacts and their metadata between applications, without losing their relationships; such exchanges are currently rather limited.

To further develop the knowledge creating inquiry pedagogy, it is valuable to consider that teachers and administrators face many institutional-level problems when they try to create the necessary flexibility for multidisciplinary collaboration. These include booking spaces and arranging longer sessions with multiple universities, involving more than one teacher at a time, being able to stretch the curriculum to accommodate new types of courses, acknowledging tutoring and mentoring of groups or projects as a valid type of tuition, and supporting creation of networks where new ideas for societal innovations emerge. Involving experts from outside the academia calls for extensive networks and articulated possibilities for mutual benefit. Network access or user rights are often not available when collaborating across campuses or various in-house tools. Another challenge lies in developing ways to evaluate collective products and processes with equal formalism as individual products and processes to enable comparisons across educational systems.

A burning question for the present research has been that how should one measure the impact of these pedagogical interventions in terms of 'learning gains'. There are several points to consider. For instance, specifying a targeted, predefined corpus of knowledge and measuring the learning outcomes accordingly has not been the aim of the teachers or the researchers involved. This change from commonplace direction was made because the intent has been to engage the students in an open-ended process which is expected to take new directions or combine knowledge and practices from various domains. This process often takes directions into unfamiliar terrain to teachers. It could even be claimed that if the process does not reach unfamiliar terrain, then the students' learning process has not taken the necessary depths. Further, some authors have suggested that the mechanisms for teaching competencies for tackling complex problems may turn out to be surprising. Kapur (2008) has provided evidence for the hidden efficacy of failure: a collaboration not producing the correct outcomes generated

significant improvements later on, presumably because students had learned to conceptualize and analyze the problems while struggling without success in the first place. Similarly, Schwarz and Martin have suggested allowing students “to generate original productions that are incorrect by normative standards. Although this production appears inefficient by itself, it has a later payoff when students find resources for learning” (2004, p. 171). These investigations speak for the use of complex problems, since these problems were associated with the development of corresponding skills when examined in a longer timeframe.

5.4 Theoretical implications

A central issue to further theorize and clarify is the foundations of epistemic objects and knowledge objects, and other epistemic entities that would enable one to further specify the best types of practices to design for technology-mediated collaborative inquiry. From the perspective of pedagogical implementation and empirical studies, the term ‘epistemic’ is extremely fuzzy, and should be further elaborated to facilitate operationalizations into teaching practices and investigations. In the present work, “epistemic” rather than “cognitive” phenomena are discussed to indicate that the processes in question do not take place merely within the mind. The triological learning framework appears to provide a theoretical tool to address the gap between how present day work place knowledge practices take form and how educational practices could provide pre-work experience in them. Yet, more research is needed to understand the mechanisms of development of epistemic and knowledge objects and related knowledge practices both in professional practices and in educational practices to understand contextual constraints and possibilities. Such research is necessary to understand the differences between applications of theories of knowledge creation to classroom communities, public organizations, open source communities, scientific communities, or private companies, to name a few. Further iterations of empirical and theoretical development are needed to specify the implementation principles of object-centered activities in higher education courses in order to invite wider application in education and to assist in evaluating the design of educational practices.

The notion of metaskills of knowledge creating inquiry has been used in this dissertation work. It is a notion that requires further articulation and concretization. One

source of vagueness appears to be the delineation of skills, competencies, and abilities: further efforts are needed to position metaskills in relation to these concepts. Another is that making a claim that metaskills pertain to the individual, collective, and object-oriented monitoring of inquiry on a collective object covers a broad spectrum of actors and actions. However, the potential usefulness of the concept may precisely be in its integrative character, and further elaboration should take place by drawing on other concept and related research, such as agency, self-regulation of learning, co-regulation of learning, and co-configuration.

5.5 Future directions

Higher education is a thriving field of study with active pedagogical development taking place. The present work has argued for a deeper understanding and application of knowledge creating inquiry as a part of educational practices. The overarching motivation for this has been expressed by Scardamalia and Bereiter; they advocated that “sustained knowledge advancement is seen as essential for social progress of all kinds and for the solution of societal problems. From this standpoint the fundamental task of education is to enculturate youth into this knowledge-creating civilization and to help them find a place in it” (2006, p. 98). The theoretical and empirical research carried out on the dialogical approach to learning contributes to a pedagogical reorientation emphasizing knowledge creation as a potentially important component of educational practices. However, the reorientation does not become feasible without a more profound understanding of pedagogical models and competencies for object-centered inquiry. This entails an epistemological shift, where the knowledge transmission practices in education take their place as timely servants in a learning community’s inquiry into complex problems and epistemic entities.

The development of metaskills for knowledge creating inquiry appears to require that a group of students engage in a process that they cannot fully determine beforehand due to its complexity, but develop ways to monitor and regulate it through the engagement. The literature on identity (e.g., Holland et al., 1998) offers valuable examples of such transformations, and it would be fascinating to study what it takes to start developing an identity as a creator of solutions to societal problems.

Understanding the nature of knowledge creation in educational practices also

involves paying due attention to ethical consideration of the ownership of developed ideas and the recognition of contributions needs to be further disentangled. Open source communities have been tackling these issues since their early steps. Such ground rules for exploitation of innovative ideas developed in student teams working together with experts may need to be established in addition to the support for start-up businesses (for example the TULI program of TEKES, the Finnish Funding Agency for Technology and Innovation, www.tuli.info).

Finally, the preconditions for successful collaboration between industry and university are a complex issue to explore further on multiple levels of analysis. These include questions about what kinds of institutional policies and practices facilitate the cross-fertilization of knowledge practices between institutions, and what kinds of knowledge creation challenges are pedagogically most suitable and motivating for students.

6 References

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