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Jari Laru

SCAFFOLDING LEARNING ACTIVITIES WITH COLLABORATIVE SCRIPTS AND MOBILE DEVICES

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JARI LARU

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Abstract

The use of mobile devices, including mobile phones and tablets, is a growing trend in education. The practice has been widely technology driven and often justified simply by the importance of using new technology in a classroom and by claiming such devices to be important in reaching something referred to, although not that well defined, as 21st century skills. This thesis is one answer to the challenge represented by this development. It brings together theoretical ideas of scaffolding learning with collaborative scripts and the use of mobile devices as cognitive tools in a real life educational settings.

This thesis has constructivist grounds and aims at exploring how to support collaborative learning when students have ill-structured problems and their activities are supported with mobile technologies. The study consists of three case studies, which together form an example of how important it is to design, develop and deliver lightweight digital tools and activities for learners to construct knowledge.

Overall, the results of three case studies in this thesis confirms that it is a dubious assumption that learners will automatically take appropriate and measured advantage of the affordances of mobile devices and other emergent technologies involved in cognitive activities: rather, these cognitive tools require deliberate attention and effort from learners to make use of the affordances of the tools. Furthermore, results from the case studies reveal that personal factors such as students' prior knowledge and their metacognitive and collaborative skills, as well as contextual cues such as cultural compatibility and instructional methods, influence student engagement.

Keywords: case study, cognitive tools, collaborative learning, collaborative scripts, distributed cognition, mobile learning, scaffolding

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Tiivistelmä

Mobiililaitteiden, kuten puhelinten ja tabletien, opetuskäyttö lisääntyy hyvää vauhtia. Aihepiiri on ollut teknologiavetoinen, opetuskäyttöä on perusteltu lähinnä tarkemmin määrittelemättömillä 2000-luvun kansalaistaidoilla (21th century skills) ja uuden teknologian hyödyntämisen tärkeydellä. Tämä väitöskirja on teoreettisesti ja metodologisesti perusteltu vastine tähän keskusteluun. Tutkimus yhdistää pedagogista vaiheistamista ja kognitiivisia työkaluja käsittelevän teoreettisen viitekehyksen kolmeen todellisissa oppimistilanteissa tehtyyn kokeiluun.

Työ koostuu kolmesta tapaustutkimuksesta, jotka yhdessä muodostavat esimerkin kuinka mobiililaitteiden avulla tuettua opiskelua voidaan suunnitella ja toteuttaa erilaisissa konteksteissa. Ensimmäisessä tapaustutkimuksessa tutkittiin maantieteellisesti hajautuneen opetusta suunnittelevan yhteisön vuorovaikutusta. Toisessa tapaustutkimuksessa selvitettiin kuinka tukea luontopolkutyöskentelyä mobiilisovellusten avulla. Kolmannessa tapaustutkimuksessa tutkittiin yliopisto-opiskelijoiden opintojen tukemista mobiilin sosiaalisen median sovelluksia hyödyntäen.

Kolme tapaustutkimusta osoittavat että oppilaiden ei voida olettaa automaattisesti osaavan hyödyntää uusinta teknologiaa ja pedagogisia menetelmiä opiskelunsa tukena. Päinvastoin, käyttäminen vaatii opiskelijoilta paljon päämäärätietoista ponnistelua. Henkilökohtaiset tekijät, kuten aiemmat kokemukset, opiskelutaidot, mutta myös tilannesidonnaiset tekijät kuten opetusmenetelmät vaikuttavat opiskelijoiden kykyyn hyödyntää uutta teknologiaa opiskelussa.

Asiasanat: mobiililaitteet, pedagoginen suunnittelu, tutkiva oppiminen, yhteisöllinen oppiminen

Acknowledgements

As who know me, know that I love computers and gadgets. This thesis has thus grown out of my personal interests, which originate from 1983, when I acquired my first computer. When I started my PhD work, I got the first PocketPC which was more than state art in the early years of the 21st century. I have to admit that at that time technology was a major motivator for me. Recently, however, I have learnt that strong theories and robust methodologies are much more important than technological tools and gadgets. Now I know that it is possible to implement innovative socio-technological design without most expensive technology – more important are ideas and instructional design. This is the most important lesson I have learnt during this journey in postgraduate studies.

I am most grateful to my supervisor Professor Sanna Järvelä. She has guided me from my very first step into the scientific world of learning. Becoming involved in different multidisciplinary academic efforts with her at domestic and European levels has enabled me to see that my work is relevant and meaningful. In addition, the trust that Sanna has shown in my divergent research efforts in the world of emergent technologies and methodologies has been really important. You helped me to learn that a combination of strong theories and innovative ideas is the key to the use of emergent technology in educational settings. Thank you.

I would like to thank Professor Marcelo Milrad for serving as the opponent in the doctoral defence. I would also like to thank the official reviewers of this thesis, Professor Teemu Leinonen and Senior Researcher, Dr. Raija Hämäläinen. Their constructive comments made me understand more about the research addressed in this study. It is my pleasure to thank another expert as well, Professor Roy. B. Clariana, who was co-author in the one of the original publications. Your expertise in mindmap analysis and other statistical issues has been very valuable.

I have been fortunate not to be a lonely researcher, but have been surrounded by inspiring and intelligent colleagues in the Learning and Educational Technology Research Unit (LET) at the University of Oulu. I want to thank them all for their collaboration, for our shared experiences of joy and sorrow, and for their great attitudes to life. In particular, I would like to thank Johanna Bluemink and Piia Näykki from the team. We have shared similar ups and downs on our postgraduate paths. Thank you for many, many (non)productive discussions during these years. I also want to express my gratitude to Hannu Goman. Together we made the impossible possible in the first data collection years ago. The collected data first used in our master’s thesis is a central part of this work. I would also like to thank, in chronological order (based on case studies), Juha Pohjonen, Kari Liukkunen, Kari Pankkonen, Matti Matero, Harto Pönkä, Karsten Stegmann and everyone else who participated in designing and conducting the three case studies in this thesis.

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Oulu, September 2012 Jari Laru

List of original papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals (I–IV):

I Laru, J. & Järvelä, S. (2004). Scaffolding different learning activities with mobile tools in three everyday contexts. In P. Gerjets, P. A. Kirschner, J. Elen & R. Joiner (Eds.), *Instructional design for effective and enjoyable computer-supported learning. Proceedings of the EARLI SIGs Instructional Design and Learning and Instruction with Computers* (pp.11–21). Tübingen: Knowledge Media Research Center. Available at: URI: http://www.iwm-kmrc.de/workshops/SIM2004/pdf_files/Laru_et_al.pdf

II Laru, J., & Järvelä, S. (2008). Social patterns in mobile technology mediated collaboration among members of the professional distance education community. *Educational Media International, 45*(1), 17–32. doi: 10.1080/09523980701847131.

III Laru, J., Järvelä, S. & Clariana, R. (2012). Supporting collaborative inquiry during a biology field trip with mobile peer-to-peer tools for learning: A case study with K-12 learners. *Interactive Learning Environments, 20*(2), 103–117. doi: 10.1080/10494821003771350.

IV Laru, J., Näykki, P. & Järvelä, S. (2012). Supporting small-group learning using multiple Web 2.0 tools: A case study in the higher education context. *The Internet and Higher Education, 15*(1), 29–38. doi:10.1016/j.iheduc.2011.08.004.

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1 Introduction

One of the most significant mechanisms through which learning is transformed today is technology. Over the course of history, a range of artefacts have been produced which modify the way people learn in various situated practices (e.g. the invention of the chart) (Pea, 1993). In particular, representational tools such as calculators and mind-maps have quite dramatically changed our daily practices in many spheres of life (Säljö, 2010). New digital and networking tools provide opportunities for creating learning environments that extend the possibilities of old technologies (books, blackboards, television, radio) and offer new possibilities for multiple social interactions (Bransford, Brown, & Cocking, 2003).

Ever since Mark Weiser (1991) coined the term 'ubiquitous computing', an increasing amount of attention has been paid to technologies that provide support to people on the move and in practice (Brodt & Verburg, 2007; York & Pendharkar, 2004). The early years of research on the innovative use of mobile technologies focused on mobility and other contextual issues, such as spatial and temporal flexibility of workers (Bly & Bellotti, 1996; Chatterjee, 2007; Luff & Heath, 1998). It also highlighted ways in which collaboration between mobile workers (Lundin & Magnusson, 2003) or K-12 learners (Roschelle & Pea, 2002) can be supported with mobile technology.

More recently, research on the use of mobile technologies have contributed to the potential to support learners studying a variety of subjects (Scanlon, Jones, & Waycott, 2005; Sharples, 2000) in elementary education (Laru, Järvelä, & Clariana, 2012; Zurita & Nussbaum, 2004) as well as in higher education (Järvelä, Näykki, Laru, & Luokkanen, 2007; Laru, Näykki, & Järvelä, 2012; Milrad & Jackson, 2008; Näykki & Järvelä, 2008). There have also been efforts to improve the performance of knowledge workers in workplace settings (Brodt & Verburg, 2007). Meanwhile, the various educational affordances of wireless technologies suggested by researchers (Looi *et al.*, 2009; Roschelle & Pea, 2002) have paved the way for the emergence of so-called mobile learning or ubiquitous learning initiatives (C. Liu & Milrad, 2010; T. Liu *et al.*, 2003; Trifonova, 2003).

Today, a plethora of digital and networking tools have appeared and been established on the Internet. These digital applications, which enable interaction, collaboration and sharing among users, are frequently referred to as Web 2.0 (Birdsall, 2007) or social software (Kesim & Agaoglu, 2007).These applications are further assumed to be a step change in the evolution of Internet technology in higher education (Wheeler, 2009), which has evolved from being primarily used to distribute course materials, communicate and evaluate to a role of enhancing educational processes that support collaborative learning and knowledge building (Collins & Halverson, 2010; Cress & Kimmerle, 2008; Schroeder, Minocha, & Schneider, 2010).

However, according to a recent literature review analysis of the state of the art on mobile learning (Frohberg, Göth, & Schwabe, 2009), communication and collaboration play surprisingly small roles in mobile learning projects. A considerable amount of research effort has been driven by the technical challenges and capabilities of new devices, while few studies have dealt with the question of how meaningful and productive mobile technology supported collaboration actually is (Futurelab, Naismith, Lonsdale, Vavoula, & Sharples, 2005; Järvelä *et al.*, 2007; Park, 2011).

Similarly, much has been written on the benefits of blogs (Halic, Lee, Paulus, & Spence, 2010; Hemmi, Bayne, & Land, 2009; Wheeler, 2009; Xie, Ke, & Sharma, 2010), wikis (Cress & Kimmerle, 2008; Hemmi *et al.*, 2009; Wheeler, 2009) and social networking sites (Arnold & Paulus, 2010) in education, but very little empirical research focusing on the integration of multiple social software tools in higher education pedagogy (Crook, Cummings, Fisher, & Graber, 2008; Meyer, 2010) or the educational use of Web 2.0 in higher education has been published as of yet (Uzunboylu, Bicen, & Cavus, 2011; Wheeler, 2009).

The new technologies present new challenges related to supporting collaborative learning as teachers have to integrate them into more or less traditional learning methods, curricula and the everyday life of schools (Arvaja, Hämäläinen, & Rasku-Puttonen, 2009). This thesis approaches emergent mobile technologies from an educational science perspective and as a cognitive tool to facilitate learning. The primary research question is: *How can emergent mobile technologies be used in such way as to be pedagogically meaningful tools in complex (collaborative) learning situations*?

The thesis is based on four peer reviewed publications: one paper (Paper I) in conference proceedings and three in journals (Papers II–IV). It consists of three separate empirical case studies carried out during the past ten years in multiple contexts in multidisciplinary settings. This time-span means, therefore, that the thesis also reflects the evolution of mobile computer supported collaborative learning.

The early phases of this thesis (Paper I) were done in the context of the SmartRotuaari (Ojala *et al.*, 2003) research project funded by the Finnish Funding Agency for Technology and Innovation, the main aim of which was to develop and test technologies and business models for mobile multimedia services of the future. The main aim of the first paper was to analyse how mobile computers and cognitive tools could be used for scaffolding everyday activities in different contexts. This paper described initial endeavours, but also laid the basic foundations, both theoretical and empirical, for the present work.

The first case study, reported in Papers I–II, examined interactions between designers when they were designing a new, virtual master's program. The original aim in this case study was to explore how sentence openers in mobile tools could support geographically distributed collaborative work. The study was a part of the Virtual Campus project (Goman & Laru, 2003; Liukkunen, Tolonen, & Laru, 2005). This case revealed non-participative behaviour among participants, leading the main aim to be reformulated so as to identify social patterns in mobile technology mediated collaboration.

The second case study (Paper III) continued the efforts to support collaborative learning in the mobile technology mediated contexts. It was conducted in the Mobile Support for Integrated Learning (Mosil, 2004) project funded by the European Commission Framework programme FP6, this case included fine-grained instructional design which was inspired by the ideas of the integrated scripting discussed and developed in the project.

The third case study (Paper IV) continued the previous efforts to support mobile computer supported collaborative learning. It was conducted in the context of the project Pedagogical Structuring of Collaboration and Self-Regulated Learning: Individual and Group-Level Perspectives (Score) (Häkkinen, Arvaja, Hämäläinen, & Pöysä, 2010). The main aim was to examine how deeply structured learning designs contribute to the learning outcomes of students. The pedagogical design was based on the findings of the second case study, showing that emphasis should be on a deeper structuring of integrated learning activities, including not only individual and collaborative phases, but also technology-mediated and face-to-face phases.

This work consists of two parts. The first part comprises the introduction, theoretical framework, aims and methods of the study and the main findings, which are followed by a general discussion. The second part consists of one international peer-reviewed conference paper (I) and three international peer-reviewed journal papers (II – IV), which report the empirical results on which the first part of this doctoral thesis is based.

2 Theoretical framework

The emergence of collaborative technology and software over the last decade is visible in the tools for learning and living now available, which enable us to design and implement 'constructivist' environments that seek to motivate, cultivate, and meet needs of the 21st-century learner' (Beldarrain, 2006, pp.140). Educational organisations, researchers and other stakeholders are exploring the types of learning skills that schools should be promoting in order to prepare people for the 21^{st} century learning society (Sawyer, 2006). These skills include collaboration, communication, digital literacy, problem solving, critical thinking, creativity and productivity (Dede & Hall, 2010; Hämäläinen & Vähäsantanen, 2011).

The theoretical framework and empirical experiments of this thesis are based on the ideas of distributed cognition, cognitive tools, collaboration and ill-structured problem solving as one account of the discussion of the 21^{st} century learning skills. This thesis is rooted in the idea of distributed cognitive system (Perkins, 1993) in which routine cognitive tasks are performed by tools (technological artefacts) and more complex communications and tasks are core intellectual capabilities of people. This does not mean that routine cognitive skills should be removed from the curriculum: instead, Dede and Hall (2010) argue that the fundamental change in 21^{st} century education involves de-emphasizing fluency in simple procedures, but using routine skills as a substrate in mastering complex mental performances that will be valued in the future workplace.

Generally, this thesis follows major ideas in constructivism, that i) learners are active in constructing their own knowledge; and ii) social interactions are important in this knowledge construction process (Woolfolk, 2010). While older cognitive views emphasized acquisition of knowledge, newer approaches, including constructivism, stress its construction (Anderson, Reder, & Simon, 1996; Greeno, Collins, & Resnick, 1996; Mayer, 1996). According to constructivistic ideas, learning is extending and transforming the understanding we already have, not simply writing associations on the blank slates of our brains (Greeno *et al.*, 1996).

Constructivists believe that students should learn in environments that deal with 'fuzzy', ill-structured problems. There should be not one right way to reach a conclusion, and each solution may bring a new set of problems. These complex problems should be embedded in authentic tasks and activities, the kinds of situations that students would face as they apply what they are learning to the real world (Needles & Knapp, 1994). In the present work, all empirical experiments have been conducted in real contexts with authentic tasks and activities. Furthermore, many constructivists share the belief that higher mental processes develop through social negotiation and interaction, so they value collaboration in learning.

According to Woolfolk (2010),in order to achieve the goals of advanced knowledge acquisition in constructivism, it is essential to enable students to revisit 'the same material, at different times, in rearranged contexts, for different purposes and from different conceptual perspectives' (Spiro, Feltovich, Jacobson, & Coulson, 1991, p.28). Students tend to oversimplify as they try to apply what they have learnt if they have not encountered multiple representations of content using different analogues, examples and metaphors. Instructional design in the experiments reported here has been iterated towards to that goal from the early phases, with free collaboration continuing to the last experiment with sequential and structured instructional design.

Finally, all constructivist approaches share the idea of making students aware of their own role in constructing knowledge (Cunningham, 1992). Students own assumptions, beliefs, and their experiences shape their thinking, and thus construction of knowledge. The theoretical idea of a distributed cognitive system and scaffolds as a part of that system reinforces the idea of students' own role.

2.1 Distributed cognition

People's actions are intertwined with the artefacts of their work, with their team member's roles, responsibilities, and actions, and with even their cultural and historical setting (Olson & Olson, 2003). Different artefacts are constantly used for structuring activity, for saving mental work, or for avoiding error, and they are adapted creatively almost without notice. (Pea, 1993) Such actions and artefacts are an example of distributed cognition, a theoretical framework that provides insights into how we use our environment and its sub-components as integral parts of our learning processes (Kim & Reeves, 2007; Pea, 1993).

Distributed cognition (Hutchins, 1996; Salomon, 1993) takes the view that cognition does not reside only in a person's head, but is distributed among people, artefacts and symbols during thinking, reflection and learning (Salomon, 1993). It has not, however, been conceived and described consistently (Kim & Reeves, 2007). The first major distinction among advocates of this approach lies in the focus on social aspects of human thinking: there are some theorists who agree with Vygotsky (1978), that cognition and activity are basically distributed among people, but mediated by signs and tools (Wertsch, 1998), whereas others hold that cognition resides not only in persons but also in signs and tools, conveying cultural meanings and history (Perkins, 1993; Salomon, 1993). Altogether, these mediational means are any and all tangible and intangible objects, such as visual representations, sign systems, or technical tools that are involved in human action. Such tools are constantly used for structuring activity, saving mental work or avoiding error, and they are adapted creatively almost without notice (Norman, 1993; Pea, 1993; Wertsch, 1998).

According Kim and Reeves (2007), another disagreement within research on distributed cognition relates to whether or not the distributed cognition is an absolute characteristic of human thinking. While some theorists suggest that cognitive activity is always distributed in some respects, even when carried out by a person in isolation, by virtue of the language used (e.g. Cole & Engeström, 1993; Pea, 1993; Wertsch, 1991), others recommend making a distinction between individual cognition and distributed cognition (Brown *et al.*, 1993; Perkins, 1993; Salomon, 1993). However, both views share the notion that human cognition relates to the environment outside of an individual.

2.1.1 Cognitive tools

Throughout our history, different mechanical tools have been developed to amplify and facilitate physical work. Those tools have provided humans enormous mechanical advantage. (Jonassen, 1999; Scardamalia & Bereiter, 1994) Besides mechanical tools, humans have also developed and implemented different *cognitive tools*. The most pervasive and the most self-explanatory of these is (verbal) language, which importantly distinguishes humans from animals, and, amplifying the thinking of the learner, affords possibilities of expressing and sharing ideas and beliefs.

The concept of *cognitive tools* is used to refer to any tool that can support aspects of learner's cognitive processes (Lajoie, 1993). Jonassen and Reeves (1996) broadens Lajoie's view of the term, using it to refer to any tools that 'enhance the cognitive powers of human beings during thinking, problem solving, and learning' (p.693). The theoretical foundation of cognitive tools comes from distributed cognition (Hutchins, 1996) and distributed intelligence (Pea, 1993) theories, which regard cognition not as residing only in a person's head, but as distributed among people, artefacts and symbols. Our living environment offers many examples of 'smart tools' that we are using to mediate activities and augment our thinking processes (e.g. measuring or calculating) (Norman, 1993; Pea, 1993).

According to Perkins & Grotzer (1997), cognition has social, symbolic and material (physical) distributions. The social distribution of cognition is exemplified in collaborative learning. Symbolically distributed cognitions includes any and all tangible and intangible objects such as visual representations, sign systems that are involved our daily life. Physical distributions include everything visible or tangible, ranging from paper and pencil to technical tools that make our everyday activities easier to accomplish. The graphing calculator is an example of a success story form the perspective of physically distributed cognition, in many mathematics and science classrooms this device is ubiquitous (Keefe & Zucker, 2003).

When we are using these physical artefacts and representations for mental processes, they become a part of our interactions and outcomes of our thinking (Pea, 1993; Salomon, 1993). Sometimes, the involvement of novel symbolic and/or physical means in mental process change the very nature of the activity (Cobb *et al.*, 1991). In this sense, computers, tablets and mobile phones as symbolic and physical means, 'enhance or extend our cognitive powers, through speed and accuracy in processing information and representations, off-loading laborious tasks for higher-level thinking and decision-making and problem-solving based on the result of the computer processing' (Kim & Reeves, 2007, pp.216; also Dede, 2010).

According to Pea (2004), but also Carmien and Fischer (2004), there is a fundamental distinction related to distributed intelligence and the change of tasks in a tool-rich world, which can be seen in two major design perspectives (see Table1): a) *tools for living* (such as feature phones) are grounded in a distributed intelligence perspective, in which intelligence is mediated by tools for achieving activities that would be error prone, challenging or impossible to achieve without them. Such tools are limited to what Perkins (1985) called 'the first order fingertip effects' (p. 11); b) *tools for learning* (such as simulations) are 'mindtools' (Jonassen, 1999) with second-order fingertip-effect. According to Perkins (1985) this effect is an answer to the question 'What difference will a computer really make?' to a person's higher-order skills, such as decision making, reflection, reasoning, and problem solving (p. 11). In his paper about mindtools, Jonassen (1999) indicated that the second order effects should help 'in the construction of generalizable, transferable skills that can facilitate thinking various fields' (p. 18).

Table 1. Overview of tools for living and tools for learning.

	Tools for Living	Tools for Learning	
Type	Tools with first-order fingertip effect (Perkins, 1986)	Tools with second-order fingertip effect (Perkins, 1986)	Mindtools (Jonassen, 1996)
Definition	Tools that are used spontaneously without chancing basic aspirations, endeavours, or thinking habits	Tools that enhance higher-order skills	Tools that engage and facilitate critical thinking and higher-order skills
Aim	Improve productivity and efficiency	Change our goals and the ways of thinking	To make effective use of the mental efforts of the learner
Examples	Eyeglasses, feature phones	Handheld calculators	Productivity software, expert systems, computer conferences, smartphones, digital learning environments, mobile applications

The idea of cognitive tools (mindtools) is closely related to the way in which constructivists think about the role of computers in the process of learning (Kim & Reeves, 2007). The computer is no longer perceived as a mere delivery medium, but as a tool with unique capabilities that supplement learners' cognition (Kozma, 1991). Such tools have been adapted or developed to function as intellectual partners with the learner in order to engage and facilitate critical thinking and high-order learning. When learners are using mindtools to represent what they know, it necessarily engages them in variety of critical, creative and complex thinking modes (Jonassen & Carr, 2000; Kirschner & Erkens, 2006).

2.1.2 Understanding mobile devices as cognitive tools

Until now, mobile devices have been seen almost merely devices for person-to-person communication (Nyiri, 2002) or platforms for the dissemination of knowledge (Herrington, Herrington, Mantei, Olney, & Ferry, 2009). However, the newest mobile devices (e.g. smartphones, pda's) have become versatile cognitive tools with rich educational possibilities (Chen, Tan, Looi, Zhang, & Seow, 2008). It is exciting that cognitive tools which first existed only on expensive personal computers (desktop machines) are now a part of an amalgam of digital tools that lie in the close physical surrounding of contemporary learners.

Contemporary smartphones, tablets and other mobile devices resemble the idea of Wireless Internet Learning Devices (Roschelle & Pea, 2002), which are powerful, small and personal, networked mobile devices. We are approaching the landscape of ubiquitous computing (Weiser, 1991), where computers are embedded in our everyday activities, so that we unconsciously and effortlessly harness their digital abilities as effort saving strategies for achieving the benefits of distributed intelligence (Pea & Maldonado, 2006). The graphing calculator is an example of a success story in this regard (Keefe & Zucker, 2003).

Much charm exists in the power of the multiple representations that graphing calculators have made available in the classrooms. Yet, mobile devices in today (handhelds, smartphones, tablets etc.) are increasingly attractive from the educator’s point of view, as they combine desktop productivity applications, the functions of application task-specific devices – like graphing calculators and versatile modular hardware (e.g. probes) – desktop computers and complex interactions with other devices. (Pea & Maldonado, 2006). These converged devices are becoming available ‘anywhere anytime’ for many intellectual activities, raising the fundamental question of what it means to learn in 21st century (G. Fischer & Konomi, 2007).

With more generalized mobile devices with integrated functions, cognitive tools for doing things like mapping concepts, running simulations, gathering data, and structuring discussions are appearing with novel technological affordances introduced by rapid technological advancements (G. Fischer & Konomi, 2007; Futurelab *et al.*, 2005; Roschelle, 2003; Sharples, 2007). Many contemporary researchers (Lai, Yang, Chen, Ho, & Chan, 2007; Looi *et al.*, 2009) have argued that mobile devices have technological attributes that provide unique technological, social and pedagogical affordances (Kirschner, Strijbos, Kreijns, & Beers, 2004). However, lists of such affordances are often limited to just the most cited affordances, as summarized by (Klopfer & Squire, 2008; Squire & Dikkers, 2012), which are portability, social interactivity, context, and individuality. Despite that, researchers are developing new sets of affordances. One example from recent research is that of affordances for personalized learning suggested by Looi *et al.*(2009).

Table 2. Technological, social and pedagogical affordances enabled by mobile cognitive tools.

Type of affordance	Roschelle& Pea (2002)	Klopfer& Squire (2008)	Looi et. al (2009)
Technological	Leverages topological (or physical) space Augments physical space with the information exchange	Connectivity Portability Context sensitivity	Multimodality
Social	Aggregates individual's participation into group reflection opportunities	Social interactivity	Supports the creation and sharing of artefacts on the move Supports student improvisation in situ
Pedagogical	Situates teacher as conductor of activity Uses students' actions as artefacts for discussion	Individuality (provides unique scaffolding)	Multiple entry points and multiple learning paths

The most profound set of affordances for mobile computer supported learning have been the five application level affordances, as suggested by Roschelle and Pea (2002) in their seminal paper about *wireless internet learning devices* or WILD. Roschelle and Pea suggested that the educational use of mobile devices can augment physical space with information exchanges, leverage topological (or physical) space, aggregate individual participation in group reflection opportunities, situate the teacher as a conductor of activity and use students' actions as artefacts for discussion. These affordances were suggested in the early 2000s, when enabling technology was not available, but there were abstract examples for educators and instructional designers about what might be possible in the close future – today.

In order to fit the role of mobile devices and applications into today's world of distributed cognition, an appropriate framework is needed. One approach for this is a distributed view of thinking and learning, as suggested originally by (Perkins, 1993). In his *person-plus-surround* conception, Perkins adopts systemic view on cognition that goes beyond the individual actor: a system engaging in cognition usually consists of an individual (person-solo) and his immediate physical (person+artefact) and social (person+surround) surround. This surround (environment) might include tools such as paper, personal computers and mobile devices (person+artefact), as well as other persons (person+surround) (see Figure 1).

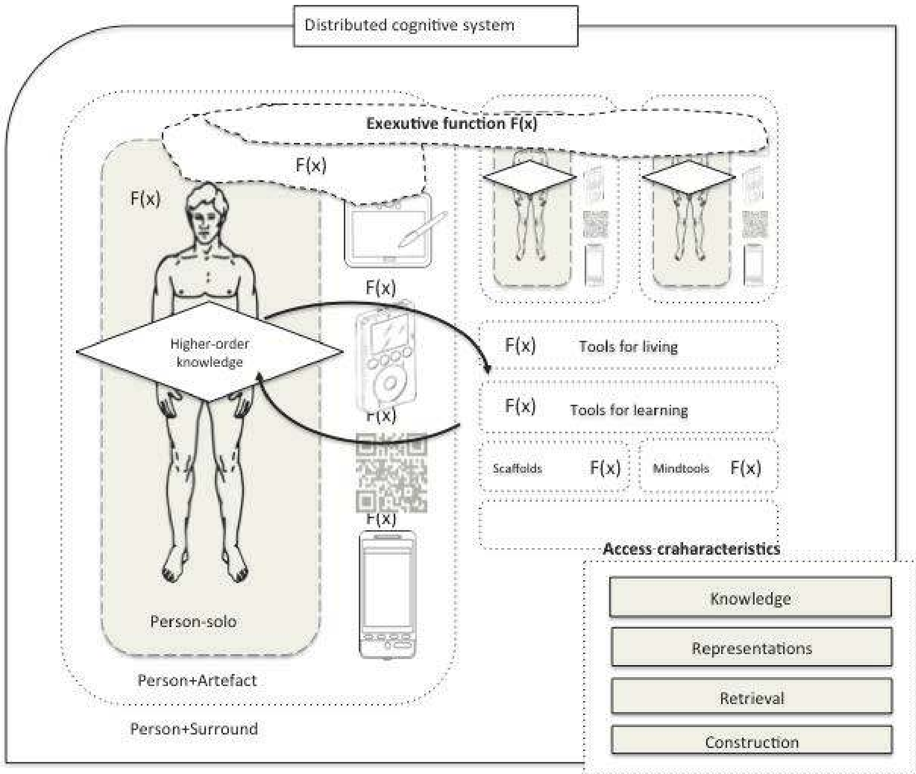

Fig. 1. Distributed Cognitive System.

This surround participates in cognition, not just as a source of input and a receiver of output, but as a vehicle of thought. Nevertheless, the person-solo is the central actor in this model, because transference of knowledge to an external tool (person+) is adequate if the tool only performs routine tasks that cost too much to internalize (e.g., some mathematical calculations). Higher-order knowledge (e.g., knowledge about argumentation), as opposed to knowledge about routine tasks, should reside in the person-solo or between multiple person-solos (or be internalized by the person-solo).

The role of mobile device within distributed cognitive system is as a dynamic mediator of interaction between learners, their environment, other tools and information (Koole, 2009). To perform a task, it matters less *where* the needed knowledge is represented – what counts are the *access characteristics* of that knowledge, that is, how easily the system consisting of a learner(s) and the immediate social and artefactual surround can access the relevant knowledge (Perkins, 1993). While mobile tools are considered as dynamic mediators, capability of information access and selection of the mobile devices are important parts of the access characteristics to the knowledge in the distributed cognitive system. The capability of the knowledge navigation and production are restricted by the affordances enabled by the mobile devices, as described above (Koole, 2009).

In general, the access characteristics consist of four items:

1. In many learning situations, neither learners nor surround contain much of this higher-order task related *knowledge,* a situation where learners will fail to accomplish the collaboration task. Mobile devices can be used to facilitate learning skills with contextualized and individualized, unique scaffolding (Klopfer & Squire, 2008)
2. Besides mental *representations*, learners employ text, drawings, models and formulae and other external representations during their learning activities (Perkins, 1993). It is likely today that learners will utilize mobile technology, with its powerful capacity to leverage topological and physical spaces, and augment physical spaces with the information exchange (see (Roschelle & Pea, 2002).
3. Knowledge has to be retrieved under authentic conditions of the use, portability and mobility of mobile technology (Squire & Dikkers, 2012), enable situated learning activities in real contexts (Järvelä *et al.*, 2007; Laru, Järvelä, *et al.*, 2012; Laru, Näykki, *et al.*, 2012), and therefore enable educators and learners to arrange contextually appropriated knowledge *retrieval* (Perkins, 1993).
4. The learners equipped with mobile devices are amid a ubiquitous surround that provides massive short-term and long-term memory support through cognitive tools. In addition to memory, mobile technology also affords computational support for a number of valuable operations: it enables context-sensitive and situated collaborative knowledge *construction*, and also

the ability to aggregate individual participation into group reflection opportunities (Roschelle & Pea, 2002).

The distributed cognitive system can further be characterized as dependent on which of its components has the *executive function* – E(f) in Figure 1 – with respect to the task being accomplished. In the distributed cognition model, executive function is distributed naturally – distributions occur in our surround all the time (for example when teacher makes a decision that students follow, the instructions at the course wiki, collaborative learning scripts with information about learners' learning activities) (Perkins, 1993). It is important notice that after distributed cognition system has operated some time, one tool or one individual can be taken away and the remaining system can adjust. (Hutchins, 1996). However, the location of the executive function impacts on the ability of a distributed cognitive system to adjust to the removal of an agent. In practise, the agent controlling the executive function cannot be removed without compromising the functioning of the system (Perkins, 1995).

2.2 Computer supported collaborative learning

Computer supported collaborative learning (CSCL) is an emerging branch of the learning sciences that focuses on how people can learn together with help of computers (Koschmann, 1996; Stahl, Koschmann, & Suthers, 2006). The primary aim of CSCL is to provide an environment that supports collaboration between students to enhance their learning processes (Kreijns, Kirschner, & Jochems, 2003) and facilitate collective learning (Pea, 1996) or group cognition (Stahl, 2006).

Collaborative learning and knowledge building is seen as one of the most meaningful ways to support individual learning mechanisms with the help of the social and interactive learning (Bereiter & Scardamalia, 1989; Dillenbourg, 1999). Collaboration necessitates that participants are engaged in a co-ordinated effort to solve a problem or perform a task together. This coordinated activity, synchronous or asynchronous, is the result of a continued attempt to construct and maintain a shared conception of a problem (Roschelle & Teasley, 1995).

The nature of the learning task is one crucial determinant of successful collaboration (Arvaja, Häkkinen, Eteläpelto, & Rasku-Puttonen, 2000). One of the enduring challenges for instructional designers is to provide real group tasks and contexts that stimulate questioning, explaining and other forms of knowledge articulation (Järvelä, Häkkinen, Arvaja, & Leinonen, 2003). The challenge here is grounded in the idea that the authenticity of the learning situations and tasks is assumed to be an important factor that can facilitate higher order learning (Brown, Collins, & Duguid, 1989). This means that if learning tasks are too obvious and simple there is no space for productive interactions (Arvaja *et al.*, 2000), like: a) providing and receiving explanations (Webb, 1984), b) the mediating role of solving conflict and controversy (Doise & Mugny, 1979), and c) jointly building knowledge on each other's ideas and thoughts (Palinscar & Brown, 1984; Scardamalia & Bereiter, 2006). In this thesis mobile technologies have been employed to develop learning in authentic contexts, those of the workplace (Case Study I), nature park (Case Study II) and the informal contexts of university learners (Case Study III).

The situative approach to learning emphasizes the understanding that knowledge is always created and made meaningful by the context and activities through which it is acquired. In other words, cognition is seen as situated and distributed in the social and physical context. An example is an inquiry learning context (Case Study II) carried out by a triad of learners with a single mobile tool and representations produced during the inquiry task in the nature trip. The social aspects are approached by examining the triad's shared social practises and the ways in which individuals participate in the activity (Greeno, 2006). Considering the complex nature of learning, it seems justified to study collaboration in close relation to context, since every act of communication always takes place in a specific context (Clark, 2003). Therefore, the impact of the context for learning and collaboration should be discussed as an inseparable part of the collaborative activity.

There is an increasing number of technology supported collaborative applications claiming and aiming to facilitate collaboration today. To ease the educators' selection, the suggestion was made to divide tools into the *collaboratively usable technology* (in which software alone does not scaffold collaboration) and *collaborative technology* (in which software is designed specifically to support collaborative knowledge construction), based on the instructional and pedagogical aspects of tools (Lipponen & Lallimo, 2004). In this thesis, the FLE3mobile (Case Study I) and Wikispaces (Case Study III) tools for collaborative knowledge construction can be categorized as examples of collaborative technology, while other tools (in Case Studies II and III) are examples of collaboratively usable technology (see Table 3).

Although only collaborative technology tools are designed to support those interactions and mechanisms that have been found beneficial to learning, these mechanisms were made explicit to learners in Cases II and III in such phases of instructional design where collaboratively usable tools were used. This was done by structuring learners' collaborative interactions with different scaffolds. Regardless of the medium, the core purpose of all computer supported collaborative environments is to create conditions in which effective group interactions are expected to occur (Dillenbourg, Järvelä, & Fischer, 2009).

Table 3. Collaborative tools in the case studies.

Cases	Collaboratively usable technology	Collaborative technology
Case 1: FLE3mobile	-	FLE3mobile
Case 2: Flyers	Flyers	-
Case 3: Edufeeds	Shozu, Flickr, Wordpress, Google Reader	Wikispaces

2.3 Supporting learning with emergent mobile technologies

Strengthening the role of smartphones, internet tablets and other mobile devices in our everyday life is an example of *ubiquitous computing,* a term coined by Weiser (1991), who wrote that 'the most profound technologies are those that disappear [because t]hey weave themselves into the fabric of everyday life until they are indistinguishable from it' (p.94). He is widely considered to be the father of ubiquitous computing, an environment in which the computer is integral to but embedded in the background of daily life.

Although Weiser was the first to use the term 'ubiquitous computing', others had explored this notion as much as two decades previously. As early as the 1970s, Alan Kay (1972) had imagined a handheld, notebook-size computer for children, which he called the Dynabook. He thought that computers might be instruments that would support the construction of knowledge in a variety of media anytime, anywhere (Feldman, 2004; Kay, 1972). About the same time, Papert (1980, p. viii) predicted 'a massive penetration of powerful computers into people's lives' and, with it a paradigm change in teaching and learning. Papert called his approach to learning 'constructionism', viewing it as a variant of constructivism (Piaget, 1952). Early efforts at Xerox Parc laboratory supervised by Allan Kay led immediately to the development of personal computing and can be seen as an enduring success of research into technology enhanced learning. Instead, the development of mobile devices and applications at the level of realizing the visions of scientists in the early 1970s took until late 90s, when the first handhelds and mobile communicators appeared in the USA and Europe (Sharples, Sanchez, Milrad, & Vavoula, 2009).

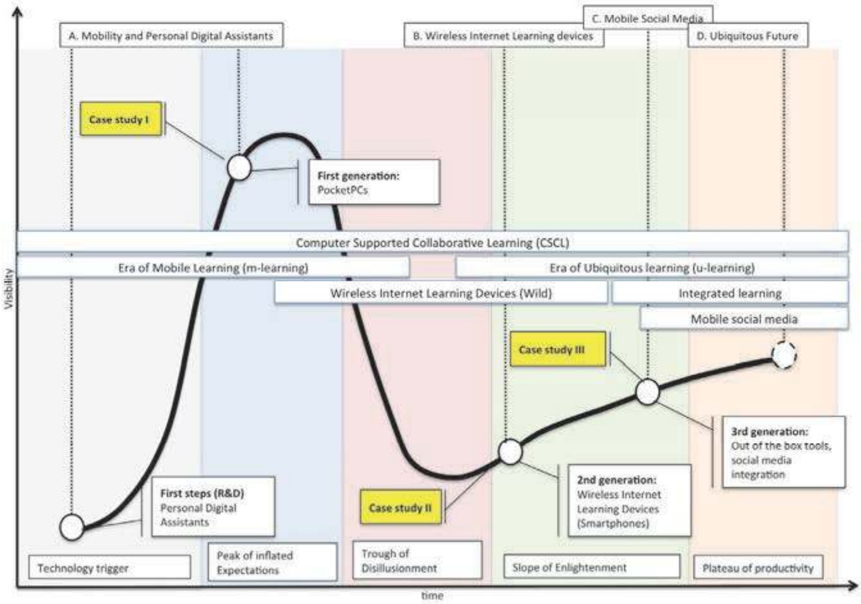

Fig. 2. Gartner's Hype Curve and development of ‘mobile learning’.

In this chapter. Gartner Group’s hype curve (see Figure 2) is used as a basis on which to categorise and analyse research on the educational use of ubiquitous computing because, as noted by Fenn (2007, p.3) the hype curve ‘characterizes the typical progression of an emerging technology’ (italics added). As depicted (Figure 2), there are five stages of the hype curve: technology trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment and plateau of productivity. Because the technology is at different levels of development in each of the five portions of the curve, research into the educational use of the technologies can be made in steps (O’ leary, 2008). These steps are not linear in the strictest sense ; rather, they follow the steps of the development of research in the field. In this thesis, the hype curve is also used to structure an examination of the development of the general idea of mobile computer supported learning. This is achieved by adding a layer of several megatrends in the technology enhanced learning field on top of the hype curve (shown at the top of Figure 2).

This history begins with the era of technology triggers, which were the product launches by Apple Newton, Palm Pilot and Nokia Communicator in the late 1990s, followed by Microsoft's PocketPC in early 2000s. Later devices are considered as first generation gadgets in this cycle. These early developments in ubiquitous communication led to a peak of inflated expectations when some scholars thought that mobile devices would revolutionize education (Trifonova, 2003; Williams, 2009). Typical for this period was the move of referring to the educational use of mobile devices under the terms 'mobile-learning' and 'm-learning' (Keegan, 2005; Park, 2011; Quinn, 2000). This time period is described in the following subsection (below).

In the third stage, that of disillusionment, critical accounts toward technology determinism started to appear. For example, in extensive review of the early mobile learning projects made by Frohberg *et al.* (2009) found that the 'tool support of most projects is not pedagogically ambitious, [and only] a … minority provide tools that aim at realizing higher pedagogical goals' (p.317). At the same time as the first critical considerations started to emerge, seminal accounts of mobile computer supported learning were also published, for example the ideas of wireless Internet Learning, as suggested by Roschelle & Pea, (2002a) and integrated learning (Dillenbourg, 2002). These developments together with new affordances of mobile technologies led to the hype curve stage of enlightenment. In this stage, some second generation of mobile devices (smartphones with 3G connectivity, for example) eased the research in the field. Two major phases in emerged, related to the development of wireless Internet learning devices and mobile social media (below).

From the present perspective, this field of research is currently in the phase of plateau of productivity. The world is entering the Age of Mobilism (Norris & Soloway, 2011). New technology tools fit more readily and naturally into our lives; increasingly wide-ranging, inexpensive, and easy-access-to-Internet wireless devices, and a variety of web based personal publishing and social software tools are making computing a truly ubiquitous and 'continuous' part of our lives (Roush, 2005, p.49).

2.3.1 First years of research on the educational use of mobile technologies: Mobility & PDA(s)

The first years of research on the educational use of mobile technologies focused either on mobility and other contextual issues, such as the spatial and temporal flexibility of workers (Bellotti & Bly, 1996; Luff & Heath, 1998), or on exploring the educational use of three distinct families of mobile devices: i) laptops (Freiman, Beauchamp, Blain, Lirette-Pitre, & Fournier, 2010; Rockman, 2003; Trimmel & Bachmann, 2004), ii) personal digital assistants, and a wave of devices that followed in this category (e.g. PocketPC, Palm Pilot) (Rieger & Gay, 1997; Shin, Norris, & Soloway, 2006), and iii) scientific calculators (Crowe, 2007; Hennessy, 1999). In this thesis, interest is in the area of handheld computers or handhelds (Personal Digital Assistants [PDA], Smartphones, Tablet computers, [networked] graphing calculators, etc.), so laptop experiments are not further discussed.

Most of the research before the years 2002–03 has been done with personal digital assistants (PDAs), although there were also projects exploring the possibilities of the Wireless Application Protocol (WAP) and other emerging technologies (Trifonova, 2003). One of the biggest explorative studies was a evaluation of handheld technology in education – the Palm Education Pioneer programme – which distributed classroom sets of handheld computers through competitive grant process (Crawford, Vahey, Lewis, & Toyama, 2002). The goals of this project were to evaluate the effectiveness of the handheld computers in real-world settings and to aggregate the knowledge base for participating teachers. In their initial grant proposals, teachers anticipated that the handhelds would engage students in personalized and self-directed learning activities. However, teachers reported increased collaboration and cooperation as benefit of this technology use in their classrooms (Crawford *et al.*, 2002; Vahey, Tatar, & Roschelle, 2006). Collaboration in the PEP programme was limited to face-to-face situations mediated by handhelds, however, due to limitations in connectivity (short-range infrared connectivity between handhelds).

In their literature review of this early stage research in the field, Shin, Norris & Soloway (2006) distinguished three major educational uses for early handheld computers in K-12 education: i) researching, organising and expressing, ii) capturing and analysing scientific data (Metcalf & Tinker, 2004; Tinker & Krajcik, 2001), and iii) limited communicating and collaborating. Shin, Norris & Soloway found many curricula or teacher related issues. They identified ‘teacher factor’ as one emergent pattern, which can be described thus: '[T]eachers in their first year of using a digital tool – be it handhelds, laptops, graphing calculators, and so on – will not use that technology particularly effectively at first.' This review reveals how teacher-centred the educational use of handhelds in the classrooms was at that time; several authors, however, argue that activity patterns since then have not changed greatly (Sharples *et al.*, 2009; Squire & Dikkers, 2012).

New generations of early mobile devices improved incrementally, with higher resolution screens, built-in cameras, expandable memory, and a variety of wireless capabilities that were not available during the first periods of the research in this field (Shin *et al.*, 2006). Suddenly noteworthy were the increasing educational affordances and converging functionalities of contemporary mobile devices, both Personal Digital Assistants (PDA) and smartphones, moving them from the markets of basic telephony and electronic diaries to that of small laptops (Patten, Arnedillosanchez, & Tangney, 2006). However, early smartphones, PocketPCs and other networked handheld devices were marked by different usability and technological issues (Luchini *et al.*, 2002; Pea & Maldonado, 2006) and can therefore be regarded as first generation 'mobile learning' tools.

The idea of *mobile learning* was presented by Mike Sharples (2000) in the line of the technological developments. According to Sharples, new technological affordances enabled a 'new genre of educational technology – personal (handheld or wearable) computer systems that support learning from any location throughout a lifetime'. The various educational affordances of wireless technologies suggested by researchers thus far (Looi *et al.*, 2009; Roschelle & Pea, 2002) have paved the way for the emergence of so-called mobile learning or ubiquitous learning initiatives, such as G1:1 learning (Chan, Roschelle, *et al.*, 2006). While some researchers elaborate terms deeply in scientific practices, mobile devices and wireless networking technologies in education are still understood by many as 'an extension of e-learning' (Brown, 2005; Quinn, 2000) or the mainstream, pervasive learning delivery medium (Williams, 2009). However, these simplistic views ignore the fact that modern education and pedagogy puts a high value on active, productive, creative and collaborative learning methods that go far beyond the absorption of codified information (Hoppe, Joiner, Milrad, & Sharples, 2003).

The advent of modern smartphones and tablets in the early 2000s saw a second wave of pioneering projects. In this set of projects the focus was switched from explorative initiatives for identifying the benefits and constraints of using handheld computers to supported learning activities. Four different trends can be distinguished: i) augmented learning experiences, in which mobile devices are used to create situated educational location based games (Colella, 2000; Klopfer & Squire, 2008; Price, Rogers, Stanton, & Smith, 2003; Rogers *et al.*, 2004; Squire & Jenkins, 2003); ii) classroom response system systems (Abrahamson, Hantline, Fabert, Robson, & Knapp, 1991; Dillenbourg & Jermann, 2010; Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996); iii) teaching and learning support systems and organisers (Corlett, Sharples, Bull, & Chan, 2005; Niramitranon, Sharples, & Greenhalgh, 2010); and iv) tools supporting collaborative activities amongst students for individual, small group and whole class learning (Laru, Järvelä, *et al.*, 2012; Laru, Näykki, *et al.*, 2012; Milrad & Jackson, 2008; Roschelle & Pea, 2002).

2.3.2 Appearance of first Wireless Internet Learning Devices (WILD) together with pedagogically ambitious learning goals

More recently, research on the use of mobile technologies has contributed to the potential to support learners studying a variety of subjects (Scanlon *et al.*, 2005; Sharples, 2000) in elementary education (Laru, Järvelä, *et al.*, 2012; Zurita & Nussbaum, 2004) as well as in higher education (Järvelä *et al.*, 2007; Laru, Näykki, *et al.*, 2012; Milrad & Jackson, 2008). While the main focus of research activities has been in the developed countries, some of the projects have aimed to bridge the digital divide by 'enabling people in the developing world not only to access information, but also to contribute information back – thus becoming active participants in the information society' (Ford & Leinonen, 2010, p.212; also Freudenberg, Ohshima, & Wallace, 2009; Leaning, 2010).

A considerable amount of research effort in this decade has been driven by technological challenges, but few studies have dealt with questions of how meaningful and productive mobile technology supported (collaborative) learning actually is (Futurelab *et al.*, 2005; Järvelä *et al.*, 2007; Park, 2011). These concerns are explicitly made in an extensive review of mobile learning projects by Frohberget *et al.* (2009), where the authors argue that 'tool support of most projects is not pedagogically ambitious, [and] a strong minority provide tools that aim at realizing higher pedagogical goals' (p. 317). Ford and Leinonen (2009) suggest separating 'mobile learning' into 'mobile' and 'learning', and argue that the learning aspect is the most important concept. For them, computing devices just happen to be mobile, and it is instructional design and learning activities that are important. Their argumentation highlights a problematic bias in technology determinist research projects: these tend to dismiss the most important part of mobile computer supported learning, the learning itself.

One explanation for the lack of pedagogical ambition during the first years of research might be, as Sharples *et al.* (2009) argue, that ‘evaluations of mobile learning systems and applications often show that learners, children and adults alike, enjoy using mobile devices for learning and report increased motivation as a result of this use’ (p.10). Tiene and Luft (2001) argue that it is common in any technology-rich learning context for students to be motivated and focused because of the tools themselves and the learning opportunities they facilitate. However, the stimulation of technology or technology rich contexts alone are not sufficient conditions for ensuring motivation and focus among learners (Looi *et al.*, 2009).

In order to ensure engaged learners, a proper pedagogical or lesson design is needed for when enthusiasm for using the new technologies begins to worn out. (Looi *et al.*, 2009). Yet, although many scholars, most notably Roschelle and Pea 2002) have predicted tensions between traditional learning models, which are highly centralized, and emerging pedagogical ideas amplified with mobile technologies, which are naturally situated, collaborative and distributed, educational technologists tend to create applications which are designed to work within ‘inherited educational ideas rather than transform them’ (Squire & Dikkers, 2012).

As mentioned, the most profound ideas of mobile computer supported learning have been suggested by Roschelle and Pea (2002) in their seminal paper about Wireless Internet Learning Devices (Wild). These devices are small and powerful networking computing devices intended for personal use (Ford & Leinonen, 2010; Norris & Soloway, 2011; Roschelle & Pea, 2002). Although Roschelle and Pea included seminal ideas for the educational use of mobile devices, they also described functions of second generation ‘mobile learning’ tools: i) size and portability ii) small screen size (although contemporary tablet computers challenge this somewhat) iii) computing power and modular platform, iv) communication ability through multiple wireless networks v) wide range of available multipurpose applications; vi) ready ability to synchronize and back-up with other computers; and vii) stylus driven interface (technology development has made this category obsolete). In practice, the characteristics described above fit our current smartphone and internet tablet line-up, showing this to be a relevant case to consider not only for learning outside schools and other educational contexts, but also for the possibility of students and instructors bringing their own devices into educational contexts (Pea & Maldonado, 2006).

Roschelle and Pea (2002) also predicted how mobile technology might revolutionize the role of teachers by breaking contrastive teaching paradigms of ‘sage on the stage’ (teacher centred instruction) and ‘guide by side’ (teacher guided discovery): instead they offered the idea of ‘conductor of performances’, which has been further developed by other scholars (Dillenbourg & Jermann, 2010) using the term ‘orchestration’ to describe run-time adjustments in complex socio-technical designs that include multiple social planes in different contexts mediated by multiple devices.

Many recent research projects in the CSCL (mobile or otherwise) field have further reduced or negated the role of teachers in supporting collaboration. Focus in these *socio-constructivist* projects has typically been on enhancing interactions in virtual environments without real-time teacher support (Dillenbourg & Jermann, 2010). However, the emergent idea of orchestration aims to supplement this approach with timely teacher support (when possible) and focuses on flexible ways of arranging collaboration (Hämäläinen & Vähäsantanen, 2011). At the same time, there is an increased interest in longer-term research projects where mobile tools are increasingly integrated into daily school activities at the curricular or practical levels (Alvarez, Alarcon, & Nussbaum, 2011; Roschelle, Rafanan, Estrella, Nussbaum, & Claro, 2010).

2.3.3 Era of social mobile learning: combining affordances of social software and mobile learning

Personal, portable and wirelessly networked technologies are becoming more prevalent in the lives of learners, while the development of social media has simultaneously led to new ideas about what it means to participate in educational activities (Lewis *et al.*, 2010; Lewis, Pea, & Rosen, 2009; Liu & Milrad, 2010; Multisilta & Milrad, 2009). Milrad and Multisilta (2009) coined the term ‘mobile social media’ to describe integration and interplay between these two emergent technologies. In its simplest form, mobile social media makes possible access to and situated updating of one’s weblog. In other words, the use of mobile social media converts students’ acts into artefacts (Roschelle & Pea, 2002). At its best, mobile social media tools can be used for creating ‘personalized-to-social learning activity’ (Wong, Chin, Tan, & Liu, 2010), where mobile devices are used as an integral part of pedagogical design consisting of individual and collective learning activities (Laru, Näykki, *et al.*, 2012).

However these outcomes are not due to the technology alone, but also to the frameworks of 'participation' and 'sharing' they enable, structure, and call upon us to enact (Jenkins, 2006), which reflect societal changes in which social software has become an important element in our culture (Lewis *et al.*, 2010). Much has been written on the benefits in education of blogs (Halic *et al.*, 2010; Hemmi *et al.*, 2009; Wheeler, 2009; Xie *et al.*, 2010), wikis (Cress & Kimmerle, 2008; Hemmi *et al.*, 2009; Leinonen, Vadén, & Suoranta, 2009; Wheeler, 2009) and social networking sites (Arnold & Paulus, 2010), but very little formal research focusing on the integration of multiple social software tools and mobile devices in higher education pedagogy has been published as of yet (Laru, Näykki, *et al.*, 2012; Uzunboylu *et al.*, 2011; Wheeler, 2009).

The interplay between Web 2.0 tools and mobile technologies is setting new challenges on supporting collaborative learning as teachers have to integrate these new technologies into more or less traditional learning methods, curricula and school's everyday life (Arvaja *et al.*, 2009). 'While educators have harnessed the web to develop formal e-learning platforms, many are struggling to unleash the power of social media to support learning. In part this is due to perceived difficulties in integrating its emergent fluid norms and meanings into highly structured learning environments' (Lewis *et al.*, 2010, p.5).

New affordances provided by the combination of mobile devices and social software tools leads us into a new phase in the evolution of technology enhanced learning, one that forges new learning spaces and continuity between pedagogical phases of the instructional design (Alvarez *et al.*, 2011; Laru, Näykki, *et al.*, 2012; L.-H. Wong & Looi, 2011). In practise, the increasing use of mobile social media in education is stitching learners' formal and informal learning contexts together and bridging individual and social learning which are leading towards seamless learning.

However, most papers considered in the extensive literature review made by L.-H. Wong and Looi (2011) tend to discuss or analyse personalized and social learning in their studies separately, or else only focus on one of these aspects. Furthermore, very few papers discuss the mechanisms of bridging the individual and collaborative activities. In this thesis, the third case study is focused on bridging individual and collaborative activities as well as face-to-face and mobile social media activities. This third case study includes a full activity design, as suggested by (L.-H. Wong & Looi, 2011), with multiple phases; the mobile mediated conceptualization activity (see Appendix III) was just one phase of the instructional design. Products created in that phase can be characterized as artefacts that were used as a mediating tool for reflections, elaborations, reviews and knowledge building (L.-H. Wong & Looi, 2011).

2.3.4 Ubiquitous tomorrow: learning environment consisting of amalgam of tools around the corner

The world is entering the Age of Mobilism (Norris & Soloway, 2011). New technology tools fit more readily and naturally our lives; increasingly wide-ranging,, inexpensive, and easy-access-to-Internet wireless devices, and a variety of web based personal publishing and social software tools are making computing a truly ubiquitous and 'continuous' part of our lives (Roush, 2005, p.49). What's important is the fact that 'essentially anyone who wants mobile device can afford to purchase one … cost is (almost) no longer a barrier to owning and operating an Internet-connected personal computing device.' (Norris & Soloway, 2011, p.4). The current adoption of mobile devices is extremely rapid: smartphone sales surpassed global PC shipments for first time in history in 2010, and are set to surpass sales of feature phones.

Ubiquitous computing has evolved from Weiser's, Kay's and Papert's initial ideas about the interplay between the human world and communication technologies with the widespread adoption of mobile devices that require proactive involvement rather than the calm computing originally suggested by Weiser. Mobile phones have grown beyond a tool for conversations to become a connected computing devices that offers a multitude of services (Ford & Leinonen, 2010; Greenfield, 2006) and which currently are perceived as much more than just as a phone, having also developed into a movie player, gaming platform, camera, etc. (Pea & Maldonado, 2006; Satyanarayanan, 2005; Squire & Dikkers, 2012). Current trends are increasingly focusing on effective personal learning environments as being characterized by an amalgam of technology devices, software, and services; access to variety of digital tools simultaneously for everyone, anywhere, anytime; and choices about which technology is most appropriate in a given situation. (Dabbagh & Kitsantas, 2011; van 't Hooft & Swan, 2007). In many techno-centric papers on context-aware technology, previous killer features – contemporary human/computer interaction paradigms (RFID tags, QR-Codes, GPS etc.) – are fast becoming regarded as mainstream in current mobile devices. Timely, contextualized information afforded by these can serve as evidence to support partially formed ideas and misunderstandings and to trigger comparison with previously stored data on the device, as well as to support an inquiry process or dialogue in situ. Actually these affordances are enabling the preparation of instructional designs based on the ideas suggested a decade ago by (Roschelle & Pea, 2002).

Western students today may have ‘one or more devices per student’ if needed, but the number of devices in the ubiquitous environment is quite variable. Indeed, device-to-user ratios range from the use of multiple computing devices (like sensors) by 1 student (10:1) to a class of students with one interactive whiteboard (1:all), and encompass the in-between usage scenarios of 1:1 (as G1:1 initiative members originally suggested), 1:2 (as in pair work sharing a device), and 1:4 (as in small group work discussions mediated by a shared device) (Dillenbourg, 2010 in L.-H. Wong & Looi, 2011). These device-user ratios set new challenges for instructional designers, because each ratio provides different dynamics of interaction and collaboration (L.-H. Wong & Looi, 2011).

In other words, different device-student ratios are an example of converged cognitive tools that we unconsciously and effortlessly use for achieving the benefits of distributed intelligence (G. Fischer & Konomi, 2007; Pea & Maldonado, 2006). From an educational perspective, this is a part of an environment in which ‘all students have access to a variety of digital devices and services, including computers connected to the Internet and mobile computing devices, whenever and wherever they need them’ (van ’t Hooft, Swan, & Cook, 2007, p.6). It is also line with the tenets of constructivism insofar as it involves a learning environment in which both teachers and students are active participants in the learning processes (critically analyzing information, creating new knowledge in a variety of ways, communicating what they have learnt) mediated by tools they have chosen and which are appropriate for particular tasks (Dabbagh & Kitsantas, 2011).

2.4 Scaffolding learning with collaborative scripts

The fact that students are nowadays regarded as ‘digital natives’ and make use of different electronic devices which are available ubiquitously does not make them good users of the media they have their disposal. In other words, according to Perkings (1993) and Salomon (1993), learners do not automatically know how to take appropriate and measured advantage of computer tools when involved in cognitive activities with them. Cognitive tools do not become an extension of human cognition, without learners’ striving for a mindful engagement in activities. Such engagement not only requires learners’ deliberate attention and effort to make use of the affordances of the tools, but also full involvement with the learning task itself (Kim & Reeves, 2007). Thus, in order to favour the emergence of productive interactions and to improve the quality of argumentation, adequate scaffolds must be provided (Dillenbourg *et al.*, 2009; Sharma & Hannafin, 2007; Weinberger, Stegmann, Fischer, & Mandl, 2007). Scaffolding makes learning more tractable for students by changing complex and difficult tasks in ways that make these tasks, accessible, manageable and within the students' zone of proximal development (ZPD) (Vygotsky, 1978).

The original concept of scaffolding addressed learning in face-to-face situations (Wood, Bruner, & Ross, 1976) where adults provided flexible scaffolding to a child. However, many of the contemporary learning approaches are based on socio-constructivist model emphasising that learning occurs in a rich social context, marked by interaction, negotiation, articulation and collaboration. Instead of a single knowledgeable person or software providing support, there are multiple ZPDs consisting of tools and resources, peers, or the learning environment itself, which can be further distinguished as distributed scaffolds (see Figure 3) (Puntambekar & Hubscher, 2005).

It is important to notice that the notion of scaffolding is in flux at the moment (Belland, 2011; Pea, 2004; Puntambekar & Hubscher, 2005). As we move into increasingly collaborative learning activities mediated and scaffolded by specific technological tools (Sharma & Hannafin, 2007; Van Joolingen, De Jong, & Dimitrakopoulou, 2007) in a variety of ill-structured problem domains and multiple learning contexts, the individualized face-to-face support as defined by Wood et. al (1976) is not possible (Belland, 2011; Puntambekar & Hubscher, 2005). In such cases, technology can provide procedural or metacognitive support for routine tasks and allow the teacher to provide dynamic support (Jonassen & Kim, 2010; Sharma & Hannafin, 2007). In general, the notion of scaffolding is now increasingly being used to describe support provided to students to learn successfully in technology-rich environments (Puntambekar & Hubscher, 2005).

Most recent research on computer supported scaffolding has been focusing on providing significant support concerning content learning with specific cognitive tools (Quintana *et al.*, 2004). Against that, more generic cognitive tools, such as social networking tools and interactive whiteboards or tabletops, are increasingly popular among educators and instructional designers (Ludvigsen & Mørch, 2010). Such tools are progressively being used in educational contexts, but are not usually specifically designed to help students engage in and gain skill at processes like problem solving, collaborative knowledge construction or inquiry learning.

Altogether, both types of tools share the notion that these rarely offer support with specific instructional guidance concerning collaboration and argumentation. Instead, both generic and specific cognitive tools (Kim & Reeves, 2007) typically provide rather open problem spaces, where learners are left to their own devices. In such spaces, learners are free to choose a) what activities to engage in with respect to problem at hand, and b) how they want to perform those activities (Kollar, Fischer, & Slotta, 2007).

Open learning spaces are an example of minimally structured learning environments, where students may struggle to become engaged in productive collaborative interactions, such as questioning, explaining and justifying opinions, reasoning, elaborating and reflecting upon their knowledge (Kobbe *et al.*, 2007). With respect to challenges in collaborative learning, Kollar, Fischer & Hesse (2006) have distinguished two classes of scaffolds: a) scaffolds that emphasise the activities of individuals by providing a higher degree of scaffolding using sentence openers, question prompts or detailed descriptions that may gradually be faded out as learners become more competent; and b) scaffolds that set-up conditions in which favourable activities and productive interaction should occur, but leave the detailed aspects of interaction unconstrained. Especially in research on computer supported collaborative learning (CSCL) such scaffolds have been called 'collaboration scripts' (the former have been referred to as 'micro-scripts' and latter as 'macro-scripts'), which, in short, are structuring and orchestration tools for enhancing the probability that productive interactions occur in a group (Dillenbourg, 2002; Dillenbourg, Jermann, Weinberger, Stegmann, & Fischer, 2004; F. Fischer *et al.*, 2007; Hämäläinen & Vähäsantanen, 2011).

Collaboration scripts are rooted in the scripted cooperation approach. In this approach, the focus is placed on the specific activities in which learners are expected to engage, whereas others leave them unspecified or vague (O'Donnell, 1999). Using scripts in education is assumed to lead to higher level cognitive processing and therefore to better learning outcomes (Kobbe *et al.*, 2007).

In this thesis, conceptual and procedural level supports are especially important, because ill-structured problem solving is a core task in all three case studies. Belland (2011) suggests guidelines for creation of scaffolds which support ill-structured problem solving tasks as follows: (a) support problem reformulation through qualitative problem modelling, (b) do not give specific end goals, (c) enable students to make comparisons between cases, and (d) have students work collaboratively ('cooperatively' in Belland's suggestion).

Collaboration scripts give appropriate tools for creating instructional designs which follow Belland's guidelines.

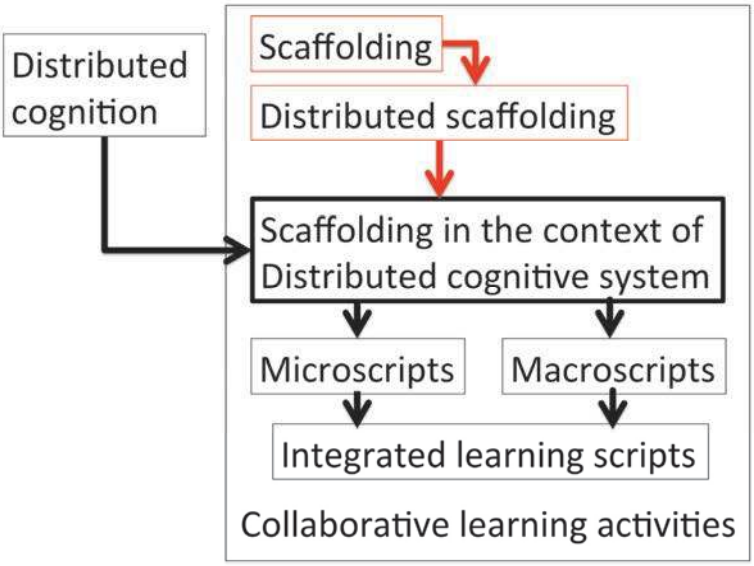

Fig. 3. Evolution of the scaffolding in the context of distributed cognitive system.

2.4.1 Interplay between external and internal scripts

In this thesis, the term 'collaborative script' refers to 'external script' which is a pedagogical scenario, the didactic artefact that students are asked to play, while the term 'internal script' describes the cognitive structure that, in many cases, existed before activities and will continue to exist after learning activities (see Kollar *et al.*, 2006). Scripts are examined through the metaphor of distributed cognition which have been argued to appropriately apply to computer based scaffolding (scripts) 'because the latter do not simply add, but fundamentally change the nature of cognition' (Belland, 2011, p. 583; Kollar *et al.*, 2006).

This view helps also to address problems of the central concept of scaffolding, called 'fading', which fits neither the idea of computer supported scaffolding (Belland, 2011; Pea, 2004) nor ill-structured problem domains which are popular in the constructivist instructional designs (Belland, 2011). Pea (2004) suggested that scaffolds that do not incorporate fading are actually a part of distributed cognition. One way to consider cognition is in terms of a process of information flow (executive function) as presented by Perkins (1993, 1995). According to this perspective, a cognitive system consist of information and an executive function(s) (see below, Section 2.1).

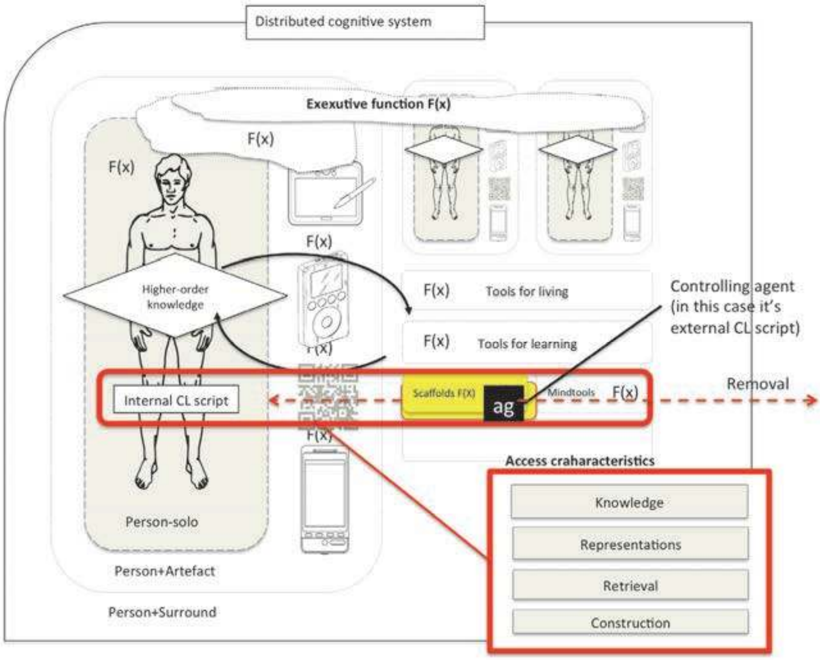

Fig. 4. Scaffolding in the distributed cognitive system.

Similar to fading, as suggested by Wood *et al.* (1976), one tool or one individual can be taken away after a distributed cognition system has operated for some time and the remaining system will be able to adjust itself (Hutchins, 1996). However, the location of the executive function affects the ability of a distributed cognitive system to adjust to the removal of an agent. In practise, the agent controlling the executive function cannot be removed without compromising the functioning of the system (Perkins, 1995). According to Belland (2011), '[T]he ultimate determinant of whether students can assume responsibility from a distributed cognition system is the extent to which they maintain throughout the executive function of the system' (p. 584), with this defined as 'making choices, operating at decision points to explore the consequences of options and select[ing] a path of action' (Perkins, 1993, p.96). If students to fail to do this, they will not be able to assume the responsibility of a scaffolded task and therefore will not be able to complete the task unaided (See Figure 4) (Belland, 2011).

From the perspective of learning resources, executive functions can include both external and internal resources that can be used to support and orchestrate interactions and task structures (Hämäläinen & Vähäsantanen, 2011). External resources are cognitive tools for learning or living as described in the section describing cognitive tools (above). At their best, these external resources are valuable in enhancing collaborative learning. According to Hämäläinen and Vähäsantanen (2011), research has mostly focused on the use of external learning resources, but a rising trend also is the use of internal resources (internal scripts). As a result, collaboration can be supported by the conflicting or complimentary interests of different group members.

Positive learning outcomes are dependent on i) metacognitive activities like the planning and control of goal setting, and ii) how the planning and control of performance is realised (Kollar *et al.*, 2006). This question can be answered from three perspectives: internal scripts, external scripts or a combination of both. First, students may have developed schemas (internal scripts) that reflect effective modes of collaboration used during prior collaborative projects (Belland, 2011; Kollar *et al.*, 2006). In the best situation, this internal knowledge about collaboration might be translated quickly into adequate collaborative actions (Kollar *et al.*, 2006). Unfortunately, it can also render scaffolding external scripts less effective or harmful if they are redundant or too highly structured compared to student's internal scripts (Belland, 2011; Kollar *et al.*, 2006). Second, if learners do not have existing scripts about collaborative learning, they may rely on knowledge represented in the external collaboration script to guide their activities which hopefully results in the group successfully solving the task. Third, if the knowledge about collaboration is not accessible in either internal or the external scripts, a system consisting of two or more individuals and external collaboration script will fail to accomplish the task (Kollar *et al.*, 2006).

In this thesis, scripts are considered as a resource (method) to be used during activities in different case studies, not as a pedagogical objective with goals to be internalized for the future. However, Dillenbourg and Jermann (2007) argue that when scripting is used as a method, the internal script is instrumental to playing the external script well. In practice, this does mean that during learning activities, each student constructs some internal script that will – to some extent – be different from the external script (see Figure 5).

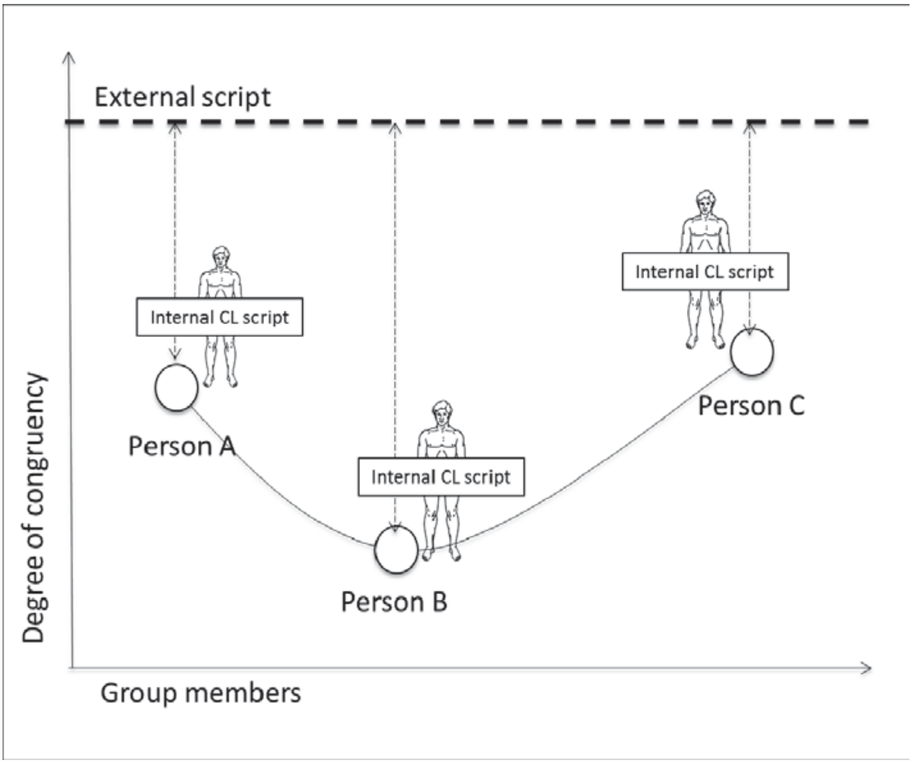

Fig. 5. Differences in internal scripts of students.

In collaborative learning contexts, the interactions that actually take place may be slightly different from those prescribed by the collaborative script. Congruence between the collaborative script and emergent interaction patterns depends upon four script features presented by Dillenbourg & Jermann (2007): the degree of coercion, the intelligibility of the script, the degree of granularity and its fit to the team distribution.

The first congruency factor is the degree of *coercion* of the script. A script may simply be conveyed through initial instructions or be regularly enforced by prompts or other design features. A high degree of coercion reduces the gap between the external script and emergent interaction patterns but increases the risk of over-scripting (Dillenbourg, 2002).

The second congruence factor is the *intelligibility of the script*. This does mean the degree of complexity of the script. Rather, learners have intelligibility problems with the script when it is too complex and if complexity cannot be reduced with the help of different scaffolds, learners do not manage to construct a clear internal script and interaction patterns will drift away from external script (Dillenbourg & Jermann, 2007).

The third factor is *granularity*, which refers to time scale (the duration of each phase) and the grain size of the phase (subtask) definition. In this thesis, the design of the third case study includes phases that last one week, while the second case study runs for four hours with phases ranging from five to thirty minutes. According to Dillenbourg & Jermann (2007), fine grained scripts tend to be more coercive. The gap between the external script and emergent interaction patterns may increase if there is a mismatch between the natural granularity of the task and granularity enforced by the script.

The fourth congruence factor, *fitness*, is important for scripts that specify a distribution of roles among group members. However, all the case studies in this thesis fall into class of the scripts which do not explicitly differentiate roles within teams (e.g. Dillenbourg & Hong, 2008). Instead, natural differences of opinions among students of the same class are used as roles. In third case study, different pictorial artefacts taken by students are used as natural differences.

2.4.2 Microscripts vs. Macroscripts

Technology enhanced learning activities are often facilitated by the design of the interface (Baker & Lund, 1997; Scardamalia & Bereiter, 1996) to establish environments that implicitly or explicitly favour the emergence of rich interactions (Dillenbourg & Hong, 2008). One approach to shaping group interactions is to design a communication tool for learning, 'for instance semi-structured interfaces, that proposes predefined speech acts in the form of buttons or sentence openers' (Dillenbourg & Hong, 2008, p.6).

These theoretically grounded cues embedded in the environment are examples of micro-scripting, which are aimed at providing additional instructional support for facilitating tasks that exceed individual learners' current levels of competence. Such scaffolds may be sentence starters, question prompts or detailed descriptions that are often considered to be gradually faded out as learners become more competent (Kollar *et al.*, 2006, 2007; Pea, 2004), although there is emerging discussion about the problems with scaffolding (Belland, 2011).

However, there are contradictory results of using semi-structured tools (Stegmann, Weinberger, & Fischer, 2007; Weinberger, Stegmann, & Fischer, 2010). The main limitation of semi-structured tools for learning and other dialogue models is that they focus mainly on the first process of collaboration, communication, although organisation/coordination and the task level/problem solving processes are equally important for successful collaborative learning (Dillenbourg, 2002). Actually, some contradictory results have shown that scripting content related activities might lead to better individual learning outcomes under relatively unscripted rather than carefully scripted conditions (Mäkitalo, Weinberger, Häkkinen, Järvelä, & Fischer, 2005).

According to Hämäläinen and Vähäsantanen (2010), research on scripting CSCL has concentrated on reviewing the connection between micro-scripts and individual learning (Kollar *et al.*, 2006; Weinberger *et al.*, 2007), whereas much less is known about the effects of macro-scripts on collaboration within groups in authentic learning contexts. This thesis focuses on macro-scripts as a pedagogical method to facilitate group collaboration in authentic settings. In general, macro-scripts take more pedagogical and top-down approach to collaboration (Kobbe *et al.*, 2007). This approach to scripting collaboration, according to Häkkinen *et al.* (2010) and Dillenbourg & Tchounikine (2007), is based on coarse-grained scripts that set up conditions under which desired activities and productive interactions between students should occur, while leaving the details of the interaction itself unconstrained.

2.4.3 Fine-tuning individual and collaborative interactions with integrated learning scripts

The design of the second study in this thesis was influenced by the development of macro-scripting in CSCL, as it was one scenario in mobile support for an integrated learning project (MOSIL).[1] This project explores ways in which technology and physical spaces might be integrated, and also how individual and

[1] http://www.noe-kaleidoscope.org/pub/researcher/activities/jeirp/activity.php?wp=14

collaborative activities might be scaffolded with the help of macro-level collaboration scripts. In this project, Dillenbourg *et al.* (2004) expanded the scope of collaboration scripts presented by Dillenbourg (2002) to encompass more than just small group interaction by introducing a concept of didactic envelope: '[W]e discriminate the *core script from its didactic envelope,* i.e. a set of pre- and post-structuring activities' (p.13). Such structuring activities (e.g. introducing the topic, reflecting on what was discussed, etc.) allow triggering the core mechanisms and enable scripts to be optimally integrated into the lesson plan and are an essential part of macro-scripting (Dillenbourg & Hong, 2008; Dillenbourg & Jermann, 2007; Dillenbourg & Tchounikine, 2007).

Macro-scripts are not restricted to either computer based activities or collaborative activities in small groups (Dillenbourg & Hong, 2008; Dillenbourg & Jermann, 2007). Instead, pedagogical design can include also individual reflection (like writing a personal weblog, Case Study III) which is required in order to transform experience into learning and collective activities (conclusive discussion at class level, Case Study II), which are important phases to structuring the informal knowledge that emerges in individual or collective phases. (Dillenbourg & Hong, 2008)

Dillenbourg & Hong (2008) have termed these scripts which are neither purely computerized nor purely collaborative 'integrated scripts'. Such scripts integrate several activities (read, summarize, etc) across multiple places (classroom, field trip) and social planes (individual, collaborative, collective) within a single workflow (Dillenbourg & Hong, 2008). However, activities (e.g. argumentation) alone do not automatically produce high-level learning (Dillenbourg, 2002). Rather, learning is affected by the ability to build new and novel knowledge and the quality of shared processes (Hämäläinen & Vähäsantanen, 2011). While collaborative learning is often defined as a process of constructing and maintaining a shared understanding (Roschelle & Teasley, 1995), the effects of group learning are more dependent on the effort exerted to develop a shared understanding despite differences among group members (Schwartz, 1995).

According to Dillenbourg and Hong (2008), macro-scripts are aimed at engineering and fine-tuning the frequency and quality of explanation, argumentation and mutual regulation that are necessary for students to develop a shared understanding. In other words, the design of a macro-script succeeds when it disturbs collaborative systems in such way that interactions are necessary between participants in order to maintain or restore collaborative actions to gain desired learning outcomes (Dillenbourg & Hong, 2008).

Dillenbourg & Hong (2008) have termed their approach to disturbing collaboration as 'Split Where Interaction Should Happen' (SWISH). They summarize it with these three axioms:

1. Learning results from interactions in which learners have to engage in order to compensate for splits introduced by a macro-script, i.e. constructing shared solution based on materials gained during individual reflections (case study III in this thesis);
2. The nature of a 'split' thus determines the nature of interactions. Interactions are mechanisms for overcoming task splits;
3. The splits can therefore – in reverse engineering – be designed to trigger the very interactions that the designer wants to foster.

Their SWISH model is pedagogical design model, a set of principles that can be used to help scaffold specific classes interaction. Because these complex multi-level activities need run-time adjustments, teachers or learning designers must permanently regulate scripted activities (Dillenbourg & Hong, 2008; Hämäläinen & Vähäsantanen, 2011). This puts the teacher back at the centre of activity for orchestrating (Dillenbourg & Jermann, 2010) scripted activities and thus challenges the teacherless approach of constructivism (Dillenbourg & Hong, 2008).

According to Dillenbourg & Hong (2008) integrated scripts and the SWISH model are not deterministic: the potential learning outcome of scripted collaboration depends on numerous parameters (e.g. the personalities of students and teachers) besides the script itself. In other words, the success of scripted collaboration depends on the interplay between internal collaboration scripts and external collaboration scripts, as described.

3 Research questions and aims

This thesis approaches emergent mobile technologies from an educational science perspective and as a cognitive tool to facilitate learning. The primary research question can be formulated as follows: *How can emergent mobile technologies be used in such way as to be pedagogically meaningful tools in complex (collaborative) learning situations?*

In order to answer this question, three specific aims are defined in relation to three case studies, thus:

1. To analyse the nature of collaboration in the mobile technology supported settings of collaborative learning (Papers I and III–IV) and work (Paper II);
2. To experiment with the kind of scaffolding of mobile computer supported collaboration that can enrich collaborative learning (Papers I, III–IV) and work (Papers I and II);
3. To find relevant methods with which to study social interaction and collaborative learning in authentic mobile computer supported activities (papers I–III).

4 Methods

Research in computer supported collaborative learning is a multidisclipinary field including socio-technical aspects and is often guided by learning design, implementation and practice. This research deals with the emergent mobile technologies and instructional design of the use of lightweight cognitive tools (Krogstie, 2010). The analytical approach used thus combines a variety of methods.

There are many different aspects to what makes for an effective design in education: success or failure cannot be simply evaluated in terms of how much students learn according to some measurement criterion (Strijbos, Martens, & Jochems, 2004). Instead, in order to evaluate dependent variables, such as climate, learning and systemic variables, it is necessary to use a variety of evaluative methods, including both qualitative and quantitative techniques (Collins, Joseph, & Bielaczyc, 2004; Wang & Hannafin, 2005). The techniques in this thesis include pre- and post-tests, interviews and surveys, interaction databases and log-files (Creswell, 1996, 2009). These combine with a goal of looking at many different aspects of the design and development of a qualitative and quantitative profile that characterizes the instructional design in practice.

All cognitive tools, pedagogical designs, and suchlike described in this thesis have been influenced by researcher participation and involvement, meaning that an action-oriented approach was used. Within this process, two other methods are used to bridge theory and practice: design based research (Design Based Research Collective, 2003) and case studies (Yin, 2003). These are presented in the following sections.

4.1 Research design of the empirical studies

The research design employed here combines characteristics from the designed based research (DBR) approach (Barab, 2006; Brown, 1992), case-study approach (Yin, 2003) and situated approach (Greeno, 2006). In this study, instructional design is developed in an iterative fashion following guidelines set by the DBR approach. From the perspective of contexts, software tools and other factors other than instructional design, all three empirical studies represent a case study approach, defined as an empirical study that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and the context are not evident (Yin, 2003). In many aspects, the situated approach is closest to the research design of this thesis, especially in its goal of understanding cognition as the interaction among participants and a tool in the context of an activity (Greeno, 2006; Hutchins, 1996). The goal of the situated approach is to understand a distributed context in terms of problem solving, planning and reasoning carried out by a group of people working with multiple technological artefacts. This goal describes also the main aim of this thesis. In addition, the types of data collected from the three case studies are records of interaction, including joint discussions, tool specific log-data and databases, and visible representations.

4.1.1 Design based research

This doctoral research has been partly carried out through setting up iterative design experiments (Brown, 1992; Collins *et al.*, 2004; Research, 2003) in different learning settings. The iterations were not explicit between the technologies used, but have tended more to the side of instructional design.

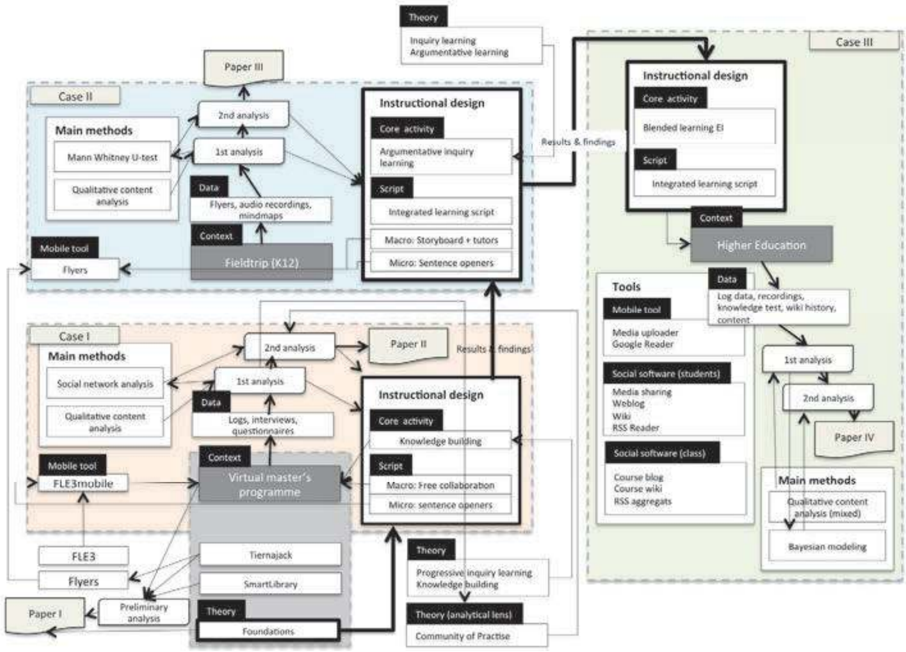

Fig. 6. Design of the study.

From the perspective of design based research, analysis was aimed at investigating participants' performance in learning and social activities, while paying attention to requirements for each iteration. In experiment design, appropriate tools for handheld computers and instructional design and practical arrangements for learning setting are designed in multidisciplinary collaboration to ensure that both technological, social and educational affordances of technologies and learning settings are taken into account. Outcomes of the design phase are to be taken into the learning setting where they will be implemented and evaluated with real participants. In this thesis, only iterations between the three empirical studies were included in the theoretical constructs and instructional design, that is, ideas distributed cognition, collaborative learning and scripted collaboration. Each case study served two purposes for the iterative development of instructional design: a) outcomes were used to guide revisions to the instructional designs and practical arrangements themselves, but also informed the selection of mobile tools; and b) outcomes also served to help researchers to understand the learning processes and how these were affected by the tools, the instructional designs and the arrangements themselves (see Figure 6).

4.1.2 Case study research

Schramm (1971) defines the essence of case study research as that of an approach which 'tries to illuminate a decision or set of decisions' related to the problem domain. This is typically attributed to practice, implementation and results. According to Yin (2003), the case study is defined as 'an empirical study that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.' The contemporary nature of the case study, combined with its practice and action oriented approach, fits well the research aims of this research study (above, Chapter 3).

Using the case study as a research strategy can be categorized according to the type of questions asked and eventual control imposed on the research settings. Based on this categorization (proposed by Yin, 2003), the case study research strategy – which deals with questions such as 'How and Why', requires control over' behavioural events' and has a 'contemporary' focus – is regarded as an experiment. Experiments used as a case-study strategy offer the researcher the possibility of full control over the activities under investigation. With regard to the features presented above, the case study is a qualitative research method and, to some extent, is associated with an action based approach and scenario based design. This characteristic of the case-study approach has been very beneficial for the research described in this thesis, since it was used as a catalyst for integrating different methods to achieve a useful approach.

4.2 Subjects and contexts

Ill-structured problem solving was a core task in all these studies. A problem in its simplest definition is a difference between the current and desired state. For example, in the first experiment a virtual team of instructional designers planned a new master's programme, the difference being between the current state (the existing programme) and desired state (the new programme). According to Jonassen (1997), problems can be either well-structured, when there is one clear solution and solution path, or ill-structured, when there are unclear problem elements and multiple possible solutions and solution paths. This thesis shares the constructivist belief that students should learn in environments that deal with 'fuzzy', ill-structured problems. There should be not one right way to reach a conclusion, and each solution may bring a new set of problems. These complex problems should be embedded in authentic tasks and activities, the kinds of situations that students would face as they apply what they are learning to the real world (Needles & Knapp, 1994).

Table 4. Scaffolding guidelines for ill-structured learning tasks.

Scaffolding guidelines (Belland, 2011)	Case study I	Case study II	Case study III
Support problem reformulation through qualitative modelling			X
Do not give specific end goals	X	X	X
Enable students to make comparison between cases		X	X
Have students work collaboratively	X	X	X

In order to support ill-structured problem solving, Belland (2011) has suggested the following guidelines for the creation of appropriate scaffolds (see Table 4):

1. Support problem reformulation through qualitative problem modelling;
2. Do not give specific end goals;
3. Enable students to make comparisons between cases;
4. Have students work collaboratively ('cooperatively').

4.2.1 Case Study I: Designing a new virtual master's programme in the context of a distance education network

This study was conducted in realistic settings with the University Learning Center, which offers distance education on information processing sciences through several retraining programmes in seven independent regional learning centres. The voluntary participants (N=10) were split into three teams at two different locations in a northern area of Finland. The participants (nine males and one female) comprised four project managers, a lecturer, a computer specialist, an educational designer and three new media designers. All participants had previous experience in working together in the same distributed organization.

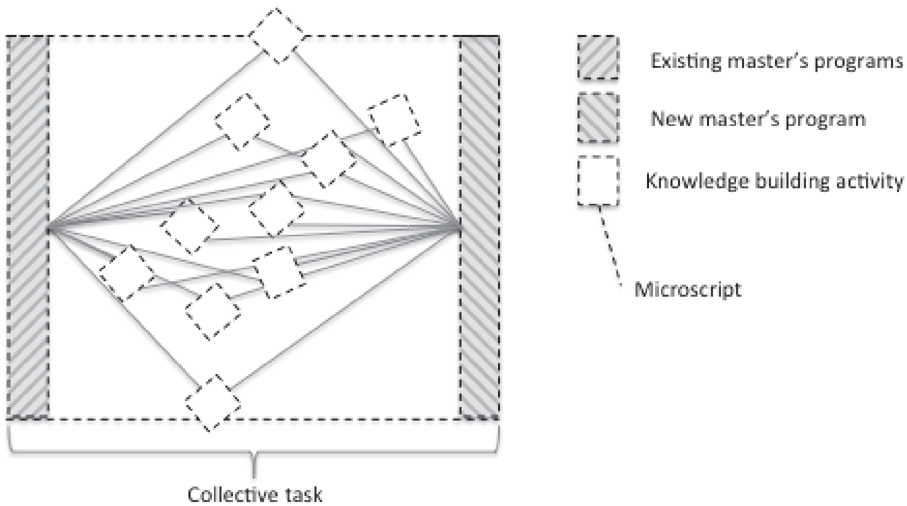

Fig. 7. Instructional design of the first case study.

In this case study (Laru & Järvelä, 2008), the participants shared a major problem, which was to design new distance education master's programme in a new domain (see Figure 7 and Appendix I). Instructional design in this first case study was simplified: a knowledge building tool was just embedded into existing practises. To design the programme, participants were offered a mobilized version collaborative technology (FLE3mobile) with dialogue model of knowledge building at their disposal. Ideas of knowledge building and progressive inquiry learning were operationalized in sentence openers, which are examples of micro-scripts. At the pedagogical level, participants were free to collaborate as they desired while designing the programme.

4.2.2 Case Study II: Field trip to a nature park in a wilderness forest setting in the context of informal K-12 education

The participants in the second case study were primary school students (n = 22, all 12 years of age) who participated in a one-day learning project during a field trip to a nature park in a wilderness forest setting in northern Finland. The field trip activities in this case study were designed and developed by the research team in collaboration with the nature park's local expert, a biologist. The students were randomly assigned to eight groups (six triads and two dyads), and each group was provided with a mobile phone. Before the experiment, the principles and procedures of collaborative inquiry learning and argumentation were presented, and practical training for the fieldtrip was given in the classroom by the researchers and the biologist.

The major problem in this study was to explore inanimate and animate traces of nature in small groups in order to create argumentative knowledge claim messages (Laru, Järvelä, *et al.*, 2012; Mosil, 2004). This study is an example of a teacher led outdoor learning activity in which students learn in groups within confined time periods, which is a subtype of 'formal learning in informal settings' (L.-H. Wong & Looi, 2011).

From the perspective of instructional design (see Figure 8 and Appendix II) a collaborative core script was aimed at scaffolding co-construction of argumentative discussions in small groups during inquiry learning. It consisted of 'soft' scaffolding (Sharma & Hannafin, 2007, p.39), provided by tutors and the nature guide, and 'hard' argumentation scaffolds, provided by the messaging tool (sentence openers). The didactic envelope included pre-structuring activities that provided procedural scaffolding in the form of storyboard messages (Laru, Järvelä, *et al.*, 2012) and post-structuring activities that included debriefing activities, such as a review and comparison phase in the collaborative and conclusive synthesis at the end of each task at the collective level. Together, these activities followed the principles presented in the design model of integrative scripting that was originally presented as a deliverable of the MOSIL project and further elaborated in later papers (Dillenbourg & Jermann, 2007; Dillenbourg *et al.*, 2004).

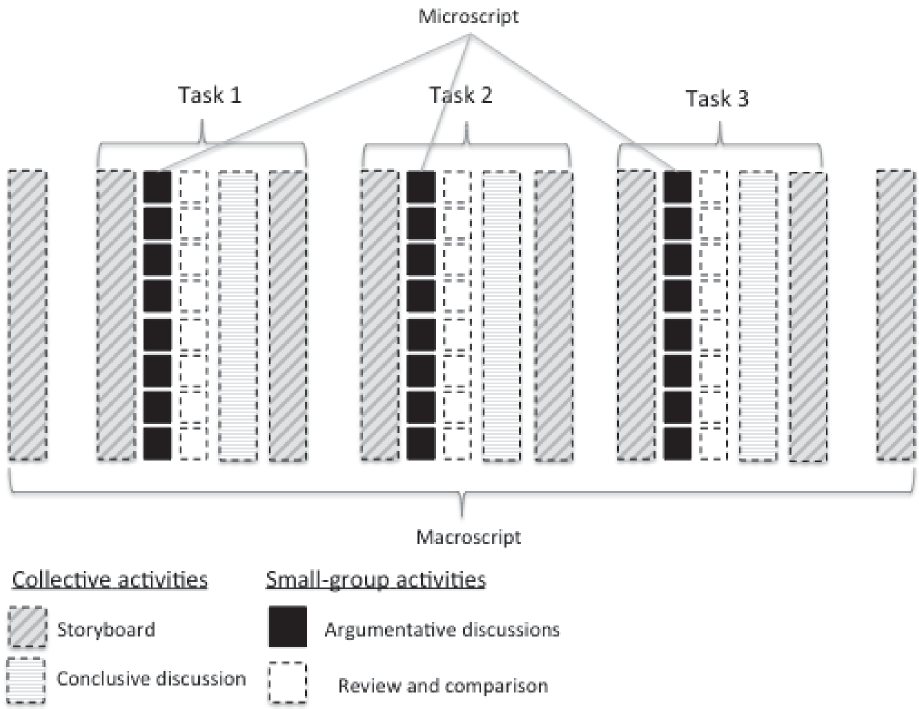

Fig. 8. Instructional design of the second case study.

4.2.3 Case Study III: Future scenarios and technologies in learning: A course in the context of higher education

For the third case study, the research participants were 21 undergraduate students in a five-year teacher education programme at the Faculty of Education in the University of Finland. All of the students were enrolled in a required course entitled *Future Scenarios and Technologies in Learning* during the spring semester of 2009. The 21 participants included 16 females (76%) and 5 males (24%). The prevalence of females reflected the gender ratio of education majors at the university. The mobile phone mediated activities in this course are an example of course related activities outside of the normal class hours, such as artefact creation in daily life (largely incidental encounters or improvisations), which is another subtype of formal learning in informal settings (L.-H. Wong & Looi, 2011).

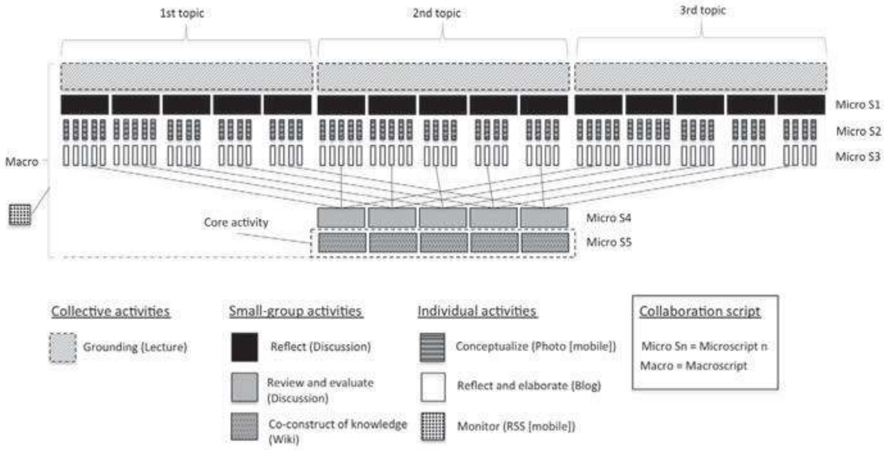

Fig. 9. Instructional design of the third case study.

In this case study, the same content was elaborated multiple times when students encountered multiple representations of each of the content topics (six altogether) using different analogues, examples and metaphors. In other words, the instructional design required students to revisit 'the same material, at different times, in rearranged contexts, for different purposes and from different conceptual perspectives' (Spiro, Feltovich, Jacobson, & Coulson, 1991, p.28). From the perspective of ill-structured problems and tasks, one problem was split into multiple smaller problem solving tasks by students as phases in the instructional design proceeded.

In this experiment, the learners' core task was to integrate selected individual blog reflections and visual representations into coherent and a comprehensive wiki (see Figure 9 and Appendix III). Although this wiki was also the main outcome of the activity (the end goal for their activities), it was not specified as such. There were also multiple individual and collective phases before the wiki activity, and the goals for these were not specified either.

The students needed to make choices in three phases concerning their learning objectives aimed at solving ill-structured problems, thus:

1. *Reflection* (collaborative): After a grounding lecture in which students discussed the lecture topic in groups and formulated a problem to be solved during the following individual learning phases;
2. *Conceptualization* (individual): Following the reflection phase, which included an activity in which students were required to conceptualize their

group members' shared interests (i.e. shared problem); this task can be considered as standalone ill-structured task which led students to qualitative modelling in order to reformulate group-level problems;

3. *Knowledge co-construction* (collaborative): An assigned task focused on integrating each group's selected blog entries and photos into a cohesive and comprehensive group wiki; this activity could not be conducted without qualitative modelling to reformulate shared learning objectives and problems, because individual activities affected the shared objectives and problems.

The instructional design of the third experiment enabled students to make comparisons between the cases. This was done both in face-to-face activities and with help of technological tools. The activities involving comparison comprised two phases:

1. *Reflection and elaboration* (individual): After individual conceptualization, students were required to analyse photos taken by mobile phones in order to discard ideas that were not relevant to their groups' shared learning objectives; they were also required to write blog entries on selected photos in which they further elaborated associations between the photos, group-level objectives and students' everyday situated practices (note: students were able to see photos taken and blog entries written by other students and in other groups by monitoring their activities with an RSS reader);
2. *Review and evaluation* (collaborative): After individual reflection and elaboration, students were tasked with reviewing group members' blogs and evaluating usefulness of blog entries in the context of their shared learning objectives.

4.3 Technological tools used in this thesis

The research articles of this study were written and published during 2004–12. Customization work of cognitive tools used as described and discussed in the articles was carried out in the years 2002–2007. Because of the close relationship between the research articles (Papers I–IV) and the tools, the latter are described briefly here, before presenting the research articles. Those tools were, in chronological order of their use:

<u>Tool I</u> *Mobile version of the Future Learning Environment 3 (FLE3)*: A modified (mobile user interface) version of a web based toolset for

collaborative knowledge building aimed at to be used in the PocketIE www-browser (Papers I–II);

Tool II *Prototype of mobile peer-to-peer messaging application (Flyer)*: An example of a social proximity application, which belongs to an emerging class of mobile networks, mobile encounter networks (MENs) (Paper III);

Tool III *Mobile Social media*: Implementation consisted of recurrent individual and collective phases in which students used multiple Web 2.0 tools and personal mobile phones in concert to perform designed tasks (Paper IV).

4.3.1 Tool I: Mobile version of the Future Learning Environment 3 (FLE3mobile)

Each participant in Case Study I was provided a Hewlett-Packard Jornada 586 handheld computer, which was equipped with wireless Internet connectivity. The tools used in the experiment consisted of the FLE3mobile (Goman & Laru, 2003; Laru & Järvelä, 2008), an experimental mobile version of FLE3mobile (*lähde*) and a proprietary software suite consisting of generic tools (Pocket Word, Pocket Excel, Pocket Internet Explorer, Pocket Outlook, MSN Messenger, Terminal Services Client, Note Taker, Voice Recorder, Calculator, File Explorer). In practise, a mobile version of FLE3 was created by adapting user interface to be compatible with html/css level restrictions of the PocketIE (www-browser of the PocketPC) (see Figure 10).

The FLE3[2] is designed to support group centred work that concentrates on creating and developing expressions of knowledge. The knowledge creation takes place in a shared working space where students carry out a progressive discourse interaction and add their knowledge artefacts to the database (Leinonen, Kligyte, Toikkanen, Pietarila, & Dean, 2003; Leinonen, Virtanen, Hakkarainen, & Kligyte, 2002; Rubens, Emans, Leinonen, Skarmeta, & Simons, 2005).

[2] FLE3 was developed by the Learning Environments for Progressive Inquiry Research Team at the UIAH Media Lab, University of Art and Design Helsinki with the Centre for Research on Network Learning and Knowledge, Department of Psychology, University of Helsinki.

Fig. 10. Left: FLE3 Right: FLE3mobile (II, published by permission of Taylor & Francis Group).

The desktop version of the FLE3 consists of three modules that are designed to facilitate collaborative knowledge building and collaborative design work: i) a virtual desktop module (webtop), ii) a knowledge building module, and iii) a Jam session module (Leinonen *et al.*, 2003; Rubens *et al.*, 2005). In the mobile version of the FLE3 tool, only webtop and knowledge building modules were activated. The knowledge building module was also the only functionality that was used in the actual experiment (Goman & Laru, 2003; Laru & Järvelä, 2003).

To help writing contributions, knowledge building discussion is scaffolded and structured by knowledge types in the form of semi-structured sentence openers, which label the thinking mode of each discussion note. In other words, the FLE3 offers a semi-structured communication interface for participants, enabling them to publish problem statements or questions, and engage in a knowledge building dialogue around these problems by posting their messages to common workspace according to predefined categories that structure the dialogue. The categories used in this study were *Question, Own explanation, Scientific explanation, Summary, Comment* and *Process comment* (Leinonen *et al.*, 2003).

4.3.2 Tool II: Prototype of mobile peer-to-peer messaging application (Flyer)

The tools used in Case Study II were smartphones and a prototype of a mobile Peer-to-Peer messaging application, called *Flyer.* Flyer is an example of a social proximity application, which belongs to an emerging class of mobile networks, mobile encounter networks (MENs). The technology used created a digital 'field' around each group by enabling their phones to broadcast information to and fetch information from nearby groups or storyboard phones (see Figures 11 & 12) directly, without, that is, connection to a network or server (cf. Volovikov *et al.*, 2008). Information in this digital realm was used to support and augment existing collaborative inquiry learning practises in real space, instead of using it as a collaboration tool per se. The application of Flyer was adapted to suit collaborative and argumentative inquiry learning by employing a design that embedded procedural and meta-cognitive scaffolding into the interface design of the system in the form of knowledge claim message templates and fixed storyboard messages. The following section describes the features of the Flyer prototype (Laru, Järvelä, *et al.*, 2012).

Creating Flyers In practise, students were asked to edit Flyer templates from saved Flyer folders (see Figure 11A). The Flyer editor allowed users to add a title, text and image and choose the background colour. In order to constrain the argumentative discussion, student groups were cued to the main components of the knowledge claim message (metacognitive scaffolding) by the templates, which specified the components in reasoning from data to claim in the form of embedded sentence openers. Furthermore, sentence openers were provided as suggestions: students were able to ignore the openers, change them, or create new ones. Suggested sentence openers were always present and available to the students through the learning phases in each template, and provided five pre-defined structural components (see Figure 11B), viz.: (Field 1) a research question for expressing group level presumptions; (Fields 2 – 4) sentence openers for knowledge claim creation (e.g., claims, grounds, warrants); and (Field 5) a photographic image (visual representation that supported the group's claim).

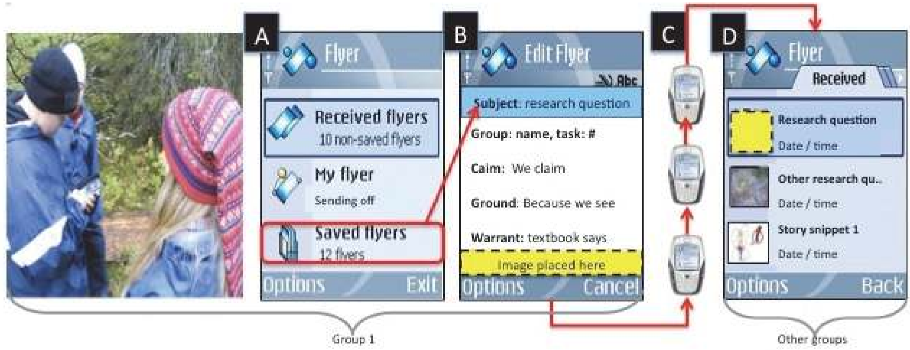

Fig. 11. Left: students working with a phone; A & B: Editing a knowledge claim message; C & D: Publishing and receiving a message (III, published by permission of Taylor & Francis Group).

Background receiving This feature scanned the environment for other Flyer users and Bluetooth devices, and presented found storyboard and knowledge claim messages in a list (Figures 12A and 11D). The list displayed the subject of the message, and the date and time the message was received. In practice, the storyboard messages functioned as activity placeholders (procedural scaffolding) for each of the four learning phases, while knowledge claim messages were artefacts created by the students. The former were automatically pushed to student groups' phones at appropriate phases or places along the nature trail before and after students' activities, and the latter were distributed to peer phones after they were published manually by the student dyads/triads.

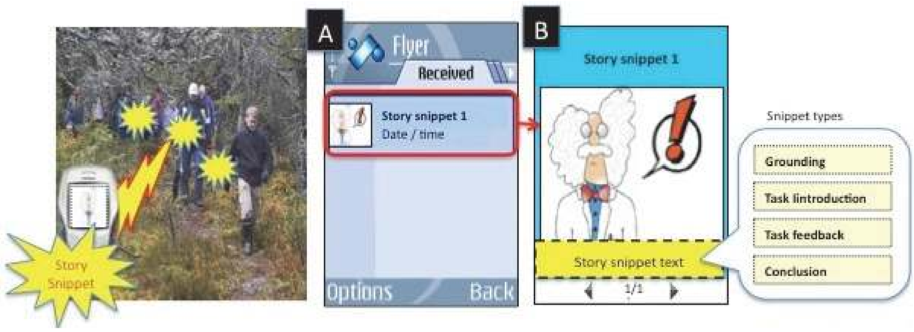

Fig. 12. Left: Pushing storyboard messages; Right (A & B): Receiving a storyboard message (III, published by permission of Taylor & Francis Group).

4.3.3 *Tool III: Using multiple social media tools and mobile phones in concert to perform learning tasks*

The socio-technical design of the second case study consisted of recurrent individual and collective phases where students used multiple Web 2.0 tools and mobile phones in concert to perform designed tasks (Figure 13) (Laru, Näykki, & Järvelä, 2009; Laru, Näykki, *et al.*, 2012).

First, all students in this case study received a personal mobile multimedia computer, which was integrated with features including a 3.2 megapixel digital camera, 3G connectivity and internet browser. The mobile device was the main tool for the students in phase C, where they were required to identify and capture situated pictorial metaphors describing their group's shared interests.

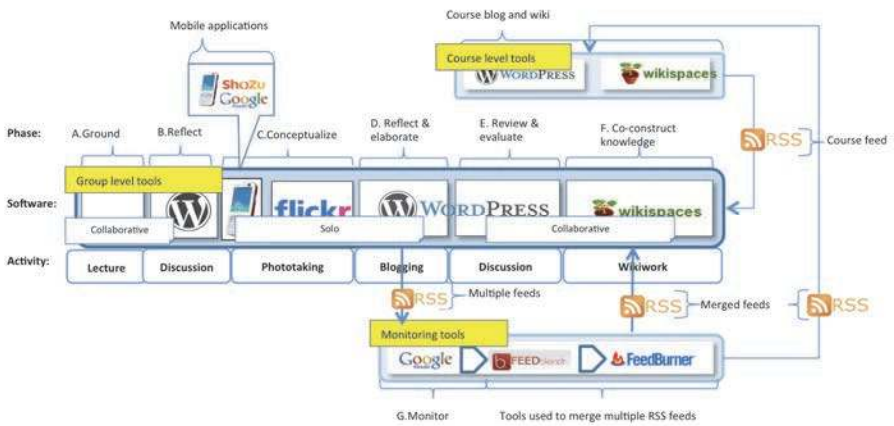

Fig. 13. Socio-technical design of the course (recurrent individual and collective phases, students using multiple Web 2.0 tools and mobile phones in concert to perform designed tasks) (IV, published by permission of ELSEVIER).

The device was equipped with a ShoZu cloud based file sharing tool which was used as a bridge to connect mobile phones to the Flickr cloud based file-sharing service for photos. ShoZu offered functions to add tags, titles and descriptions before putting photos on the Flickr photostream. In addition, the phone's web browser was configured to show students' accounts on the Google Reader Mobile cloud based RSS aggregator. This service was used to show all of the course related content on the mobile phones at the students' disposal (Figure 13).

Second, an individual Wordpress.com account was created for each student. This blogging service was used as a personal learning diary for the students, where they individually reflected further on their ideas by writing journal entries regarding the respective pictures/videos sent to blogs via the Flickr file sharing service (Phase C). The students' blogs were used to store their group's shared working problems (Phase B) and as an anchor resource in the review and evaluate phase (Phase E). In addition, the blogging service was the platform for the course level activities, a place for course related announcements.

The cloud based Wikispaces wiki service was also used for two purposes. First, it offered collaboration tools for the groups to use (i.e. an empty wiki page and discussion tool) in order to support their collaborative knowledge co-construction (Phase F). Second, it was used at course level for distributing resources (i.e. course curricula, lecture slides, hyperlinks, and how-to guides) and displaying syndicated content from Flickr (student accounts) and WordPress (course blog, student blogs).

In addition, FeedBlendr and FeedBurner RSS services were used to merge individual, group and class-level feeds from multiple Flickr, WordPress and Wikispaces accounts. In practise, these merged feeds were included as RSS widgets in a sidebar of the respective blog or wiki. These tools enabled the students to bind social software tools together and may be seen as additional collaborative tools that facilitated relationships between different task phases, the students, the content they produced and tools used in this study (Lee, Miller, & Newnham, 2008).

4.4 Data collection

This thesis consists of four papers in which three empirical experiments are reported. The research carried out consists of individual semi-structured interviews (Paper II), audio or videotaped small-group discussions (Papers II and III), log-files (Papers II, III and IV), history data (Paper IV), digital contributions (photos, flyers, blog entries etc.; all Papers), and conceptual knowledge tests (Papers III and IV). Additionally, the background information (Paper II) on the participants has been utilised to complement the other data and give contextual information about the individuals in the small groups in distributed virtual organisation.

The three case study experiments took place over a five-year period (in 2002, 2004 and 2007). According to Yin (2003), a case study research strategy can be employed multiple times and in the same problem domain. To explain this approach he proposes a 2x2 matrix, where he suggests that case studies can be holistic (with a single unit of analysis) or embedded (with multiple units of analysis). Yin’s matrix has been adopted and applied in this research, as illustrated in Figure 14. Research activities that are part of this dissertation have been designed as multiple (the three) case-study experiments, with an embedded perspective employed for their analysis. Therefore, this research approach can be placed in the lower-right quadrant of Yin’s T matrix.

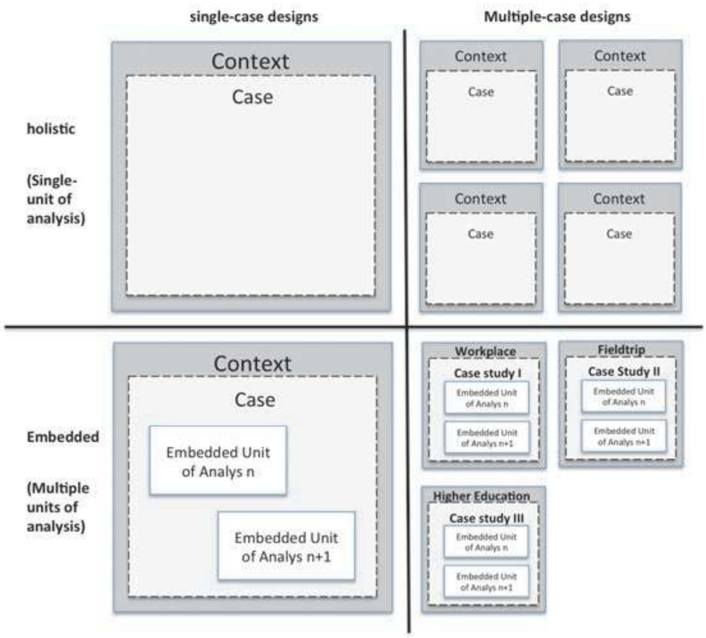

Fig. 14. Embedded research on multiple case studies (from Yin, 2003).

The cross-case analysis used in the Introduction (above) was made using with an analytical (theoretical) approach, a type of generalization in which an investigator attempts to link findings from cases to a theory (theoretical tools, models and concepts) (Schwandt, 2007; Yin, 2003). In practice, theories of distributed cognition, collaborative learning (while supported with mobile tools) and scaffolding were bridged with results of the cross-case analysis.

In the first case study (Papers I and II), the data consisted of log-files, knowledge building database and participant interviews. Summarized results of the database and log-files were used as a stimulus for participant interviews. Collected log-file data included the number of page views and logins, length of logins and the number of written and read messages. All participants were interviewed in semi-structured individual interviews which lasted for one hour, and were audio-taped and then transcribed.

The second case study (Paper III) took place in September, 2004 in the nature park in a wilderness forest setting in northern Finland. Data collection activities included audio recordings of group interactions, knowledge claim messages and pen-and-paper based mind-maps. First, the pen-and-paper mind-map task was used as a measure of the students' learning during the field trip. Second, the interaction data was drawn from transcribed digital recordings of authentic interactions during the field trip and captured by means of personal digital audio recorders and lapel microphones that students (one student per dyad/triad) wore on their pockets during the field trip. Third, all flyers were stored for latter analysis.

In the third case study (Paper IV), the edufeed learning environment was set up in spring 2007 using Cloud based social software and mobile social media tools. Again, the plans for the experiment were ambitious, this time in relation to the research design and data collection. The data was composed of video recordings, social software usage activity and pre- and post-tests of students' conceptual understanding. First, social software usage activity data was collected through multiple sources. Such variables described student-level activities, like photo taking, blogging, wiki editing and rss reading. Second, to assess their conceptual understanding, the students were required to complete identical pen-and-paper pre- and post-tests with a pre-test/post-test quasi-experimental design. Specifically, the conceptual-knowledge measure consisted of six constructed response questions that were developed based on the key concepts of the course. Third, video recordings were used to capture each group's six collaborative reflection sessions and two collaborative reviewing and evaluation sessions.

4.5 Analytical framework

The main analytical framework in this multiple study involved a qualitative case-study approach consisting of multiple the three case-study experiments with an embedded perspective of unit of analysis. In practice, a mixed method approach was used to analyse the subunits of each case. The main unit was the cases as whole, while the smallest unit was the individual member. In practice, such subunits consisted of pre- and post-tests, databases, interviews, log-files, transcribed discussions etc. Because the research design of this thesis combines characteristics from the design based research (DBR) approach (Barab, 2006; Brown, 1992), Case-study approach (Yin, 2003) and situated approach (Greeno, 2006) each case study provided information about performance on learning and social activities which was further used in the iterative development of instructional design and as a basis when choosing tools for next case study.

The data collected from subunits, that is, the real, collaborative activities, may be referred to as 'messy data' (e.g. log-files, interviews and videos). However, there is an increasing need to gather this type of data in the areas of education and cognitive science. Traditional methods seem inadequate to handle data gathered from complex activities in their natural surroundings (Chi, 1997). In this thesis, these problems were tackled by starting with qualitative analyses and then continuing with quantitative methods in the further analyses.

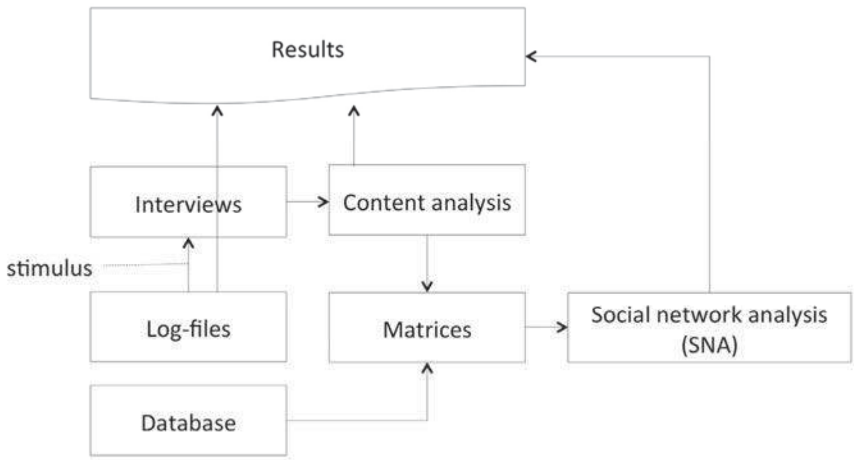

Fig. 15. Analytical framework of the first case study.

Content analysis, is a research technique for making replicable and valid interferences from data to their context (Krippendorff, 2004) which has largely been adapted as a method for studying social interaction in CSCL contexts

(Strijbos, Martens, Prins, & Jochems, 2006). The central idea in content analysis is to classify many words into fewer content categories. Words, phrases or other units of data, which are presumed to have similar meanings, are classified into the same category, and the occurrences in each category are counted later (Tesch, 1990; Weber, 1990). The categories in the empirical studies of this thesis were either data (Papers I, II and IV) or theory driven (Papers III and IV). The first categorization method means that the categories arose from the data, and the second that the categories were established in the theoretical framework of collaborative learning and CSCL.

The units of content analysis, a central characteristic of the content analytic approach, were chosen on the basis of the type of data in each empirical study. For verbal data, the defining cut can occur at many points (Chi, 1997). In the interview data (Paper II), a natural choice for the unit of analysis was one answer. The relatively slow paced face-to-face discussion data (Papers III and IV), consisting of longer elaborations from individual students in small groups, was analysed based on the non-content features (turn taking).

In the first case study (Papers I and II), the first analysis was made of the FLE3mobile log-files in order to use these results as stimulus for participant interviews. Qualitative data collected from the interviews was then used to characterize network data for quantitative social network analysis (SNA), and also to characterize the participants' work practices, as well as technologies they used to support their work and collaboration. In the following quantitative phase of the analysis, information retrieved from the interviews and the databases was used to identify and compare underlying patterns in the data of social relations in face-to-face (workplace) and virtual networks (mobile supported workplace) using SNA methods (see Figure 15) (Liebowitz, 2007; Scott, 1991; Wasserman & Faust, 1994).

In the second case study (Paper III), content analysis was used to investigate the extent to which learners were jointly engaged in collaborative inquiry learning during the different task phases (see Figure 16). This was done by analysing transcribed audio recordings of authentic interactions during the field trip. On-task activities were further segmented in order to reveal the division of the argumentation into the respective phases. Second, transcripts were further analysed using categories of social modes of co-construction, which were developed originally as a framework for argumentative knowledge construction. In addition to that, both structural components and epistemological nature of the knowledge claim messages were analysed against the condensed argument model. (Weinberger & Fischer, 2006)

The second case study included also multiple quantitative analysis techniques. First, a mindmap task was used as a measure of content knowledge. Mindmaps were scored by two raters using a scoring rubric that employed both erroneous and correct associations. Next, average mindmap scores were used to identify top-performing and low-performing groups for further qualitative analysis, as described (above). Contrasting the activities and artefacts of top-performers with those of low performers is intuitively appealing (Jonassen, Tessmer, & Hannum, 1999), and has been shown to reveal important characteristics and aspects that are not uncovered by using other approaches (Wyman & Randel, 1999). Specifically, this analysis focused on group differences in collaborative argumentation activities. Inter-group differences were analysed by non-parametric Mann-Whitney *U*-tests (Gliner & Morgan, 2000).

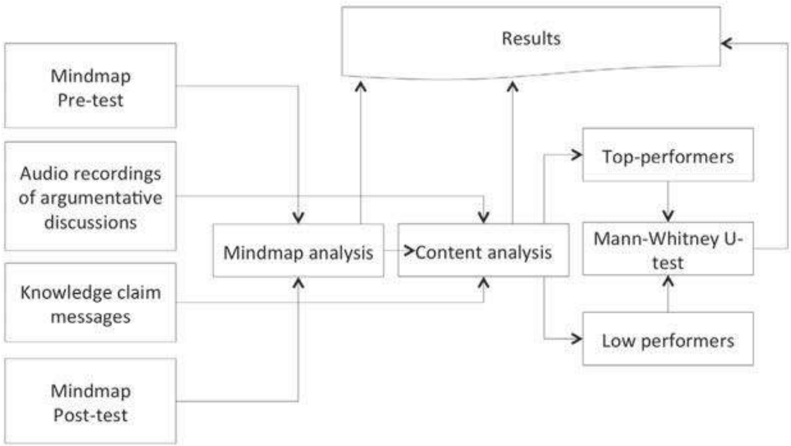

Fig. 16. Analytical framework of the second case study.

The third case study (Paper IV) included multiple phases where qualitative content analysis techniques were used (see Figure 17). First, results of the conceptual knowledge tests were analysed using a data driven categorization system, which was developed by three independent researchers. In the next stage, video data transcripts were analysed in order to clarify individual students' activity levels in collaborative face-to-face assignments. The analysis was adapted from the method that focuses on the duration of on-task and off-task episodes (see Järvelä, Veermans, & Leinonen, 2008). In the third stage, all social media usage except RSS-feeds was coded by using on-task and off-task categories as the basis for analysis. This was done in order to separate real activities from additional content (e.g. test blog entries or sample photos). Fourth, activity measures of students' wiki usage were categorized by using adds and deletes as coding categories for cumulative wiki history data.

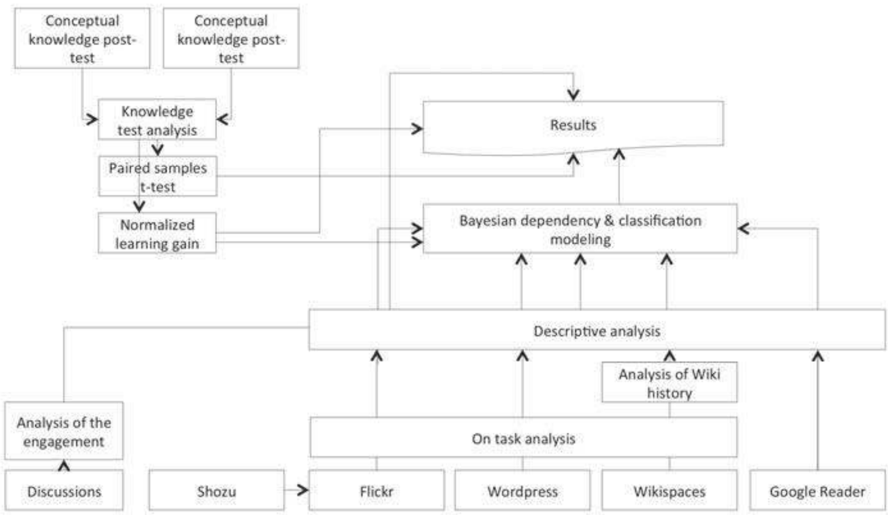

Fig. 17. Analytical framework of the third case study.

As in the other case studies (above), multiple quantitative techniques were used in the third case study. First, to analyse the learning outcomes through the pre-test/post-test scores, a paired samples t-test was conducted, and a normalized learning gain was calculated (Hake, 1998). Next, the average normalized gain score was used to identify high-performing and low-performing students for further explorative Bayesian analysis (Jensen, 2001), for similar reasons to those described in the context of second case study. In the second stage, a descriptive analysis was carried out for all the variables in the course design. First, the average values of an individual student's face-to-face and social software activities were calculated for Bayesian analysis. Second, the mean, standard deviation and max-min values for all students were calculated in order to assist in the interpretation of the results of Bayesian classification modelling and to provide an overview of the students' activities during the course. In the third stage, Bayesian analysis was conducted to study the probabilistic dependencies between the variables. In practice, the analysis was conducted with the web based online data analysis tool B-Course, which allowed users to analyse their data using two different techniques, Bayesian dependency and classification modelling.

4.6 Issues of the validity and reliability of the study

There are several ways to improve the validity of a study. To improve external validity (or externalization) of the findings in the case study approach, one can undertake multiple case studies to identify general patterns. However, as suggested by Khan (2008), positivist notions of generalizability have been largely abandoned or modified in case study research, and instead new concepts have emerged to extend and amplify the impact of a single case beyond the case itself (Becker, 1990; Yin, 2003).

The case studies in this thesis were limited by the single-case design and the lack of other student groups completing the same socio-technical design. The rationale for the single-case design has been that all cases are revelatory cases (Yin, 2003). In practice, case studies have been rare contributions following the Gartner hype cycle of emerging products (above, Section 3.2). Furthermore, all studies used embedded multiple units of analysis in order to collect and analyse multiple activities and tools in the respective cases, which raises concerns of a small sample size within subunits in the cases (Yin, 2003). To overcome problems raised by the relatively small sample sizes in the studies, data were analysed by using approaches which do not have limits with small sample sizes or skewed distributions (Gliner & Morgan, 2000; Jensen, 2001).

Furthermore, cross-case analysis was made by using an analytic approach to bridge the single case studies. This theoretical approach is type of generalization in which inquirer attempts to link findings from cases to a theory (theoretical tools, models and concepts). (Schwandt, 2007). Although it is argued that findings of the case studies cannot be generalized in a probabilistic sense, findings from case studies may still be relevant to other contexts (Khan & VanWynsberghe, 2008). Two approaches relevant to this thesis are comparability and translability. The former means the degree to which the parts of a study are sufficiently well described and defined that that other researchers can use the results of the study as a basis for comparison. The latter approach differs by referring to the importance of a clear description of theoretical perspective and research techniques.

However, Khan & VanWynsberghe (2008) have recognized three practical concerns for cross-case analysis. The first is the need to preserve the uniqueness of cases. In this thesis, ample contextualized details of the cases and cross-case analysis are provided in which both are considered important (Stake, 2006). The second issue is contextual stripping in cross-case analysis, where the contextual origins are in danger of being lost as cases are compared. However, according to (Ayres, Kavanaugh, & Knafl, 2003), losing some contextual detail may be consistent with the goals of cross-case analysis. The third issue concerns the selection of cases and their corresponding units of analyses, both of which are important methodological considerations in the case study comparisons. Cases chosen into case oriented comparison represents insights into aspects of doctoral studies, but also into development of mobile computer supported collaborative learning as general. This approach was chosen because it allows comparison of a low number cases without needs for similarities between them (Khan & VanWynsberghe, 2008).

In order to ensure internal validity, triangulation (Stake, 2003) was used throughout the thesis process by having multiple data sources and a mixed method approach for analysing and confirm the findings. The triangulation in this thesis is done in three ways: firstly, by integrating the outcomes of one (or more) methods into the following method; secondly, the summary tables produced during content analysis of the FLE3mobile (Case I) were used as stimulus during the interviews in which participants were asked to reflect on patterns showing non-participating behaviour in the FLE3mobile; and thirdly, by using the outcomes of one method to interpret and contextualize the outcomes of another method, for example, by relating analysis of the argumentative discussions with the quality of knowledge claim fliers. The forms of triangulation used in this thesis are referred to as 'data' (gathering data at different times) and 'methodological' (using more than one method to gather data) triangulation.

4.7 Evaluation of ethical issues

Within this study, the guidelines of the (National Advisory Board on Research Ethics, 2002) were followed. The study followed modes of action endorsed by the research community, that is, integrity, meticulousness and accuracy in conducting research, in recording and presenting results, and in judging research. As regards data collection also, ethical issues were taken into consideration: all of the participants in the three case studies were volunteers and prior to the experiments they were thoroughly informed about what would happen during the experiments. All participants were also told the aims of the particular study, data collection methods and methods of reporting. All participants were asked to sign written permission for their participation (including parent/guardian permission with students under 18 years (Paper III)). None of participants were given extra credits or paid for their participation. Privacy issues were also considered, so it is not possible to identify participants in the reporting of the cases in respective papers (pseudonyms are used). The collected data will be archived at the Department of Educational Sciences, University of Oulu.

Other researchers' work and achievements are referred to with good scientific practice. The sources of financing and other associations relevant to the conduct of research were made known to participants and reported in published articles (Papers III and IV) and in the summary of the study. To sum up, this study was planned, conducted and analysed (see Summary and Papers I–IV) according to the standards set for scientific knowledge (National Advisory Board on Research Ethics (2002)).

5 An overview of the empirical studies

5.1 Laru, J. & Järvelä, S. (2004). Scaffolding different learning activities with mobile tools in three everyday contexts.

The aim of this study is to apply the theoretical framework of collaborative learning and distributed cognition for developing mobile tools that scaffold people's everyday learning and information searching and processing needs. It includes experimental case studies conducted in natural settings with randomly sampled or conveniently selected subjects. The contexts of the case studies varied from the urban pedestrian street to the main library of the university. Both qualitative and quantitative methods and multiple data collection techniques were used to acquire information how these tools could be used for scaffolding everyday activities in different contexts. Multiple contexts give a more accurate picture how mobile devices can be used as cognitive tools to scaffold activities from collaboration to topical information delivery. Preliminary results show that subjects used mobile devices as cognitive tools with versatility, but not always in the manner that researchers expected.

Publication: In P. Gerjets, P. A. Kirschner, J. Elen & R. Joiner (Eds.), *Instructional design for effective and enjoyable computer-supported learning. Proceedings of the EARLI SIGs Instructional Design and Learning and Instruction with Computers* (pp.11–21). Tübingen: Knowledge Media Research Center.

5.2 Laru, J., & Järvelä, S. (2008). Social patterns in mobile technology mediated collaboration among members of the professional distance education community.

The aim of this study was to identify social patterns in mobile technology mediated collaboration among distributed members of the professional distance education community. Ten participants worked for twelve weeks designing a master's programme in information sciences. The participants' mobile technology usage activity and interview data were first analysed for an overview of the density and distribution of collaboration at individual and community levels. Second, the results of the social network analyses were interpreted to explore how different social network patterns of relationships affect online and offline interactions. Third, qualitative descriptions of participant teamwork were analysed to provide practical examples and explanations. Overall, the analyses revealed non-participative behaviour within the online community. The social network analysis revealed structural holes and sparse collaboration among participants in the offline community. It was found that due to their separated practices in the offline community, participants did not have a need for mobile collaboration tools in their practices.

Publication: *Educational Media International, 45*(1), 17–32

5.3 Laru, J., Järvelä, S. & Clariana, R. (2012). Supporting collaborative inquiry during a biology field trip with mobile peer-to-peer tools for learning: a case study with K-12 learners.

This study explores how collaborative inquiry learning can be supported with multiple scaffolding agents in a real-life field trip context. In practice, a mobile peer-to-peer messaging tool provided meta-cognitive and procedural support, while tutors and a nature guide provided more dynamic scaffolding in order to support argumentative discussions between groups of students during the co-creation of knowledge claims. The aim of the analysis was to identify and compare top- and low-performing dyads/triads in order to reveal the differences regarding their co-construction of arguments while creating knowledge claims. Although the results revealed several shortcomings in the types of argumentation, differences between the top performers and low performers were found to be statistically significant in terms of social modes of argumentation, the use of warrants in the mobile tool and in overall participation. In general, the use of the mobile tool likely promoted important interaction during inquiry learning, but led to superficial epistemological quality in the knowledge claim messages.

Publication: Interactive Learning Environments, 20*(2), 103–117*

5.4 Laru, J., Näykki, P. & Järvelä, S. (2012). Supporting small-group learning using multiple Web 2.0 tools: A case study in the higher education context.

In this single-case study, small groups of learners were supported by use of multiple social software tools and face-to-face activities in the context of higher education. The aim of the study was to explore how designed learning activities contribute to students' learning outcomes by studying probabilistic dependencies between the variables. An explorative Bayesian classification analysis revealed that the best predictors of good learning outcomes were wiki related activities. According to the Bayesian dependency model, students who were active in conceptualizing issues by taking photos were also active blog reflectors and collaborative knowledge builders in their groups. In general, the results indicated that interaction between individual and collective actions tended to increase individual knowledge acquisition during the course.

Publication: *The Internet and Higher Education, 15*(1), 29–38

6 Cross-case analysis and main findings

The aim of this section is to provide a detailed analysis of the main outcomes of the three experimental case studies presented in the previous chapter. These results have been analyzed from a cross-case perspective in order to present how each one of the experimental case studies has contributed to the main outcomes of this thesis. Outcomes of the experiments and the accompanied publications described in the previous chapters have been conducted over a period of five years. Figure 18 illustrates the ways in which these efforts have been conducted and how outcomes of the different activities are connected together in order to provide convincing arguments to answer the main question explored in this thesis.

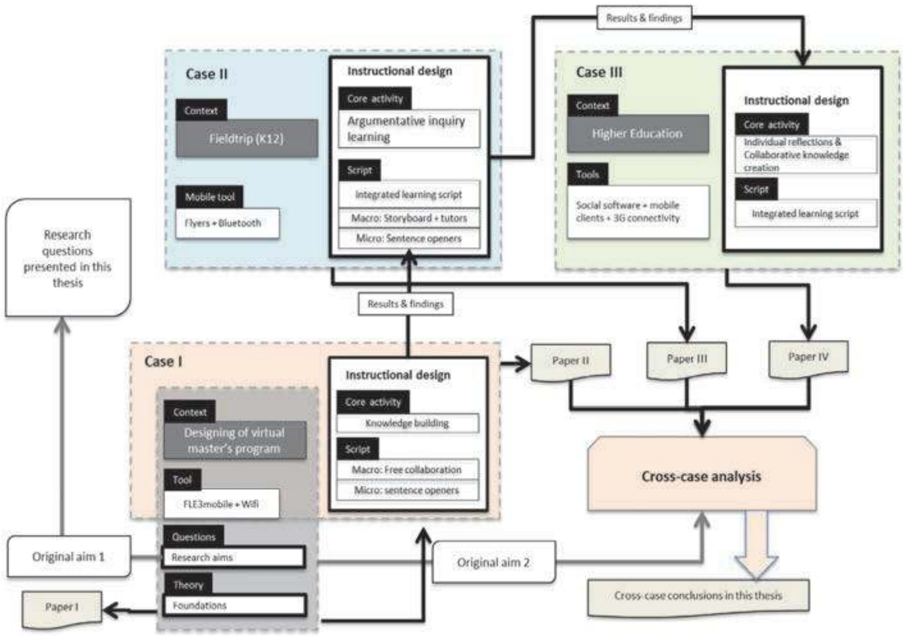

Fig. 18. Overview of research activities.

Figure 18 (above) describing the organisation of research activities for this dissertation has been inspired by Yin's (2003) suggestions regarding a multiple case study research strategy. The results of each experimental case study have been accompanied by an individual report in the form of a scientific publication.

The initial publications (Papers I and II) are connected to the Smartrotuaari project and FLE3mobile experiment. Paper I describes the initial explorations in my research endeavours, but also lays the basic foundations, both theoretical and empirical, for this thesis. Regarding the former, instructional design has been informed by same theoretical framework throughout the study, although there are differences between the cases (the general focus, as described in Chapter 4); regarding the latter, the first study case study was used as an analytical approach, though initially this was not fully appreciated. In the first phases of the research, it was believed that experiments were exclusively based on the design based approach, but in the later phases of the research, ideas of the case study and case comparison were adopted into research design.

Three empirical publications were published as an outcome of the case studies. The second publication (Paper II) is related to the FLE3mobile experiment and especially aimed at exploring the reasons behind non-participative behaviour (the first research aim, as described in Chapter 3). Paper III was related to the MOSIL (Mobile support for integrated learning) project and therefore included a fine-grained instructional design which was inspired by the ideas of the integrated scripting discussed in the project (the second research aim, as described in Chapter 2). The quality of co-construction of knowledge and quality of knowledge claim fliers, meanwhile, were analysed together with the mindmap task (the first research aim, as described in Chapter 3). The last paper (Paper IV) related to the Score-project and its instructional design was an iteration cycle from the ideas developed in the previous experiment (the second research aim). In this experiment, probabilistic dependencies between a conceptual knowledge test, social media use, individual weblog activities, collaborative knowledge building in the wiki and interaction in the face-to-face settings were analysed (the first research aim). In all of these publications (except for Paper I), methodological experiments were performed in order to find the best methods for analysing particular interactions in each case (the research third aim).

The evolution of this research process provides a clear indication as to how initial research ideas progressed; from the free collaboration with mobiles supported only with embedded scaffolds (micro-scripting) to the distributed scaffolding (macro-scripting) and ideas of integrated learning where a mobile device is just one agent in the system of the actors and tools (as elaborated in the MOSIL project in 2004), and thereafter developed towards the elaboration of the idea of complex designs, where multiple tools, social planes and contexts are integrated in learning activities (following ideas presented by Dillenbourg &

Jermann, 2006). However, ideas of collaborative scripting are not explicitly visible in the publications, because this was as an idea that emerged during the period of the research. Mentions of collaborative scripting were removed in Paper III after the peer-review process for publication. In the fourth paper, aimed for publication in the Web 2.0 special issue, were ideas of scripting in the core of the manuscript, where instead, theories of reflections in the blogs and collaboration in the wikis were elaborated. The instructional design based on the ideas of integrated scripting and the SWISH framework as presented by Dillenbourg & Jermann (2006) and Dillenbourg & Hong (2008) was carefully described in the paper without mention of the scripting.

The ideas of collaborative learning, distributed cognition and cognitive tools have stayed unchanged from my master's thesis completed in the 2003 (Goman & Laru, 2003), though elaborated many times since. Yet, it is important to notice that in each case study, a different collaborative learning approach was used: in the first study it was collaborative knowledge building, in the second it was argumentative inquiry learning and in the third, individual reflections and collaborative knowledge creation. It is also important to note the differences in the slight adjustments between the theoretical approaches in the case studies, that while the first and third case studies were based on a socio-cognitive approach, the second relied on a socio-cultural orientation. Original ideas were based on socio-cognitive approach also in this case, but non-participative behaviour among participants and their work related practices in their virtual master's programme led to the exploration of reasons for that by using ideas of community of perspective as an analytical lens. Ideas of community of practice are not further extended in this thesis, and results are examined only at the level what social network analysis revealed about the structure of the organisation and what interviewed participants said about their relationships with the tools they used to support their work practices.

6.1 Supporting collaborative learning with mobile cognitive tools

The case studies constituting this thesis represent the first three generations of educational use of the mobile tools described in the section on emergent technologies (Chapter 2). This development has seen the understanding of the educational use of mobile tools refined. Initially, and at the beginning of the history of this thesis, early adopters were experimenting with technological possibilities and mainly explorative research reports were available. In this thesis, to comprehend the purely educational value of mobile devices, these were both considered as cognitive tools (Case Studies I–III), but also integrated with other learning activities (Case Studies II and III). The first case study was conducted during the dawn of this field, when mobile devices were seen as little more than devices for person-to-person communication (Nyiri, 2002) or platforms for the dissemination of knowledge (Herrington, Herrington, Mantei, Olney, & Ferry, 2009). However, technological developments enabled mobile devices to gradually become versatile cognitive tools, which had rich educational possibilities. Therefore many contemporary researchers have argued that the educational use of emergent mobile devices has technological attributes, which provide unique technological, social and pedagogical affordances (above, the first section of Chapter 2).

In order to compare cognitive tools used in the different case studies here, the studies are mapped according to the three distinct levels listing of affordances based on their division into technological, social and pedagogical (see Table 5).

Table 5. Mapping case studies according affordances.

Case	Type of affordance	Roschelle & Pea (2002)	Klopfer & Squire (2008)	Looi *et al.* (2009)
Case Study I	Technological		(Connectivity, Portability)	
	Social		Social interactivity	
	Pedagogical			
Case Study II	Technological	Augments physical space with information exchanges	Connectivity Portability Context sensitivity	Multimodality
	Social		Social interactivity	Supports creation and sharing of artefacts on the move
	Pedagogical	Situates teacher as conductor of activity. Uses students' actions as artefacts for discussion		
Case Study III	Technological		Connectivity Portability	Multimodality
	Social	Aggregates individual participation into	Social interactivity (in the following phases)	Supports creation and sharing of artefacts on

Case	Type of affordance	Roschelle & Pea (2002)	Klopfer & Squire (2008)	Looi *et al.* (2009)
		group reflection opportunities		the move Supports student improvisation in situ
	Pedagogical	(Situates teacher as conductor of activity) Uses students' actions as artefacts for discussion		Multiple entry points and multiple learning paths

In the second case study, Flyer software was adapted for educational use by creating storyboard flyers and argument templates with sentence openers aimed at scaffolding learners' activities in the field trip. These modifications together with instructional design were used to transform a tool for living (an off-the-shelf version of the flyers) into tool for learning (a mindtool when equipped with knowledge argumentation templates and storyboard flyers). The duration of the activity (four hours) limited students' interest to exploring fingertip applications (tools for living) on their phones, so the many other applications were made unavailable (games, etc. were removed by the researchers).

In this case, Flyer technology enabled activities (Paper III) in which *physical space was augmented with information* exchanges (Roschelle & Pea, 2002). In practice, these exchanges were facilitated by using special mobile encounter networks. On the other hand, the technology used limited *connectivity* to the immediately context of the inquiry learning activities: the Bluetooth network was only available in the close proximity of participants (participants' phones) and the learning context (hidden phones). However, portability was not limited by the network, because created argumentation messages (flyers) were broadcast on the network when participants came into the proximity of other devices. All activities were situated by their nature, because of the field trip as learning context. This enabled students to *create and share their knowledge claim messages* on the move and also *supported improvisation in situ*. Furthermore, functions of the flyers tool enabled *multimodal* learning activities (Looi *et al.*, 2009), in which students created contextual demonstrations of their arguments by taking task related pictures in addition to writing knowledge claim flyers. This learning design had a comparison phase, in which student *group actions were used as material for case comparison* in the discussions.

Table 6. Cognitive tools used in the case studies.

Case study	Device	Connectivity	First-order fingertip tools (tools for living)	Mindtools (tools for learning)
I	PocketPC	WiFi (indoors)	Pocket Word, Pocket Excel, Pocket Internet Explorer, Pocket Outlook, MSN Messenger, Terminal Services Client, Note Taker, Voice Recorder, Calculator, File Explorer	FLE3mobile
II	Smartphone	Bluetooth based mobile encounter network (MEN)	Flyers (off-the-shelf version)	Flyers (with templates, storyboard flyers and instructional design)
III	Smartphone	Gprs (2.5G)	Shozu Flickr Google Reader	Shozu (with instructional design) Flickr Google Reader Wordpress Wikispaces

In the third study, off-the-shelf mobile and social media (Web 2.0) tools were used without any templates or other customization. Wikispaces and wordpress tools can be considered already tools for learning (mindtools) while other used tools were more or less first-order fingertip tools for living. However, sequential and structured instructional design was used as method to use all the tools as mindtools. In practice, that meant that Shozu was used as a tool for conceptualizing group's shared problems and in the next step, the Flickr filesharing service was used as a reflection tool together with the Wordpress-blogging platform. From the perspective of the distributed cognitive system, learner(s) and tool(s) together formed the executive function in order to complete the tasks as designed.

The third case study was conducted in the phase of the mobile social media (see the third section of Chapter 2). Affordances provided by mobile devices and software were further extended with the interplay between social media and mobile software. *Connectivity* and *portability* issues recognised in the above were solved in the third case by using smartphones equipped with 2.5G mobile Internet connections. A combination of the social media tools and mobile devices enabled the creation of sequential learning experiences in which mobile devices were a part of social interactions (social interactivity) that were richer than would have been possible using only mobile devices and tools.

The mobile tool used enabled participants to publish images and videos together with small descriptions and tags onto file-sharing services for further reflections and usage. In practice, this supported *the creation and sharing of artefacts on the move* on students' public weblogs. All participating students knew that the pictorial representations they were to create would be presented to a 'wider audience', that is, not only their peers in their respective groups, but everyone who had an interest in their products through their final wiki article. This is an example of 'audience effect', which has been shown to motivate students to produce higher quality artefacts (Looi et. al, 2009). This 'conceptualize' subtask was partly afforded by the small size and portability of the smartphones, but also reinforced by the instructional design which *supported student improvisations in situ*. In practice, students were asked to improvise when they tried to conceptualize their shared working problem by taking photos from their everyday contexts.

Many activities in the third case study included also *multiple entry points and multiple learning paths*. For example, in the individual conceptualization phase students were able to elaborate and reflect their findings (photos taken by students) i) directly in the mobile phone, ii) in the Flickr file-sharing service, and iii) in their personal weblogs. Students had also two face-to-face meetings and wiki article subtasks that they had considerable freedom to decide how to complete.

Furthermore, all photos, blog entries, wiki edits and suchlike created by the students were further used as artefacts *for personal reflections and small group discussions* in different phases of the instructional design. In addition, these outcomes of individual and group participation were also aggregated by using Really Simple Syndication (RSS) and were available for both individual monitoring and collective reflection opportunities at the group level.

6.2 Scaffolding ill-structured learning tasks with collaborative scripts

This thesis is built on the research carried out in the CSCL field to show that in mobile computer supported collaborative learning situations, the key to learning is not the technology support used but the nature of the collaborative task. In practice, ill-structured problem solving was a core task in all the case studies included here (Jonassen, 2002). The instructional design of the case studies is compared by using the scaffolding guidelines provided by Belland (2011) and ideas of integrated scripting by (Dillenbourg, 2002; Dillenbourg & Jermann, 2007).

In the first case study, the instructional design philosophy was to embed a new tool into existing practises by offering a mobilized version of collaborative technology (the FLE3mobile) with a dialogue model of knowledge building. At the pedagogical level, activities were not structured, and instead participants were free to collaborate at a collective level in the ways they desired with the help of PocketPC mobile devices. Although participants were *not given specific end goals*, and thus were able to select their own paths of action – and collaborative knowledge building facilitated student choices regarding strategy, exploration of the consequences of those choices and selection of a path of action – all results revealed non-participative behaviour among participants.

Interviews revealed that the internal collaborative scripts of adult participants conflicted with the model of progressive inquiry and collaborative knowledge building (see Kollar *et al.*, 2006, 2007). In this example, internal knowledge about collaborative work practices rendered scaffolding external scripts less powerful because it was too highly structured (see Figure 19) (for an example of over-scripting, see Dillenbourg, 2002). However, the instructional design of the first case study (Goman & Laru, 2003; Laru & Järvelä, 2003, 2008) was made in 2002, the same year that Pierre Dillenbourg published his pioneering attempt to analyse collaboration scripts in which he identified a number of aspects that have served as a preliminary framework for script design and comparison for many scholars. In this light, non-participative behaviour might be have been avoided by designing activities as a sequence of timed spaces, each characterized by fine-tuned attributes, for example describing the nature of the task and group formation (Dillenbourg, 2002).

In the second case study, in order to ensure collaborative activities in the designed learning activities, collaboration scripts at pedagogical level were taken into use. It included pre- and post-structuring phases with a high coercion level. For example, a storyboard was employed as a follow-me activity in which students received fixed flyer messages. Coercion and intelligibility of core-script were also at a high level: argumentative discussions were scaffolded with sentence openers (all findings were supposed to be in the form of arguments).

Ill-structured tasks in the core-script did not include specific end goals. Thus students were able to select their own paths of action in their own small groups within the limitations of the respective tasks. Furthermore, small groups of students were free to make their own choices regarding strategy, explore the consequences of choices and select a path of action when exploring the natural environment and creating their argumentation flyers. Pre-structuring tasks included elements enabling students to make comparisons between cases, as suggested by Belland (2011). All these steps follow scaffolding guidelines for ill-structured problem solving as suggested by Belland and are important factors when trying to assume executive control of the task supported by scaffolds.

However, the results of the second study showed that this instructional design was partly flawed. Even though the design was likely to promote important types of argumentative discussions (Laru, Järvelä, *et al.*, 2012), this was not clearly achieved because the epistemological quality of co-constructed knowledge claim messages was revealed to be superficial and almost all discussions in each group were concentrated in the phase of argumentative discussions leaving other phases to be almost purely teacher led activities. The script was too difficult for the students to comprehend easily and therefore failed to engage learners sufficiently for them to produce epistemologically appropriate argumentation messages (see Figure 19). One reason for this was the problematic application of Toulmin's model to situations that involve two or more arguments (Jonassen & Kim, 2010). Another was that argumentation (and especially) counter-argumentation has been proven to be difficult for students at this age (K-12 students) anyway (regardless of the application of Toulmin's model, that is). Instead, the mobile tool implicitly functioned as a vehicle (L.-H. Wong & Looi, 2011) to introduce and facilitate ill-structured and authentic collaborative learning tasks that were designed to trigger higher-order thinking and reasoning skills, rather than just memorization of facts during a field trip (Clarebout & Elen, 2001).

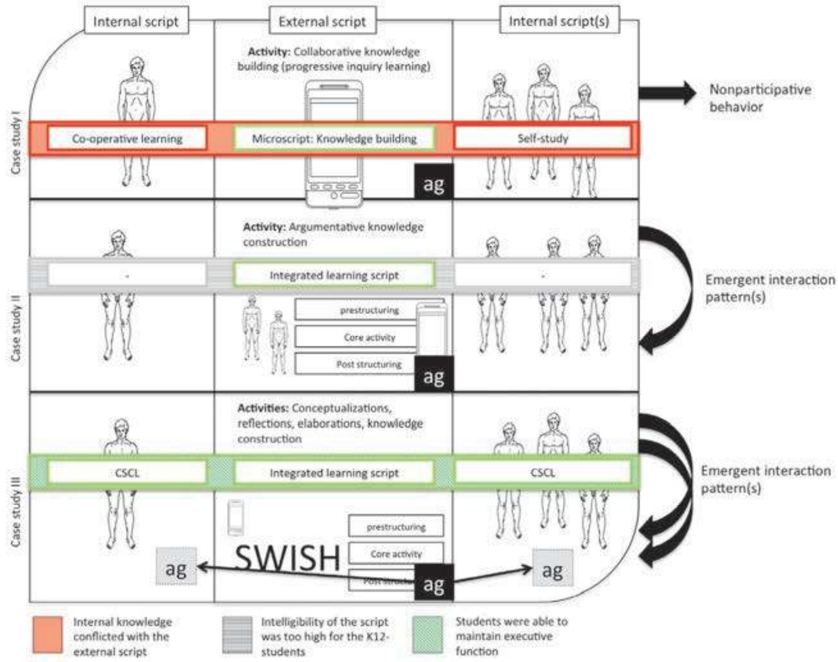

Fig. 19. Interplay between internal and external scripts in the three case studies.

In the third case study, the same content was elaborated multiple times. In practice, this did mean that students encountered multiple representations of content using different analogues, examples and metaphors. Rather, the instructional design required students to revisit ‘the same material, at different times, in rearranged contexts, for different purposes and from different conceptual perspectives’ (Rand & Spiro, 1991, p.28). From the perspective of ill-structured problems and tasks, one problem was replaced or extended to include multiple smaller problem solving tasks at individual and collaborative levels.

It can be concluded that the carefully crafted pedagogical activities and Web 2.0 tools used together to perform designed tasks probably increased students' individual knowledge acquisition during the course. This is in accordance with Meyer's (2010) claim regarding how assignments should be structured and orchestrated to encourage learning to occur. It also reinforces the findings of Halic *et al.* (2010, p.211) that a ‘technological tool works better when it is coupled with compatible pedagogical conceptions,’ and yet ‘interaction is insufficient to achieve cognitive engagement [because s]ome type of facilitation in online environments is necessary.'

In this experiment, the core-activity was to integrate chosen individual blog reflections and visual representations into a coherent and comprehensive wiki. Although this wiki was also an outcome of the activity – the end goal for their activities – it was not specified as such. Moreover, there were multiple individual and collective phases before the wiki activity, but their goals were not specific either. It can be concluded that students were able to select their own paths of action in different phases of the instructional design, which is central to students' ability to maintain the executive function (see Figure 19) (Perkins, 1996).

In this case, student groups engaged in formulating or reformulating their shared learning objectives in three different phases of the design – *reflection*, *conceptualization* and *co-construction* – in order to fit these objectives to differing task level characteristics. These activities helped them to engage mindfully in an investigation, because tasks were designed so that goals were not seen as certain and needing to be further explored. From the viewpoint of executive function, students need to make choices related to task, because it will allow them to assume the executive function (Perkins, 1996; Salomon, 1993).

The design of the third experiment also enabled students to make comparisons between artefacts produced by themselves and members of their groups or peer groups. Exploring the consequences of various choices in problem solving contexts is important for assuming executive control (Perkins, 1996; Salomon, 1993). Comparisons were made both in face-to-face activities (review and evaluate phase) and with help of technological tools (RSS Feeds as monitoring tool and individual reflection and elaboration in weblogs).

The activities described above show there were multiple collaborative and individual phases. During the collaborative argumentation students need to make choices regarding strategy, explore consequences of choices and select a path of action, all of which are also considered to be central activities when maintaining executive function (Perkins, 1996; Salomon, 1993). Taken as a whole, the third case study is an example of students being able to assume the responsibility of the scaffolded task and complete the task unaided (Belland, 2011). However, the main scaffolding agents in this study were not sentence openers at the interface level or human scaffolding agents as in the first two cases (above). Instead, the main scaffold was a recurring instructional design that consisted of sequential and interdependent flow of technologically mediated activities, face-to-face collaborative activities and individual activities.

To conclude, these cases reinforce the idea suggested by Jeremy Roschelle ten years ago (2002) that we should focus on rich pedagogical practises and simple mobile tools. In practise, the role of instructional design was increased and that of mobile tools decreased from case to case (as the research progressed). In contrast to early years of the research on mobile computer supported learning, it can be now stated that it is not only the learner being 'mobile' that matters. A stronger argument for applying mobile tools for education is that of increasing students' opportunities for interactions and sharing ideas and thus increasing opportunities for an active mind in multiple contexts (Dillenbourg *et al.*, 2009).

6.3 Methodological perspectives of studying social interactions in technology-rich contexts

The three empirical case studies in this thesis demonstrate a diversity of contexts, methods and technologies used, ranging from workplace to nature trail, from inquiry learning to collaborative knowledge building, and from PocketPCs to Smartphones. The methods vary in theoretical framework, but share a common focus on the interaction, discourse, and the participation processes emerging among community members in particular social and physical contexts (Lipponen & Lallimo, 2004). Generally, the emerging reality of our own work in this area is that the nature of interactions among participants in mobile computer supported collaborative learning is sometimes very complex and multi-dimensional. It is not easy to study the processes of these interactions supported with ubiquitous technologies and social software using any single method. This challenge has stimulated the exploration of a multi-method approach to understanding interactions among participants in contexts where interactions are supported with emergent technologies and software.

The methodological choices made for this thesis have enabled an examination of the nature of social interaction in small-group settings supported with ubiquitous technologies in three different contexts with different needs for data collection and analysis. These explicit differences have led to three independent methodological designs. Yet, these case-specific data collection and analytical methods have been chosen through multiple iterations in which appropriate measures and methods have been explored and tested.

In this round, the original idea was to conduct a micro-level analysis for a FLE3mobile discussion database by categorizing knowledge building utterances. However, the preliminary analyses of log-file and discussion database have revealed systematic non-participative behaviour among participants (Goman & Laru, 2003; Laru & Järvelä, 2003). It was concluded that a new analytical approach was needed in order to gain explanations for non-participative behaviour. Therefore, in the second round of analysis, a macro-level approach was chosen for the analysis of the activities during the use of FLE3mobile, and also of the activities before the experiments. In this new situation, interview data, log-files and discussion database were all analysed by means of Social Networking Analysis (SNA).

The outcome of the SNA led to a focus also on macro-level activities in the second and third case studies. In practice, both of the following studies include also micro-level analyses, although these were used only as a means to acquire data for the following macro-level analyses.

In the second study, analysis started at the micro-level with pre- and post-test mind-maps and continued similarly when co-constructive argumentative discussions and knowledge claim messages were analysed. The results of the mind-map analysis were used to identify top-performing and low-performing groups, though macro-level techniques were required in the next step of the analysis. However, the process halted at this point for a long period because appropriate methodology for comparison of the data sources with small number of participants was not found. Finally, a quantitative Mann-Whitney *U*-test was employed as a macro-level analytical approach in order to focus on group differences in collaborative argumentation activities.

The third study included multiple face-to-face and virtual phases facilitated by multiple social software and mobile tools. This messy data challenged researchers to explore different approaches, although the first rounds of analyses produced mainly descriptive values of the activities. The granularity of the data forced a search for macro-level approaches to analyse the data. Data analysis was begun by storing/retrieving measures of individuals' activities at particular phases, but different statistical approaches were experimented with in order to get comparable activity measures, for example between written wiki articles or blog entries. Finally Bayesian methods were found to be an effective and appropriate way of studying activity measures between different phases of the instructional design.

The unit of analysis in this thesis was both individual and group, depending on the phase of the analysis and specific case study. In the first case study (Case I), individuals' explanations for non-behaviour in FLE3mobile and their connections to peers were investigated. In the next study (Case II), the most important data was gained from co-constructive argumentative discussions. Focus in this synchronous collaborative inquiry learning activity was on how participants in small-groups engaged in the argumentation. In the third study, the analytical unit was the individual, because the focus of the analysis was on exploring probabilistic dependencies between the variables (i.e. individual activities in the collaborative learning context).

A clear limitation of the empirical studies conducted in the mobile computer supported contexts was the short and one-off nature of the experiments (Alvarez *et al.*, 2011; L.-H. Wong & Looi, 2011). In this thesis, all designs were single, once only experiments, although they were implemented in natural contexts. The duration of the second case study was three hours, which is a typical period for on-off activities (L.-H. Wong & Looi, 2011). Hours were given as fixed by the curriculum of the nature school which was a wider framework in which the second case study was embedded (Laru & J, 2008; Laru, Järvelä, *et al.*, 2012). On the other hand, the first (Papers I and II) and third (Paper IV) case studies were multi-month activities integrated into participants' daily working or learning practices (Laru & Järvelä, 2008; Laru, Näykki, *et al.*, 2012).

It can be argued that all participants in all experiments had reason to work towards a shared goal. In the first experiment, participants were co-workers in the virtual team; in the second experiment they were classmates and already knew each other; and in the third experiment, the subjects were university students who were studying on the same course. However, results revealed that the situation of the collaborative activity was not real or natural for the participants of the first empirical study (Case I). Moreover, three different datasets from three-hour to four-month instructional designs only provide a small amount of evidence, which is certainly a valid concern and limitation of this thesis in addition to the small sample size.

7 Discussion

The first decade of the research in the educational use of the mobile technology is divided in this thesis into four stages: i) a period of mobility and personal digital assistants; ii) the era of Wireless Internet Learning devices; iii) the introduction of social mobile media; and iv) a ubiquitous future. Discussion thus far has been around the assumptions that learners may be continually in motion and that ubiquity enables them to learn the right thing at the right time at the right place (Peng, Su, Chou, & Tsai, 2009; Sharples, Taylor, & Vavoula, 2007), thus leading to the notions of mobile learning or m-learning. Peng *et al.* (2009) extend this discussion by introducing the idea of 'widespread', 'just-in-time', and 'when-needed' computing powers for learners (p.175), thus introducing the increasingly popular idea of ubiquitous learning or u-learning. A seminal paper on Wireless Internet Learning Devices published by Roschelle & Pea (2002) can be counted as the starting point for scientifically ambitious research on the field, because they were able to go beyond the discussion related to mobility and mobile-learning issues by suggesting application level affordances and predicting the changing role of educators within technology rich learning contexts, all ideas presented by them that are still usable and topical.

Although we are currently living between the stages of mobile social learning and ubiquitous future, in many literature reviews and other scientific papers challenging questions are presented about role of mobile technologies in different learning contexts. These questions are similar to that presented by Vogel, Kennedy, & Kwok (2009): Do using mobile technologies really lead to learning? This was the same issue as that identified earlier by other CSCL researchers: providing technological supports and (mobile) devices does not necessarily ensure effective learning. Actually, the challenges for us as educational scientists are much bigger than questions about whether mobile technology helps us to learn. Rather, many different organisations, countries and scientists are asking: What are the learning skills schools and other educational institutions should be promoting in order to prepare people for the 21st century learning society?

This thesis is one response to this challenge. The present work is a theoretically grounded outlook on how important instructional design actually is when collaborative learning is supported with contemporary technologies. The study has constructivist grounds and aims at exploring how to support collaborative learning when students have ill-structured problems and their activities are supported with mobile technologies. It consists of the three case studies which together go against technology-determinism in showing how important it is to design, develop and deliver lightweight digital tools and activities for learners to construct knowledge when researching contemporary phenomena in the field of technology enhanced learning.

Overall, the results of the three case studies presented in this thesis confirm concerns raised by Perkins (1993) and Salomon (1993) that the assumption that learners will automatically take appropriate and measured advantage of the affordances of computer tools involved in cognitive activities with them is dubious, and that instead, cognitive tools require deliberate attention and effort from learners to make use of the affordances of the tools (Kim & Reeves, 2007). Furthermore, results from the case studies reveal that personal factors such as students' prior knowledge, metacognitive and collaborative skills, as well as contextual cues such as cultural compatibility and instructional methods influence student engagement. This study shows explicitly how successful collaboration requires both careful design of the learning environment for group interaction and provision of scaffolding, leadership and support by the instructor (Pea, 2004; Strijbos *et al.*, 2004) in order to facilitate meaning making by students. Indeed, this thesis underlines how important are 'simple tools and rich practices' as presented by Roschelle (2002).

The interplay between Web 2.0 tools and mobile technologies is presenting new challenges related to supporting collaborative learning as teachers start to integrate them into more or less traditional learning methods, curricula and everyday school life (Arvaja *et al.*, 2009). One of the biggest challenges for instructional designers and educators is the fact that 'people can become accustomed to seeing but glimpses of one another's social worlds, with only fleeting connections between symbolic representations of these worlds in photos, video or composite media, and little possibility for the melding of meaning and the co-creation of worlds' (Lewis *et al.*, 2010).

Another challenge is the prevailing view of today's students and knowledge workers as digital natives, that they are fundamentally different to previous generations in how they learn, what they value in education, how they use technology and how they interact (Bullen & Morgan, 2009; Bullen, Morgan, Qayyum, & Belfer, 2009). For example, a recent study by (Valtonen *et al.*, 2011) showed that 'the technological knowledge of student teachers is not what would be expected for representatives of the Net Generation' (p.13–14). These results indicated, just as those of Margaryan *et al.* (2011), that the range of software used was very limited and that, for example, social media was used as a passive source of information and not to actively create content, interact with others and share resources. Valtonen *et al.* (2011) conclude that the expectations and assumptions about this group of 'student teachers' abilities to adopt and adapt ICT in their teaching are highly questionable' (p.1).

Technology rich learning environments with rapidly changing ideas of what collaboration is highlight the importance of theoretically informed instructional design. However, this study is not aimed to give particular design guidelines for scientists in this multidisclipnary field. Instead, it reinforces the importance of a holistic approach when educational psychologists, educators and educational technologists are planning their research projects. Instructional design that includes ubiquitous technologies, social software and emerging, not-yet-invented-technologies, demands tasks that require a balance between different domains of expertise in order to support design for learning (Alvarez *et al.*, 2011).

To conclude, the findings of this thesis show that pedagogically grounded instructional design is needed in order to put emergent technologies into effective use. The employment of mobile devices, including mobile phones and tablets, is a growing trend in education. The practice has been widely technology driven and often justified simply by the importance of using new technology in classroom. This thesis has approached emergent mobile technologies from an educational science perspective. In the future, this perspective might be deepened further to include a theoretical understanding of self-regulation and metacognition. Emerging social media and mobile tools have the potential to offer novel affordances that can help support and promote such self-regulated learning processes which are central to learning. This new field is as yet an almost untraveled path and offers interesting opportunities for continuing research.

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Original papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals (I–IV):

I Laru, J. & Järvelä, S. (2004). Scaffolding different learning activities with mobile tools in three everyday contexts. In P. Gerjets, P. A. Kirschner, J. Elen & R. Joiner (Eds.), *Instructional design for effective and enjoyable computer-supported learning. Proceedings of the EARLI SIGs Instructional Design and Learning and Instruction with Computers* (pp.11–21). Tübingen: Knowledge Media Research Center. Available at: URI: http://www.iwm-kmrc.de/workshops/SIM2004/pdf_files/Laru_et_al.pdf

II Laru, J., & Järvelä, S. (2008). Social patterns in mobile technology mediated collaboration among members of the professional distance education community. *Educational Media International, 45*(1), 17–32. doi: 10.1080/09523980701847131.

III Laru, J., Järvelä, S. & Clariana, R. (2012). Supporting collaborative inquiry during a biology field trip with mobile peer-to-peer tools for learning: A case study with K-12 learners. *Interactive Learning Environments, 20*(2), 103–117. doi: 10.1080/10494821003771350.

IV Laru, J., Näykki, P. & Järvelä, S. (2012). Supporting small-group learning using multiple Web 2.0 tools: A case study in the higher education context. *The Internet and Higher Education, 15*(1), 29–38. doi:10.1016/j.iheduc.2011.08.004.

Original publications are not included in the electronic version of the dissertation.

Appendix I

Phase	Level	Activity
1	Collective	Discussion about group-related problems

Appendix II

Phase	Level	Activity
1	Collective	Setting-up Groups of three or two participants are formed based on either teacher or students choices. Students are equipped with appropriate mobile devices and software.
2	Collective	Introducing the activity The main collaborative inquiry topic is given in the introduction flyer. Introduction flyer can be also used as starting point for story used motivating children. After receiving the first flyer, two common hypotheses are created together with the students.
3	Group	Task(n): creating arguments The task is presented in the flyer distributed to the groups. Each group has to found arguments to support selected hypothesis by exploring the context of the activity described in the task flyer. When their argument is founded, they create their own flyer based on findings. Into the argument flyer has to be included: [this activity is scaffolded with sentence-openers] claim (‘I claim that..’) warrant (‘Because I see..’) – includes picture taken by phone camera ground (‘I have learned in the school…’ or ‘The book says…’) [Note: All published fliers may be saved into server’s database as it is not default functionality with this kind of software. This is necessary to advance to Phase 7 of that script also.]
4	Group	After task(n): Reception & Comparison Each group receives all argument flyers published in the third phase. When the groups have read the fliers, they evaluate received arguments and attach their evaluation in the end of the flyer. The evaluation can include the following sentences: [activity scaffolded with sentence-openers] the ground is [not] suitable, … [used if needed] the warrant is [not] suitable [used if needed] and a better solution would be Groups save modified flyers into saved fliers folder in their mobiles

Phase	Level	Activity
		for later elaboration. [Note: This is because the application does not support creating discussion threads or replies.]
5	Collective	After task(n): Social discussion Groups are gathered together to discuss about the findings and evaluated arguments. Discussion is led by the teacher or e.g the nature guide (in this case). The discussion is based on fliers saved into the phones in the fourth phase. Teacher tries to control discussion in direction where students' tell each other their arguments and evaluations.
6	Collective	Material for filling gap between the tasks Groups will receive both information and feedback fliers connected to the story behind the activity. (In our experiment we published feedback fliers when each task was completed and information fliers when there was long period between collaborative inquiry tasks.)
7	Collective	Conclusion and further work <u>Possibility 1:</u> Groups are gathered together in the classroom for final discussion based on groups' findings. All fliers have been transferred from mobile devices into desktop computer and superimposed on the screen. Final discussion is similar, with discussion after tasks. <u>Possibility 2:</u> Groups continue their collaborative inquiry project in classroom where they include fliers in their other learning projects.

Appendix III

Phase	Level	Activity
1	Collective	*Ground [Lecture] (weeks 1-3 and 6-8):* Each of six one-week working periods started with a lecture in which students were grounded in main theoretical conceptsThe specific themes were in the following order: 1. Learning infrastructure, 2. Learning communities, 3. Metacognition, 4. Self-regulated learning, 5. Learning design, and 6. Social Web as a learning environment.
2	Collaborative	*Reflect [Discussion] (weeks 1-3 and 6-8):* The purpose of this collaborative phase was to reflect on the lecture topic in groups and to formulate a problem to be solved based on the group members' shared interests during the following solo learning phases. Groups were advised to set their own learning objectives based on the topic and to write down these objectives in their personal blogs for further reflection.
3	Individual	*Conceptualize [Photo-taking] (weeks 1-3 and 6-8):* In this solo phase, individual students were required to conceptualize their group members' shared interests. In order to do so, they were required to identify and capture situated pictorial metaphors describing their shared interests. In practise, their tasks were to explore their everyday working and living environments and take photos with a camera phone.
4	Individual	*Reflect and elaborate [Blogging] (weeks 1-3 and 6-8):* The task of this phase was to further reflect and elaborate on photos in the students' personal blogs. First, they were required to analyse collected visual representations in order to discard ideas that were not relevant to their groups' shared learning objectives. Second, they were required to write blog entries about chosen photos in which they further elaborated associations between photos, group-level objectives and students' everyday situated practises.
5	Group	*Review and evaluate [Discussion] (weeks 4 and 9)*: The first task of this collaborative face-to-face activity was to review group members' weblogs from the previous three-week period. The second activity was to evaluate the usefulness of blog entries in the context of their shared learning objectives and to discard irrelevant ideas. The outcome of this phase was used as material for co-construction of knowledge in the groups' wikis.

Phase	Level	Activity
6	Group	*Co-construct knowledge [Wiki work] (weeks 4-12):* The task in this collaborative assignment was focused on integrating each group's chosen blog entries and visual representations into a cohesive and comprehensive product of all course topics. In other words, the given goal was to formulate what they had learnt 'in their own words' and produce it as uniform material that could be put to authentic use.
7	Collective	*Monitor peer students' contributions [Monitor]* (whole course): This was not an assignment per se, but it enabled students to obtain different perspectives by seeing what others were doing with social software tools, and it helped students to assimilate and accommodate their thinking. In practise, monitoring activities were done by using cloud-based syndication tools (RSS).

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