OULU 2011
E 116

ACTA UNIVERSITATIS OULUENSIS

Johanna Bluemink

VIRTUALLY FACE TO FACE: ENRICHING COLLABORATIVE LEARNING THROUGH MULTIPLAYER GAMES

UNIVERSITY OF OULU, FACULTY OF EDUCATION

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E Scientiae Rerum Socialium 116

JOHANNA BLUEMINK

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Academic dissertation to be presented with the assent of the Faculty of Education of the University of Oulu for public defence in Kaljusensali (Auditorium KTK 112), Linnanmaa, on 27 May 2011, at 12 noon

UNIVERSITY OF OULU, OULU 2011

Acta Univ. Oul. E 116, 2011

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ISBN 978-951-42-9422-8 (Paperback)
ISBN 978-951-42-9423-5 (PDF)
http://herkules.oulu.fi/isbn978951429423 5/
ISSN 0355-323X (Printed)
ISSN 1796-2242 (Online)
http://herkules.oulu.fi/issn0355323X/

Cover Design
Raimo Ahonen

JUVENES PRINT
TAMPERE 2011

Bluemink, Johanna, Virtually face to face: enriching collaborative learning through multiplayer games.
University of Oulu, Faculty of Education, P.O. Box 2000, FI-90014 University of Oulu, Finland
Acta Univ. Oul. E 116, 2011
Oulu, Finland

Abstract

This study focused on enriching collaborative learning through pedagogically scripted multiplayer games. Collaborative learning was examined in the synchronous discussions of small group problem-solving activities in face-to-face and virtual game settings. The theoretical approach is socio-cognitive and builds on the contextual and situated nature of learning. Interaction between group members in social situations is a key mechanism fostering students' learning. In the field of Computer-Supported Collaborative Learning the underlying aim is to stimulate and structure socially shared construction of knowledge and development of shared understanding among the collaborators.

This thesis consisted of three empirical studies. The first study focused on analysing the macro-level elements of teacher education students' face-to-face discussions in a context of an international web-based course. The focus of the second and third empirical studies was on how distributed collaboration can be enriched by scripting multiplayer game environments. The game environments were developed and tailored as part of the empirical studies. The main aim was to analyse small-group micro-level interactions and activities taking place during the game. Moreover, the particulars of a 3D voice-enhanced multiplayer game context for small-group shared collaborative activities were investigated. The focus of the last empirical study was on aspects of collaborative game activity and shared problem solving described from the perspective of individual players.

The results indicated that the synchronous small-group discussions, on the macro-level, consisted of explaining, sharing knowledge, providing critiques, reflection, and joint engagement. The micro-level elements of the players' discussions during the game were questions, content statements, social statements, suggestions, instructions or orders, encouragements, and responses. Both macro and micro level elements varied in random order during the discussion, forming a base for small-group discussion and joint problem-solving efforts. Not all problem-solving situations in the game data were shared, indicating that if shared collaborative activity was pursued, the scripting of the game tasks must require equal participation and teamwork during the game. The 3D game environment created a strong shared context for the distributed groups by engaging the players and reinforcing individual participation through the avatar activity. The findings of this thesis contribute to the future development of serious games and highlight the potential of multiplayer games as tools for supporting the social aspects of distributed teamwork.

Keywords: 3D multiplayer games, computer-supported collaborative learning, scripting collaboration, small-group discussion, socially shared cognition

Bluemink, Johanna, Virtuaalisesti kasvokkain: peliympäristöt yhteisöllisen oppimisen rikastajina.
Oulun yliopisto, Kasvatustieteiden tiedekunta, PL 2000, 90014 Oulun yliopisto
Acta Univ. Oul. E 116, 2011
Oulu

Tiivistelmä

Väitöstutkimus tarkastelee yhteisöllisen oppimisen rikastamista pedagogisesti vaiheistettujen virtuaalipeliympäristöjen avulla. Tutkimuksessa on analysoitu pienryhmien sosiaalista vuorovaikutusta luokkahuonekeskusteluissa ja puhevälitteisissä peliympäristöissä. Teoreettisesti tutkimus pohjautuu sosiokognitiiviseen käsitykseen oppimisesta, jonka mukaan sosiaaliset tilanteet voivat käynnistää yksilöissä oppimisen kannalta keskeisiä mekanismeja, kuten esimerkiksi selittämistä ja tiedon jakamista. Yhteisöllisen oppimisen ytimeksi katsotaan jaetun ymmärryksen rakentaminen sosiaalisessa vuorovaikutuksessa, mitä tietokoneavusteisen yhteisöllisen oppimisen tutkimuslinjassa pyritään tukemaan vaiheistamalla oppimisympäristöjä.

Tutkimus koostuu kolmesta eri osatutkimuksesta, joista ensimmäisessä analysoitiin korkeakouluopiskelijoiden pienryhmäkeskustelua luokkahuonetilanteessa. Lähitapaamiset toimivat kurssilla hajautetun kansainvälisen verkkotyöskentelyn tukena. Toisessa osatutkimuksessa tarkasteltiin, voiko hajautettua yhteisöllistä oppimista rikastaa puhevälitteisen monenpelaajan peliympäristön avulla. Pelin tehtävät suunniteltiin ja vaiheistettiin yhteisöllistä toimintaa vaativiksi sekä jaetun ymmärryksen rakentamista tukeviksi. Analyysi keskittyi korkeakouluopiskelijoiden pelinaikaisen keskustelun ja ongelmanratkaisutilanteiden tarkasteluun. Kolmannen osatutkimuksen tavoitteena oli tutkia, mitä osatekijöitä työelämäkontekstista tulleet osallistujat joutuivat hallitsemaan puhevälitteisessä monenpelaajan pelissä. Tutkimusten video- ja haastatteluaineistot analysoitiin laadullisen sisällönanalyysin menetelmin.

Tutkimustulokset osoittivat, että pienryhmän vuorovaikutus koostuu makrotasolla mm. selittämisestä, tiedon jakamisesta ja reflektoinnista. Mikrotasolla mm. kysymykset, toteamukset, auttaminen ja ehdottaminen vaihtelivat puheenvuoroittain ja muodostivat yhteisen toiminnan pohjan pienryhmän pelaamisessa. Kaikki ongelmanratkaisutilanteet pelin aikana eivät kuitenkaan olleet jaettuja. Tulokset osoittavat, että kun tavoitellaan aidosti yhteisöllisiä tilanteita, pelin tehtävät täytyy vaiheistaa niin, että ne vaativat kaikkien osallistumista ja pitävät ryhmää virtuaalisesti yhdessä. Tässä tutkimuksessa käytetyt peliympäristöt muodostivat hajautetuille ryhmille vahvan jaetun tilan ja virtuaalisten ihmishahmojen eli avatarien kautta osallistuminen vahvisti yksilöiden toimijuutta pienryhmän osana. Tuloksia voidaan hyödyntää hajautetun tiimityön kontekstissa sekä käyttää tukena tulevaisuuden virtuaalisten tiimipelien suunnittelussa.

Asiasanat: oppimisen pedagoginen vaiheistaminen, pienryhmä, sosiaalisesti hajautettu kognitio, tietokoneavusteinen yhteisöllinen oppiminen, virtuaalipeli

Acknowledgements

"When you are a fish, you don't see the water, you just live in it every day". If I were a fish I could say there has been an ocean around me in the last decade that I have worked for this Doctoral thesis. From time to time the ocean has been so deep that if I weren't a fish, I could have drowned in the amount of information and impressions that a Ph D candidate may experience. Only by going away, you can learn to see the water you live in. This, I think is one of the core mechanisms of learning, the essence of perspective-taking. To be able to take a perspective, we need others "to show the other".

I owe my deepest gratitude to several "others" who have been there for me. I am most thankful to my supervisor Professor Sanna Järvelä for taking me into the research group and showing me the inspiring world of learning sciences. Thank you for your guidance and support in the many stages of my work. You have always trusted in our capabilities and taught us to aim high.

I am very grateful for the reviewers of the thesis, Professor Barbara Wasson and Professor Lasse Lipponen. I highly appreciate your work in the field of CSCL and feel honoured that you have reviewed my thesis. In the early years of my studies, Sanna instructed me to read Professor Lipponen's Ph D and I did that thinking that I had a long road ahead of me. Professor Wasson I have only admired from distance until now and feel privileged to have you as my opponent.

I have been fortunate to have Professor Emer. Rauni Räsänen as my other supervisor, thank you for your support in the tough times, when the publishing was not going so smoothly. Ph D, LudoCraft CEO Tony Manninen has been there for me for many years. Thank you Tony, for our good collaboration. I really admire your spirit.

Our LET-team, the old and current members of it, I would have not managed without you all. You have been not only great colleagues but also good friends. It has been very important for me to be able to share our exiting life situations – I think as many articles as babies have been born during the years that we have been together, but I am not quite sure. Especially I want to thank Piritta Leinonen, Jari Laru and Hanna Salovaara for shared understanding, scaffolding and friendship. With Piia Näykki, Niina Impiö, Hanna Järvenoja and Tarja-Riitta Hurme many joyful moments have paved our shared road, thank you! I also want to express my gratitude to Master's thesis workers, Laura Koponen, Sari Veijola and Jenni Kaisto. Your participation and contributions have been valuable.

During my Ph D work I have had the greatest opportunity to work with many inspiring people. My particular thanks go to Tuomo Korva and Tomi and Laura Thurlin from LudoCraft for trying to understand my explanations in the game projects! Raija Hämäläinen, Leena Kuure and Maarit Saarenkunnas have been important contributors and I want to thank you for sharing the perspectives in collaboration and linguistics. Tuija Huuki I wish to thank for her constructive and helpful comments to the earlier version of this thesis.

I owe my gratitude to a few international experts as well. I want to thank Professor Betty Collis for having me as a research assistant at the University of Twente many years ago and giving me a sparkle for research. Professor Robert Ramberg and Assistant Professor Teresa Cerratto-Pargman from Stockholm University have given me very valuable feedback during my research visit in Sweden and for that I am thankful.

In the last couple of years I have been given an opportunity to widen my scope outside the university world. I wish to express my gratitude to Professor Petri Ahokangas. You came to play and the rest is history. Thank you for believing in me. With Petri, Piritta and Jaana Kuusipalo I have stepped into a whole new world.

My Ph D study has been financially supported from several sources. I am most grateful to Academy of Finland, Finnish Work Environment Fund, Finnish Cultural Foundation, Nordic Research Board and University of Oulu.

Last but so not least I wish to thank my friends, family and relatives. Thank you for living this process with me and encouraging me forward. In particular, I wish to thank Saara Taponen and Teri Kanerva – you amazing ladies keep confirming me that we that family, work and Ph D can be combined.

Sincerest thanks to Mom and Dad for all your support, help and care for me and our family. It has been my mother who has told me to go to talk to Sanna and reminded of the importance of belonging to a group. And it has been my father who has helped in so many ways to solve the puzzle of everyday life; I could not have managed without your help.

Rosalie, Anne-Sofie and Matilde, our dearest daughters, thank you for making my life so rich and meaningful. Geert-Jan I want to thank for sharing the parenting and everyday life. I am most grateful for your love and belief.

Oulu, April 2011 Johanna Bluemink

List of original articles

This thesis is based on the following articles, which are referred in the text by their Roman numerals:

I Bluemink, J.(*) & Järvelä, S. (2003). Face-to-face encounters as contextual support for Web-based discussions in a teacher education course. *The Internet and Higher Education, 7*, 199–215.

II Bluemink, J.(*) & Järvelä, S. (2011). Elements of collaborative discussion and shared problem-solving in a voice-enhanced multiplayer game. *Journal of Interactive Learning Research, 22 (1), 23–50.*

III Bluemink, J.(*), Hämäläinen, R., Manninen, T., & Järvelä, S. (2010). Group-level analysis on multiplayer game collaboration: How do the individuals shape the group interaction? *Interactive Learning Environments, 18 (4), 365–383.*

IV Bluemink, J.(*) & Leinonen, P. (2011). How do members of distributed teams manage the aspects of collaborative game activity in a voice-enhanced multiplayer game? Manuscript.

The position in the byline order indicates each author's responsibility and contribution for a study design, data analysis and interpretations, and reporting. Corresponding author (*), supervised by Professor Sanna Järvelä, has had the main responsibility in the different phases of the study.

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1 Introduction

It has been asserted that people have an intrinsic need for collaboration as well as for mutual knowledge and 'sharing meaning' (Stahl, 2006). When interacting with others, we may notice the perspectives of others and discover something new. In working together, we may feel that many challenges are easier to solve, and afterwards we may notice that we know more and think differently. In other words, we have learnt. In the field of learning sciences, many studies have been conducted to investigate the essence of collaboration, which also is referred as joint meaning making (e.g., Dillenbourg, 1999; Barron, 2003; Stahl, 2006; Sawyer, 2006). Studies have shown that in collaborative situations, the key to learning is building and maintaining a shared conception of a problem or task. Therefore, in any successful collaborative situation, there is a constant effort to coordinate language and activity in order to reach a shared understanding (Teasley & Roschelle, 1993; Dillenbourg, 1999). This effort matters in collaboration because it places individual in situations where the key mechanisms of learning can take place (Schwartz, 1999).

Despite extensive research on collaboration, in practise we are not always satisfied with the outcome of our joint efforts. It is difficult to understand the thoughts of others who might have hidden agendas. Most of us have come to realise that in practise that collaborative learning is indeed not a recipe or mechanistic formula that would automatically lead to better results (Dillenbourg, 1999). It takes time, effort, and patience to explain, listen, and decide together so that everyone is satisfied. Sometimes we choose to carry out tasks alone since we feel that the efforts of collaborating would be greater than the benefits. Studies on collaborative learning in small groups have pointed out that the secret behind successful group activities seems to lie specifically in the way of listening to others and echoing the contributions of others in a reciprocal manner (Barron, 2003). Therefore, the ways that individuals participate in collaborative activities have a great impact on the quality of social interaction in groups, which in turn has a crucial influence on groups' problem-solving processes (Gresalfi, Martin, Hand, & Greeno, 2009). Currently, researchers seem to agree that the interaction between group members is a mechanism that fosters students' learning in collaborative situations, whether in face-to-face or technology-supported contexts (Sawyer, 2006; Kreijns, Kirschner & Jochems, 2003).

The various contexts and situations of collaboration provide challenges requiring great abilities from the collaborators to adjust to new people and tasks

in both face-to-face and virtual environments. All communication takes place in context (Clark, 2003), forming ever changing scenes for learning scientists to both investigate and support intelligent human activities as situated activity (Greeno, 2006b). During the past 15 years, hand in hand with the accelerating development of technology and the internet, the field of Computer Supported Collaborative learning (CSCL) has become an established branch in learning sciences and focuses on learning in various technologically mediated contexts (Koschmann, 1996). Because interaction is the core of collaborative learning (CL), computer supported (CS) environments have been designed and built to specifically support the efforts of fruitful collaboration (Littleton & Miell, 2004). Numerous studies on different virtual learning environments have been conducted to find out what kind of design and structuring best encourages learning and working together (e.g., Dillenbourg, 2002; Kreijns, Kirschner & Jochems, 2003; Stegmann, Weinberger, & Fischer, 2007). Interaction processes in CSCL environments can be structured to tempt participants to work together or make it impossible to solve tasks without the collaboration of participants (Weinberger, 2003; Hämäläinen, Manninen, Järvelä & Häkkinen, 2006).

To clarify the focus of this doctoral thesis to the reader, it should be noted that the empirical studies of this thesis have focused precisely on the interaction processes of small groups in CSCL environments. The thesis consists of three separate empirical studies carried out during the past ten years in higher education and workplace contexts of multidisciplinary settings. Therefore, the thesis also reflects the maturity and scope of the CSCL field.

The first study (Article I) was a part of the Networked Interaction (NINTER, 1999) research project funded by the Academy of Finland, the main aim of which was to analyse the macro-level elements of teacher-education students' face-to-face discussions. Face-to-face work was seen as contextual support in an international web-based course where the web activities were text-based discussions in the learning platform discussion area. As a typical feature of the studies at this time, the collaborative interaction was structured with the help of pedagogical model developed as a part of the research project. In the second empirical study (Articles II and III), a virtual voice-enhanced multiplayer game eScape was developed and studied to see how a social action adventure game could support distributed collaboration. The study was part of the Ecology of Collaboration (ECOL, 2003) research project belonging to the Life as Learning Research programme of the Academy of Finland. The players solved tasks together by acting through avatars and discussing through headsets in the 3D

game. The main aim was to investigate the micro-level elements of collaborative discussions. The third study (Article IV) continued the efforts to support distributed collaboration in the 3D game context and was conducted in the Gate for Collaboration (GATE, 2007) research project funded by the Finnish Work Environment Fund. The central aim was to examine the particulars of collaborative game activity from the individual's perspective when collaborating in a voice-enhanced multiplayer game. The game design was based on the findings of the eScape study, indicating that emphasis should be on scripting tasks that would lead to the participation of all players in the collaborative problem-solving activities.

The overarching aim of this doctoral thesis is on enriching collaborative learning through pedagogically scripted multiplayer games. Collaborative learning is examined as it appears in the synchronous discussions of small-group problem-solving activities in both face-to-face and virtual game settings. The approach is socio-cognitive, building on the understanding that social and cognitive involvement cannot be studied as separate issues since the social context in which the individual's cognitive activity takes place is an integral part of the activity. Social and individual aspects intertwine in social interactions, which at their best lead to collaborative and individual learning (Resnick, 1991; Dai & Sternberg, 2004).

Although a large number of studies have been conducted on social interactions and collaboration in CSCL environments (e.g., Hausmann, Chi & Roy, 2004; Dillenbourg & Traum, 2006, Sawyer, 2006), so far very few have reported empirical results from small-group collaboration in a voice-enhanced multiplayer game context. The phenomenon of sharing understanding in human collaboration has interested researchers for decades (e.g., Dewey 1958, Bruner, 1990; Thompson & Fine, 1999). However, in recent years, multiplayer game environments have provided a novel context for collaboration, and their effects remain to be explored because not only do people make spaces but also spaces make people (Sundholm, 2007; Benwell & Stokoe, 2006). Therefore, the particulars of the multiplayer game context for small-group collaborative activity are investigated here. This thesis also aims to contribute to existing research on the kind of scripting of game environments that can enrich collaboration. In addition, as the field is new, there is no generally established set of methods for studying learning in game contexts, so methodological explorations are included in this thesis.

This work consists of two parts. The first part includes the introduction, the theoretical framework, the aims and methods of the study, and the main findings, which are followed by a general discussion. The second part consists of four international peer-reviewed journal articles, which report the empirical results of this doctoral thesis.

2 Theoretical framework

Chapter Two introduces and summarizes the theoretical framework on which this thesis builds. It is structured in three main sections: the first focuses on the understanding of learning and collaboration in general; the second on the interplay of interactions, language, and learning; and the third on aspects of promoting collaborative learning through technology. Generally, this thesis builds on a socio-cognitive approach towards learning with the view that individual cognitive systems do not promote learning because they are individual, but because they perform activities that trigger learning (Dillenbourg, 1999). However, sociocultural and situated approaches to collaboration and learning will be discussed, thus complementing the socio-cognitive approach and enriching the background of the field of CSCL.

2.1 Building understanding of learning and collaboration

A fundamental characteristic of learning is that change happens. It can be, for example, a conceptual change stimulated by person–environment interactions or development of social practises in individuals or groups (Alexander, Schallert, & Reynolds, 2009). Traditional instruction presumes that change is effected by transmitting information from the more capable to the less capable, often from teacher to the students. However, more than twenty years of learning research has brought a new style of learning into focus, which is based on the view that knowledge is built together (Sawyer, 2006). Several studies on cooperation (Johnson & Johnson, 1986), peer and group learning (O'Donnell, 2006), group cognition (Stahl, 2006), and collaborative learning (e.g. Dillenbourg, 1999; Crook, 2000) have pointed out that collaboration helps individuals to learn.

In a thorough review on studies analysing collaborative discourse, Sawyer (2006) concluded that learning scientists have reached the consensus that conversational interaction is the mediating mechanism whereby collaboration contributes to learning. This consensus has been the reason why discourse processes and turn-by-turn interaction patterns have been studied increasingly in the past years (e.g., Hatano & Inagaki, 1998; Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2003; Hausmann, Chi & Roy, 2004; Dillenbourg & Traum, 2006) The studies focused on process-oriented accounts of productive talk and joint activity. A general aim has been to identify the interactional features of

collaboration that are important for learning and conceptual change (Littleton & Miell, 2004).

The research interest has been not only on collaborating to learn, but also vice versa, on learning to collaborate. Participation skills in collaborative knowledge construction are not a self-evident and innate ability. Instead, it has been found that at schools teachers may have to spend considerable time in helping the students care for one another, develop interest in helping others, consider each other's perspectives, and provide encouragement and feedback (Dawes & Sams, 2004; Mercer, 2008). It has been noted that children in classrooms often talk with each other in ways that do not engage them in any prolonged or profound thinking about ideas, reasons, or evidence of information (Dawes & Sams, 2004). The natural occurrences of so-called 'Exploratory Talk', where participants engage critically but constructively with each other's ideas, rarely have been found (Barnes & Todd, 1977; Mercer, 2008). The same concerns have been presented in the context of collaborative work, thus prompting the question of whether people learn to interact in productive ways just by doing collaborative work (Bransford, et al., 2006).

By focusing on the processes in collaborative interactions, it is possible to prompt students to be metacognitive about their social engagement and raise their awareness of the importance of small group and interpersonal skills (O'Donnell, 2006). Metacognitive and reflective skills form a central research area within learning sciences and are an essential part of the individual as well as collaborative problem-solving processes (Hurme, Merenluoto & Järvelä, 2009). It is precisely through those processes that the formal knowledge acquired through education is transformed into an expert's flexible informal knowledge (Brown, 1980, Järvelä, 1996). It has been found that for building professional expertise, these self-regulative skills are the third central element in addition to theoretical and practical knowledge (Bereiter & Scardamalia, 1993; Tynjälä, 2008). Recent studies have pointed out that regulation can be also socially shared in collaborative situations (Järvelä, Järvenoja, & Veermans, 2008).

Metacognitive skills are also key in the transfer of learning, which is a significant topic in the learning sciences (Schwartz, Bransford,, & Sears, 2005) It has been asserted that one way to improve learning transfer is to help the learners become more aware of themselves as learners who actively monitor and assess their learning strategies, resources, and performance (Bransford, Brown, & Cocking, 2000). The abilities to reflect on one's learning and the learning process are at the heart of learning in addition to the necessary precondition of the ability

to discuss. In group situations, individual representations can be seen as publicly accessible versions of their private thinking (Sawyer, 2006). While working together, the individuals may therefore witness each other's epistemic operations and processes such as defining the problem, referring to context, accepting general principles, in addition to assessment and evaluation (Palincsar & Brown, 1984, Crook, 2000). Bruner (1996) has referred to the same phenomenon as a way of exercising intelligence that consists precisely of subtle sharing in the process of distributed intelligence.

2.1.1 In search of productive collaboration

To better understand the nature of productive collaboration, a brief review demonstrates how earlier research frames current CSCL studies. The great theorists Vygotsky (1978) and Piaget (1985) introduced their concepts of "zone of proximal development" and "sociocognitive conflict," which have largely served as the basis for the further development of studies on collaboration. Piaget (1985) emphasized the socio-cognitive conflict that takes in collaborative situations. It is probable that a group discussion on an issue makes students recognise that their comprehension is not adequate. Therefore, the student might be surprised that there are a number of other perspectives different from their own and thus would find it difficult to decide on the most reasonable alternative (Hatano & Inagaki, 1998). Ultimately, these discrepancies lead the individual to question his or her current understanding and subsequently construct new knowledge. The Vygotskian perspective of the sociocultural approach towards learning sees that knowledge construction and understanding are fundamentally social activities. Learning is seen as taking place through participation in the practises of the community and its artefacts and rituals. Asymmetry in the interactions between the participants is seen as a resource, since less capable students benefit from working with more capable students (Littleton & Häkkinen, 1999; Crook, 1996). Some studies in the sociocultural tradition put more emphasis on the processes of interaction than on educational outcomes (Sawyer, 2006). However, several studies build on a mix of these views (e.g., Arvaja, 2005).

Two seminal empirical studies (Bos, 1937; Barnes & Todd, 1977) carried out in the early years of collaborative learning reveal that their main ideas greatly resemble current interests. Despite the vast amount of research on learning, the nature of collaboration remains, to a certain extent, a deep secret (Weiss & Dillenbourg, 1999). Bos (1937) conducted an experimental study on productive

collaboration in order to shed light on effects of collaboration that improve individual achievement. She found that when working on the same task, first individually and then in dyads, the collective effort clearly increased the achievement. She concluded that the higher achievement seemed to be due to the fact that the collective situation offers particularly good conditions for the functioning of those factors which primarily determine every productive working-process. Forty years later, Barnes & Todd (1977) conducted a study on communication and learning in small groups and analysed the discussion between thirteen years old students without the presence of the teacher. Their focus was to examine the short-term, small-scale aspects of social interaction in small groups and the cognitive strategies generated due to the interaction. Their key finding was that in helpful circumstances young adolescents carried out collaborative learning in small groups without a teacher, and that at times they displayed impressive social and cognitive abilities. By placing responsibility in the hands of the students, the nature of learning was changed by requiring them to negotiate their own criteria for relevance and truth. Now these findings seem partly self-evident, but they were important contributors to a new, more student-centred approach towards learning as joint knowledge construction in groups.

2.1.2 Acts likely leading to learning

Within the socio-cognitive tradition, it has been emphasized that, at the most fundamental level, learning mechanisms are those of individual cognition since even in collaborative situations individual agents are involved in group interactions (Dillenbourg, 1999). Therefore, the core benefit of group situations can be seen in the interaction launching mechanisms found essential for learning. Collaboration is thus not a recipe for learning, and not all collaboration leads to learning (Dillenbourg, 1999). Although participants in collaborative situations have more resources and more alternative suggestions than single individuals, the group does not necessarily excel in the learning that takes place. Evidently, it has been found that learning and good quality interactions in a CSCL context are less frequent than expected (Järvelä & Häkkinen, 2002; Lipponen et al., 2003; Arvaja, 2005).

Processes such as explaining, responding to questions, and giving and receiving help have been widely recognised as acts likely leading to learning (Weiss & Dillenbourg 1999, Webb & Mastergeorge, 2003; Roscoe & Chi, 2008; Hakkarainen, 2009) It has been found that externalising one's thoughts to others

is also an efficient way for the individual to learn (Palincsar & Brown, 1984). The central roles of asking questions, formulating questions, and questioning functions are also of vital importance in group situations. Barnes & Todd (1977) explored the role played by questions in learning talk while constructing shared meanings. They expected that the effectiveness of taking others' opinions and viewpoints into account in problem-solving situations through negotiation would depend upon the devices with which members of the group asked for other's opinions, encouraged explicitness, pinpointed differences, and interrelated viewpoints.

Thus, discussion in collaborative situations may be a prerequisite, but it does not automatically produce knowledge sharing and construction (Cherubini, van der Pol, & Dillenbourg, 2005). Stahl (2006) has pointed out that "shared knowledge" can refer to similarities in the individuals' knowledge, to knowledge that is shared during the interaction (individuals communicate what they already know), and finally, to group knowledge, which refers to knowledge that is interactively achieved in common discourse. Through perspective sharing the collaborators come to challenge and refine their perspectives, current understanding, and knowledge, which leads to the construction of group knowledge (O'Malley, 1995; Mäkitalo, 2006). It should be noted that despite a group's involvement in collective comprehension activity for a certain task, the result of their activity does not mean that all individuals then would have uniform knowledge. Their comprehensions may be different, but significantly, much of comprehension is achieved only after participating in the constructive interaction of the group (Hatano & Inagaki, 1998).

Because the nature of interaction and learning is multifaceted, the effects of collaboration require complex measurement. A recent study by Kapur (2008) reported that groups of students failed to solve ill-structured problems in physics, but as individuals then outperformed students in groups who had succeeded in well-structured problem solving. These findings bring an interesting point of view to the discussion on the benefits of collaboration for learning by showing how a group situation that led to failure in the initial situation finally contributed to the future performance of the individuals. Barron (2003) also has studied the failure of smart groups. She found that neither the prior achievement of the participants nor the generation of correct ideas in the groups were the keys to success. Instead, the successful groups were better at managing the two spaces of the group's problem-solving situation: the content-space, which is related to the problem-solving task, and the relational space, which is related to the social interaction of

the group. These two spaces, also discussed by Baker (2002) and Thompson & Fine (1999), intertwine to form a joint problem-solving space and compete for our attention in all collaborative situations requiring simultaneous attention.

2.2 The interplay of language, interaction and learning

The relationship between interaction and learning is a central concern and a major theme of the learning sciences in general and the current literature on computer-supported collaborative learning in particular. Interaction can be defined broadly here, referring to encounters and exchanges with others and associations through artefacts leading to individual and group-level learning (Suthers, Dwyer, Medina, & Vatrapu, 2010). One must ask the question of how precisely interaction is related to collaborative learning. This question is relevant since it has been suggested that the focus of interest in the field of CSCL should be "intersubjective meaning making" instead "collaborative learning," which is visible only indirectly and retroactively (Stahl & Hesse, 2006; Suthers, 2006). Dillenbourg (2006) also emphasizes our efforts towards shared understanding in social situations. These efforts correspond in practise to interactions such as rephrasing and explaining, which are necessary to co-construct a shared understanding of the domain. Shared understanding is not a mechanism that occurs only once in the course of interaction, but progressively emerges throughout the collaborative situation in processes such as mutual regulation, grounding, and justification (Weiss & Dillenbourg, 1999).

In the context of this thesis, discussion, or "intersubjective meaning making" is viewed as a central building block upon which collaborative learning depends. The practice of intersubjective meaning making can be found in any joint human activity, which inevitably extends the scope of CSCL studies. Learning can be seen as ubiquitous, that is, taking place in a wide diversity of activities and situations (Suthers, 2006). This can be seen as loss of focus, but it also points out the relevance and longevity of CSCL, which can contribute to many interdisciplinary fields of inquiry (Suthers, 2006).

2.2.1 Constructing shared understanding through discussion

Language plays a major role in both participation and collaboration, and can be seen not only as a mode of action but also as a means of interaction (Edmondson, 1981). The word "communication" derives from the word communicare, which

means to share. From a linguistics point of view, sharing meaning through discussion is always a joint endeavour including both speakers and listeners. The roles change as the discussion proceeds; one of the listeners must assume the role of the speaker after an appropriate interval. Participation in a discussion necessitates an active approach in taking the roles of both speaker and listener at some points in the discussion. (Kraut & Higgins, 1984; Hudson & Bruckman, 2004)

However, in collaborative situations, the participant must do more than just utter the right sentence at the right time. The contributions must add to the common ground of the participants in an orderly way (Kraut & Higgins, 1984). A closer look at the discussions shows that the contributions are actually highly coordinated activities, where the participants try to make sure that they are heard, and in their turn, listen and aim to let the speakers know that they have succeeded (Clark & Schaefer, 1989). The process previously described is "grounding," which has gained much research attention originally in linguistics studies, but it has been also strongly adapted to studies on collaborative learning (e.g. Baker, Hansen, Joiner & Traum, 1999; Dillenbourg & Traum, 2006). All collective actions are built on common ground and its accumulation. Common ground calls for effort from every participant since not only the utterances and meanings must be grounded, but all aspects of collaborative activity count in this process. The grounding process takes place throughout the interaction by updating the common ground moment by moment as the work proceeds (Clark & Brennan 1991). Probably due to the laborious nature of maintaining the common ground, it has been noticed that in discussions the participants try to minimise their collaborative effort, in others words, invest as little effort as possible to get the others to understand (Clark & Wilkes-Gibbs, 1986). Minimal effort then is followed by consequences such as a need to repair the mistakes and misunderstandings taking place within the course of discussion (Clark & Wilkes-Gibbs, 1986).

Grounding is not the same as shared understanding, but is closely connected to it, since through providing evidence the participants aim to understand each other better (Cherubini, van der Pol & Dillenbourg, 2005). The ultimate goal of grounding is to reach shared understanding among the participants as asserted by Shotter (1993):

> *"Most of the time, we realize, we do not fully understand what another person says. Indeed, in practice, shared understandings occur only*

occasionally, if they occur at all. And when they do, it is people testing and checking each other's talk, by them questioning and challenging it, reformulating and elaborating it, and so on. (p. 1)"

In this respect, the efforts of constructing shared understanding in practise means that everything has to be explicit (Biesta & Burbules, 2003). The idea that communication rests on the foundation of shared understandings has long been studied in the social sciences—in social psychology and philosophy, for example (Mead, 1934; Bruner, 1996; Thompson & Fine, 1999). The central point of interest of this previous research has been the examination of social behaviour of pairs and groups in developing and utilising collective meaning (Thompson & Fine, 1999). Central in constructing shared understanding in communication is the ability to assume the perspectives of others, that is, to view every situation and turn in the discussion from the point of view of the other participants (Krauss, Fussel, & Chen, 1995). The art of perspective taking (Selman, 1980) or situational role taking means in practise "stepping into others' shoes." Perspective taking is also at the heart of learning, forming the basis for productive collaboration.

For interpreting others during collaboration and discussions, one also must be able to read, see, and hear subtle messages, which are not necessarily verbalized. The speaker is trying to look for evidence for this understanding from the listeners acknowledgements in verbal signs (e.g., yeah, uh huh), nonverbal signs, or continued attention. This understanding can also be evident in the relevance of next contribution or in the verbatim demonstration by the listeners showing that they have understood the speaker (Clark & Schaefer, 1989). The willingness and effort by the participants to orient their actions towards shared understanding has been also called "reciprocity" (Nystrand, 1986), which is a principle that governs how people share knowledge, what knowledge they decide to share, and how they present it in the discourse. Therefore, for reciprocity to be achieved, the participants must act and contribute in terms of what they expect the others to know by tuning their messages accordingly.

2.2.2 Participating to the collaborative knowledge construction

The construction of shared understanding in collaborative situations benefits by taking into account the equal participation of individuals. A high level of unequal participation implies that collaboration is largely influenced by the dominant members of the group, leading to decreased chances of reaching shared

understanding among the participants. Despite its significance, the effect of inequity in group participation and performance has been so far relatively unexplored (Kapur, Voiklis, & Kinzer, 2008). There is, however, evidence in the context of studies in higher education (Prichard, Stratford, & Bizo, 2006), which have found that collaboration can be practiced so that group-based activities enhance rather than impede learning. The findings pointed out that in trained groups the participation of the individuals was equal, whereas in the untrained groups one team member easily dominated the discussion. Equal participation was shown to have positive effects such as resulting in more discussion for the task procedure and task content, which then enhances individual learning. The extent to which the participants distribute their task workload and participate equally depends largely on their shared understanding both of the task and one another. Thus, it can be seen that team skills training can also be an important factor in promoting the development of shared understanding (Prichard, 2002). A recent study by Kapur, Voiklis, & Kinzer (2008), which explored participation inequity, pointed out that participation levels tend to become locked early in the discussion. It was found that high quality member contribution did more good early than later in the discussion; the eventual group performance could be predicted based on the first 30–40% of the discussion. Although hasty generalizations should be avoided, these results on participation inequity call for more research. Furthermore, there is a strong implication that equal participation in group performance is tightly connected to the levels of shared understanding.

In sociocultural studies, it is viewed that discussion in collaborative situations is framed by the unwritten and tacit rules of discussion, which are learnt through participation (Edwards & Mercer, 1987). Studies conducted in collaborative situations in both classroom and face-to-face contexts pointed out that guiding children to more efficient ways of discussion (Exploratory Talk, Mercer, 2008) made a significant difference to the test results (Mercer, 2008). Moreover, the results of the same study indicated that the children not only learnt how to better use talk for thinking collectively, but also improved their individual reasoning capabilities. Since learning effects seem closely tied to the quality of discussions, the teacher's core task would therefore be to focus on ways of participating in the interaction and to develop equal participation of the students (Roth, 2008). As language can be understood as our prime tool for making collective sense of an experience (Mercer, 2008), the collaborators should be encouraged to engage in ways of participating and using language as they would in any learning context.

Overall, in light of recent studies in collaborative learning, it could be deduced that mere engagement, which requires the participants' active mental attention but not contribution (Hudson & Bruckman, 2004), finally is not as central to learning as the actual and equal participation of individuals in group situations. On the other hand, Hatano and Inagaki's (1998) study on sharing cognition in collective activity pointed out that silent members may be actively participating. They can learn by observing the debate carefully and trying to find an agent, someone who speaks for them. It could be argued that this silent learning applies to situations where the learning of content is the focus. On the other hand, the active role would be more relevant to situations in which the learning of participation in collaborative knowledge construction is the aim. However, these findings point out that social interaction and collaboration are situated (Greeno, 2006) and unique in nature, and thus the design and scale of optimal learning contexts for large groups of people is highly complex.

2.3 Enriching Collaboration through CSCL

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 a problem-solving situation that is carried out by a group of people with complex technological artefacts and material representations produced during the task. The social aspects are approached by examining the group's shared social practices and the ways in which individuals participate in the activity (Greeno, 2006b). Considering the complex nature of learning, it seems justified to study collaboration in close relation to the 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.

The discussion in Chapter Two has focused on the social aspects of collaborative learning. In the remaining part of the chapter, the scope is widened to the physical environment and tools acting as settings for collaborative learning. Today, the number of technology-supported collaborative applications claiming and aiming to facilitate collaboration is increasingly large. To ease the educators' selection, the suggestion was made to divide the applications into collaboratively usable applications (simply allowing multiple users) and collaborative technology

(especially designed to support collaboration), based on the instructional and pedagogical aspects of each application (Lipponen & Lallimo, 2004). In this thesis, the focus is specifically on collaborative technology, the underlying aim of which is to support those interactions and mechanisms that have been found beneficial for learning. In practice, this support can be carried out with several technological tools such as computers, mobile devices, and games. Regardless of the medium, the core purpose of all CSCL environments is to create conditions in which effective group interactions are expected to occur (Dillenbourg, Järvelä, & Fischer, 2009).

2.3.1 Promoting interaction through technology

The evolution of the CSCL field can be portrayed in three stages, which indicate the developments that have taken place in the last twenty years (Dillenbourg & Fischer, 2007; Dillenbourg, Järvelä, & Fischer, 2009). During the first half of the 1990s, the field evolved the key idea that co-construction of knowledge in social settings was crucial to collaborative learning and that productive interactions could be supported by careful design of CSCL environments (Teasley & Roschelle, 1993). It was seen that cognition could be distributed into computers not only socially but also physically (Perkins, 1993), and CSILE, Computer Supported Intentional Learning Environments, were implemented to support collaborative inquiry learning in classroom settings (Hakkarainen, 2009). The second stage (1995–2005) held the same principle in engineering learning environments. However, the field matured, expanded, and research methods of real time analysis were developed. Several studies have been carried out analysing the quality of participation in online discussions concerning the effectiveness of CSCL environments and seeking optimal conditions for learning online (Kirschner, 2002).

In recent CSCL studies, collaborative learning has been increasingly integrated within comprehensive environments that consist of many types of activities with multiple tools offering possibilities for both collaborative and non-collaborative learning to take place (e.g., Roschelle, Rafanan, Estrella, Nussbaum, & Claro, 2010). Within the framework of this study, the evolution of the field can be seen in the settings of the empirical studies and in the approach of supporting the productive collaborative interactions. The basic requirement for individual students, however, remains the same since despite the medium, one must contribute to the discussion in order to participate in collaborative activities.

In computer-mediated contexts of collaborative learning, the interaction can be distributed across participants, space, and time and can vary from synchronous to asynchronous within one setting (Suthers, Dwyer, Medina, & Vatrapu, 2010). Because each communication medium has affordances, the possibilities it holds for social interaction and collaborative activities (Kreijns, 2004; Mäkitalo, 2006), also affect the processes of collaboration. For example, the ways in which we discuss in phone conversations, face-to-face, and web-based discussions are therefore diverse. The fact that interactions can be distributed over different mediums and continents offers huge opportunities in terms of learning together; an example is international groups who share perspectives by the internet (Saarenkunnas, et al., 2000). Physically distributed activities may then be accompanied by other contexts. For example, in a language-learning context it was found that online learning and classroom learning play complementary roles in language learning (Hudson & Bruckman, 2004). In the first empirical study of this thesis (Bluemink & Järvelä, 2003), the face-to-face discussions were also seen as the reflective element of the collaborative activity taking place in the online environment.

The distributed setting inevitably challenges the participants and, therefore, the question of productive joint engagement and the ecology for collaboration have shaped the CSCL studies in the past (Crook, 2000). Ecology here refers to immediate environments such as artefacts, technologies, and spaces for acting, by which collaborative learning is supported. Overall, the role of technology in learning was not seen as just "a source of input and a receiver of output," but as a vehicle of thought (Perkins, 1993, p.90). Human intelligence is distributed between technology and humans, where technology not only mediates activities but also channels attention, thinking, and participation (Dillenbourg, 1996). Thus, computer support can help transcend the limits of individual cognition and in many ways aid in making the complexity of collaborative activities manageable for individuals (Stahl, 2006).

Currently, there is wide range of different computer based learning environments that can be employed to support learning. As web-based learning environments already start to look old-fashioned, Web 2.0 offers a huge potential for anyone interested in sharing and interacting in our networked world. Nevertheless, from the perspective of collaborative learning, technology has never been the real issue, which is how to engage learners and gain evidence that learning has taken place. Less than ten years ago, the discussion concerning learning communities was lively (Barab, 2003). The challenge was, as in any

web-based learning context, how to maintain the learner's interest in the learning environment so that they returned instead of visiting once or twice and then quit the course (Järvelä & Häkkinen, 2002). A lot of research interest has been shown to study the quality of the web-based learning, especially the discussion chains and their quality (Mäkitalo, 2006; Arvaja, 2005). The empirical research on CSCL has shown that networked collaboration does not automatically lead to a higher level of understanding and that not all individuals in the group participate in new knowledge creation (Dillenbourg & Traum, 2006; Salomon & Globerson, 1989). It has been found that in many text-based virtual learning environments, the students' engagement and reciprocity are on a poor level, and learning in collaborative situations is therefore rarer than commonly expected (Järvelä & Häkkinen, 2002; Stahl, 2006, Arvaja. 2006).

2.3.2 Multiplayer games as contexts for collaborative learning

In CSCL studies, the approach in the early years of the millennium was to look for technology-supported environments that could enrich the quality of distributed collaborative activities. The studies indicated that there was a need for more advanced technological solutions to support problematic issues in virtual interaction such as participants' lack of the sense of co-presence and the challenge of reaching shared understanding in distributed collaboration (Fischer & Mandl, 2001; Häkkinen, Järvelä & Dillenbourg, 2000). At this time, the fast development of technology and networks enabled a wider-spread use of 3D multiplayer environments and games, and high expectations encouraged studies on how 3D technology could raise the quality of networked interaction (Gee, 2006; Aldrich, 2009). From the perspective of CSCL, when considering the aim of promoting productive joint engagement (Crook, 2000) in distributed settings, the benefit of games was seen in the engaging nature of the medium. It was thought that certain features of games could be employed in the design of more engaging learning environments (Dickey, 2005), and that games could activate and stimulate learners to participate. Overall, games seem to have the dramatic potential to immerse players in complex systems and allow them to learn the points of view of those systems (Squire, 2006).

Increasing interest in the CSCL field is also shown by the number of publications focusing on aspects of learning. A recent book of design and use of serious games (Kankaanranta & Neittaanmäki, 2009) defines serious games as providing an engaging and self-reinforcing context in which to motivate and

educate players. Moreover, serious games in principle can be of any genre, use any game technology, and be developed for any platform; however, their common denominator is that they teach the user something and their aim in general is to raise the quality of life and well-being. Serious games can be very versatile and developed for a variety of purposes and settings—fire fighter simulator training, for example (Lebram, Backlund, Engström, & Johannesson, 2009). Serious games can be developed for work-context ethics training with "Massively Multiplayer Games" (Smith, 2010) and internet-based knowledge management simulation (Leemkuil, de Jong, de Hoog, & Christoph, 2003). In the military context of both teaching and simulation, these games have been adopted widely (Ondrejka, 2006; Squire, 2005). Moreover, commercial games, such as Sims 2 Pets, have been employed for serious use. A study carried out in primary schools built a context around game playing in such a manner that it supported learning objectives set at the beginning of the intervention. The results demonstrated that commercial videogames could be an important instrument for facilitating thought about the relationship between virtual and real words (Lacasa, Méndez, & Martínez, 2009).

In 3D avatar-based multiplayer games, the human-like figures representing the players can motivate the interaction in 3D environments and provide non-verbal features for the game communication (Manninen & Kujanpää, 2005; Talamo & Ligorio, 2001). This could be important because people have learnt to interpret other's non-verbal cues since early childhood, and they provide us with important information that cannot necessarily be expressed by words (Rogoff, 1990). A central characteristic of games is that they are organised around "doing," that is, being active. The activity fostered by game environments through the avatar is the core element of the medium, making the cognition in the digital worlds mediated by players' capacities for action and players' actions as his or her interface with the world (Squire, 2006; Clinton, 2004). Games also require action without expertise, by forcing players to hypothesize, experiment, and learn from their mistakes (Ondrejka, 2006).

An important part of acting in the game environment is the players' perception of the game world and the ability to interpret pictures, signs, and symbols (Squire, 2006). Inexperienced players might find the first experience of playing a 3D multiplayer game somewhat overwhelming and perhaps challenging. However, interpreting the visual environment is becoming a necessary skill that fosters learning in other contexts as well (Dickey, 2005). When it coordinates visual interpretation skills with other skills, the group also actively creates

something that is shared. The only way to test the understanding is to do something together when this information is needed and thus understanding will be visible (Biesta & Burbules, 2003). This is most likely the fundamental benefit of multiplayer game environments. In addition to discussion, the game context enables the players to interpret each others' understanding through the avatar activity. Gibson (1986) has described a continuous perception-action cycle that is dynamic and ongoing; agents perceive and act with intentionality in the environment at all times.

The field of serious games is still young, which is evidenced by the heterogeneous quality and scope of studies to date. However, the role of games in learning is increasing and it has been asserted (Squire, 2005) that the more videogames mature as a medium, the question becomes not whether they will be used for learning but for whom and in what contexts. More empirical studies, not merely reviews and general reports, are needed, to examine the real game situations and their relevance to learning, collaboration, and transfer (Gee, 2006). Currently, as asserted by Sawyer (2007) and Aldrich (2009), the field still has a huge research gap. However, the drive for research is not nearly as great as for building new projects, which at some point might precipitate a decrease in funding from those who want to see outcomes and returns on their investments.

2.3.3 Pedagogical scripting to support collaboration

As the research on CSCL pointed out free collaboration does not systematically produce learning (Dillenbourg, 2002). Online learning environments alone do not guarantee that high-level collaborative learning takes place (Hämäläinen, 2008). To increase the chances for learning to take place, scholars aimed to evoke the interactions that were essential for learning. For example, they aimed to augment the number of conflicts, foster elaborated explanations, and support mutual understanding. This pedagogical structuring can take the form of pedagogical models, an example of which is a model of reciprocal teaching (Palincsar & Brown, 1984). In the original study, the idea was to organize reading comprehension activities in a classroom setting so that the reading was carried out in groups to make the strategies of reading for comprehension visible.

In technology-supported learning contexts, pedagogical structuring is often carried out by designing predefined collaboration scripts for environments. Scripting can be viewed as an instructional approach to support collaborative learning. In recent years, scripting has gained significant research attention (e.g.,

Dillenbourg, 2002; Weinberger, 2003; Stegmann, Weinberger, & Fischer, 2007; Hämäläinen, 2008) and many studies have indicated that overall, participants have benefitted from the support and structuring of CSCL learning activities (Lipponen, 2000; Lehtinen, 2003). In practice, scripting often refers to a set of instructions that prescribes how students should form groups, how they should interact and collaborate, and how they should solve problems. In CSCL environments, the script can be integrated in the interface of the learning environment and dismantled through participants' contributions (Dillenbourg, 2002). In a study focusing on online discussions (Stegmann, Weinberger, & Fischer, 2007) scripting was found to improve the formal quality of students' contributions and facilitate the acquisition of knowledge of argumentation. In this research setting, however, the scripted groups did not have higher gains in the acquisition of the actual domain-specific knowledge than the non-scripted groups. However, a recent study by the same authors (Weinberger, Stegmann, & Fischer, 2010) showed positive effects of scripting in the acquisition of domain specific knowledge.

These partly contradictive results on scripted collaboration not only underline the situative nature of learning, but also point out that the line between optimal and disruptive involvement in the process of collaboration is thin. For example, in the best outcomes, the scripted roles of students are internalized and learnt so well that the students keep on using them even after the scripting is finished (De Wever, Van Keer, Schellens, & Valcke, 2010). In other cases "over scripting" can hamper the processes of collaboration and decrease the motivation of the participants (Dillenbourg, 2002). In an overview (Spada, 2010) of a recent special issue on emerging and scripted roles of learners in CSCL, he pointed out that instead of focusing only on the effects of scripting on the situation at hand, it would be beneficial to think a step further to see how students learn the scripted roles and transpose them to unscripted future situations. According to Spada, the goal should be to help students to become more aware of the conditions and consequences of roles and collaborative behavior in group situations (Spada, 2010). This is also in line with the overarching goal of learning scientists, which is to raise individual awareness of strategically efficient collaboration.

Regarding game environments and their design, major similarities can be found between collaborative scripting and the basic framework of game design. Salen and Zimmerman (2004) asserted that "Game designers do not directly design play. They only design the structures and contexts in which play can take place, indirectly shaping the actions of the players" (p. 67). According to these

authors, word play could easily be replaced by learning. They point out how a design process similar to scripting is built into game development practice. Serious game designers should strive to combine game characteristics with pedagogical elements (Dickey, 2005), while balancing the fun and the learning. This balancing act is not formulaic; hence, much research is needed to identify and explain how motivational tenets, the principles of instruction design, and the many instructional theories, models, processes, and strategies should be integrated in serious game design (Gee, 2006; Squire, 2006). The game design makes it possible, for example, to require players to analyse, synthesize, and use critical thinking skills in order to execute moves. Game designers are well versed in creating scenarios and events that subtly invoke these activities.

To conclude, it can be seen that at present, game design is at the forefront of innovative techniques for interactive design (Dickey, 2005; Squire, 2006). At the same time, learning scientists have a key role in analyzing and pointing out potential situations for actual learning to take place. A combination of these two, "the serious" content in an attractive and enjoyable package can be introduced to participants in a subtle manner.

3 Aims of the study

The general focus of this doctoral thesis is on enriching collaborative learning through pedagogically scripted multiplayer games. Collaborative learning was examined as it appears in the synchronous discussions of small group problem-solving activities, in both face-to-face and virtual game settings. Three empirical studies were carried out. The first examined small group face-to-face discussions as a part of a web-based course for university students. The second empirical experiment reported in Articles II and III was carried out in a 3D voice-enhanced multiplayer game, "eScape," and the main data was university students' small group discussions that were videotaped during the game. The data from the third empirical study reported in Article IV are individual interviews from the context of working life, which was carried out immediately after playing a 3D voice-enhanced multiplayer game "Gate" in small groups.

The detailed aims of the current thesis were the following:

1. The first aim was to analyse the nature of synchronous small-group discussion in technology-supported settings of collaborative learning (Articles I, II, III).
2. The second aim was to explore the particulars of a 3D voice-enhanced multiplayer game context for small group collaborative activity (Articles II, III, and IV).
3. The third aim was to experiment the kind of scripting of multiplayer games that can enrich collaborative learning (Articles II, III, IV).
4. The fourth aim was to discuss the methodological issues for studying social interaction and collaborative learning in 3D voice-enhanced multiplayer games (Articles II, III, and IV).

4 Methods of the study

4.1 Research design of the empirical studies

This thesis consists of three empirical studies that have been carried out as part of larger research projects at the Learning and Educational Technology Research Unit at the University of Oulu. The first empirical study was a part of NINTER (Networked Interaction), a research project funded by the Academy of Finland. The second empirical study, "eScape," was a sub study of an Ecology of Collaboration (ECOL) research project also funded by the Academy of Finland. The third empirical study was carried out in the Gate for Collaboration research project funded by the Finnish Work Environment Fund. The main goal of these empirical studies was to support collaborative learning processes through pedagogical structuring of computer-supported learning environments (see Figure 1). Because the first empirical study was carried out about ten years ago, a historical perspective of CSCL field also is discussed.

The research design combines characteristics from the design based research (DBR) approach (Brown, 1992; Barab, 2006) and situated approach (Greeno, 2006b). In line with DBR is the aim to iterate the design of the game environment between the empirical studies two and three; and the reciprocal relation between the empirical studies and a theoretical framework of learning. In many aspects, the situated approach is close to the research design of this thesis, especially in its goal to understand cognition as the interaction among participants and a tool in the context of an activity (Greeno, 2006b; Hutchins, 1995). The goal of the situated approach is to understand distributed cognitions as problem solving, planning, and reasoning carried out by a group of people working in complex technological artefacts. This goal describes the main aim of this thesis. In addition, the types of data collected from the three empirical studies are records of interaction, including joint discussions, gestures, and visible representations.

The first empirical study was conducted in 1999 in the context of an international web-based course for pre-service teachers. The course was called "Shape: Shared Perspectives in Virtual Environments." It was developed from the results gained in the first phase of the NINTER research project (Saarenkunnas et al., 2000). At the end of the 1990s, the focus in the CSCL field was the collaborative process in web-based learning environments. The NINTER research project is one example of this trend, indicating that in order to promote the

development of shared understanding among students; the latter should be more involved in the study process and work towards a joint goal. In this context, the Shape pedagogical model (see Bluemink & Järvelä, 2003, p. 204) was developed to structure the collaborative learning processes in a web-based course. Face-to-face encounters were an important part of the pedagogical model to function at a "metawork" level, allowing the students to build common ground and reflect on their experiences from the collaborative activity taking place in the web-based environment.

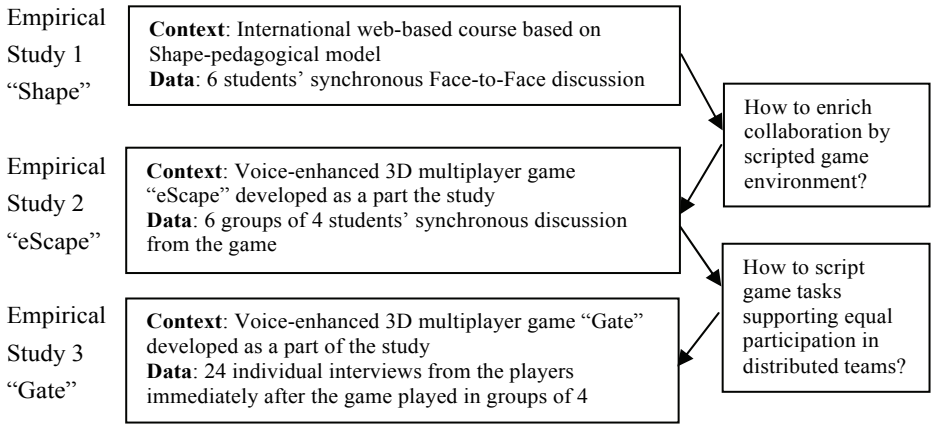

Fig. 1. Illustrating the research design in terms of the contexts and types of data in three empirical studies and the aim for iteration from one study to another

The results from the Shape study (Järvelä & Häkkinen, 2002; Kuure, Saarenkunnas, & Taalas, 2002) demonstrated that it was possible to support collaboration in a web-based context using pedagogical models. This pedagogical structuring was soon renamed collaborative scripts, which become the centre of attention in the CSCL community (Dillenbourg, 2002; Weinberger, 2003). From this development came the idea of studying how a voice-enhanced virtual game environment could support and enrich collaborative activities. The "eScape" game was developed as a part of the ECOL research project, and an effort was made to support social interaction by structuring collaboration through designing collaborative tasks and group playing processes in a virtual multiplayer game. The aim of the game design was to promote collaboration, especially in a distributed small group setting for players without previous gaming experience.

The results of the eScape-study (Bluemink & Järvelä, 2011; Bluemink, Hämäläinen, Järvelä & Manninen, 2010), demonstrated that a voice enhanced virtual game formed a strong shared context for distributed collaboration. However, the analysis pointed out that for true collaborative activity to take place, it was vital to design tasks that would force all players to participate in the shared problem-solving situations during the game. Furthermore, there was an interest in how this type of game could support the work teams in the context of distributed work gained support. Based on the results of the eScape study and the focus group of distributed work teams, the Gate for Collaboration research project is the third empirical study reported in this thesis. The development of serious game environments started progressing quickly in the period between 2002 and 2007, creating more support for the idea of employing game environments to support learning. However, the approach of a social adventure game environment based on the principles of collaborative learning without a specific content area was still novel since most of the other serious games focused on simulations and other content-related activities, as discussed earlier. In the following chapters, all three empirical studies and the methods of data collection are introduced in more detail.

4.2 Subjects and research settings

The data collection and analysis of this thesis was carried out in three empirical studies (see Figure 1. and Table 1.). The participants in the first two studies were higher education students (Articles I, II and III), and the third study used representatives from companies and organisations in Northern Finland (Article IV). A common denominator of the subjects of the different studies was that they were all adults or young adults and that all studies were conducted in a university context. In the first two empirical studies, the subjects participated in a course at the University of Oulu, and in the third empirical study, the representatives from the companies and organisations participated in game experiments organised at the University of Oulu by the Game Design and Research Unit.

In the first empirical study (Article I) the context was a compulsory English language course for teacher education students. It was organised in co-operation with four universities: the Universities of Oulu and Jyväskylä in Finland; University of Indiana in the United States; and the University of Warwick in the United Kingdom. The total number of participants in the international course was 83. However, the data for Article I was collected from the University of Oulu,

where 19 students took part in the course. From these students, a group of 6 pre-service teachers were chosen for the detailed analysis.

The second and third empirical studies were conducted as game experiments where the subjects played a virtual multiplayer game in groups of four. The subjects in the second empirical study (Articles II and III) were 24 university students participating in an optional course entitled "Innovative Technology and Research: Collaboration in a 3D virtual environment" of which the "eScape" game was one part. The third empirical study (Article IV) was a game experiment, "Gate for Collaboration," which was organised for representatives from companies and organisations in order to study how the Gate game suited distributed work teams. The 24 subjects were invited through Oulu University's MBA program and the researcher's contacts; they were asked to test a new type of collaborative game environment for team training and human resources development.

4.3 Structuring collaborative learning

As the research carried out in the field CSCL has shown, free collaboration does not necessarily lead to learning (e.g. Dillenbourg, 2002). Therefore, to support and direct learners' collaborative learning activities to enable joint knowledge construction processes, the learning environments can be specified and sequenced by structuring. In the first empirical study, pedagogical structuring took the form of the SHAPE pedagogical model, which was developed in CSCL studies at the end of the 1990s. The key idea of the model was to support students' web-based work with face-to-face meetings throughout the course. The design of the course was based on the idea of electronic case mentoring (Bonk, Malikowski, Angeli, & East, 1998; Järvelä, & Häkkinen, 2002), where students write their cases in the discussion area of the web-learning environment on a topic or a problem interesting to them; during the course the other students and mentors comment on the cases. For the learning effects, it is central that the students have generated the cases from their earlier field experiences, bringing practice and theory closer together.

In the second and third empirical studies, the pedagogical structuring was carried out in the form of scripting the game environment. Serious games provide learners with challenges (Dickey, 2005), which are seamlessly integrated with the game; it is difficult to distinguish the learning from the fun (Charsky, 2010), which was also the aim of the eScape and Gate games. In the eScape study, the

game was developed with an intention to create innovative spaces for collaboration and increase the awareness of social processes. A special emphasis was laid on developing a game that would support and mediate social interaction and facilitate the sense of togetherness among a distributed team. These goals were implemented in tasks that were situated on a prison island; each group had to complete five tasks in order to escape (see Bluemink & Järvelä, 2011). The game was intentionally designed for inexperienced players, so it was easy to play from the navigation point of view. Although gaming skills were not decisive to the outcome of the game, the ability to solve problems through negotiation and collaboration was necessary.

The basic idea of the Gate game was the same as that of the eScape game. It also included five collaborative tasks (see Bluemink & Leinonen, 2011). However, the tasks and the game environment were tailored to match the focus group and the distributed work teams. The tasks were developed based on the results and experiences of the eScape study. The most significant changes were made by taking the structure a step further to require all group members' participation, so that the tasks could not be solved alone. In eScape, the aim was the same; however, it was noticed that the tasks needed stricter structuring to compel all players to participate. It seemed that the game environment was so appealing that the temptation to discover and carry out solo activities was high for many, especially the more experienced players. Moreover, most of the task fields were designed to open one by one, which made it easier for the players to perceive the unfamiliar virtual world. The possibility to "freeze" the players was added to restrict the pointless running of the players in the game environment. This was carried out in the form of adding a cell with a time lock with the purpose of making the players stop for a moment to think and negotiate.

Overall, the changes from the eScape to the Gate game increased the pedagogical structure by decreasing pointless running and drawing the focus towards joint collaborative activity and negotiation. In addition, in the Gate game, the design objects for each task were more clearly rooted in a collaborative learning and teamwork perspective. The objectives of the tasks in the Gate game were giving and receiving help (Webb & Mastergeorge, 2003), building psychological safety (Van den Bossche, Gijselaers, Segers, & Kirschner, 2006), coordinating tasks and actions (Barron, 2000), sharing existing knowledge (Stahl, 2006), and distributed team work (Durnell, Cramton, & Hinds, 2005).

4.4 Data Collection

It has been asserted (Suthers, 2006) that in order to understand learning, we must examine what the participants do when they engage in an activity that leads to learning. Multiple types of data were collected from the empirical studies due to the contexts, which were larger research projects. The data finally employed for the empirical studies of this thesis consisted of videotaped small group classroom interaction, web-based contributions (Article I), videotaped small-group in-game activity (Articles II and III), and individual semi-structured interviews (Article IV). Additionally, the background information (Article III) on the participants has been utilized to complement the other data and give contextual information about the individuals in the small groups.

The empirical studies of this thesis were carried out in 1999, 2003, and 2007. Since these years, technology and the possibilities and contexts that it can offer for learning, collaboration, and daily life have taken leaps forward. At the same time, our theoretical understanding and approach in CSCL contexts also have developed. Both the technological and theoretical developments also can be seen in the practical aspects of data collection from each empirical study. In the first empirical study, the classroom interaction was recorded with a VHS-video recorder that was hard not to notice; in the game experiments the player actions and choices were easily recorded by an invisible virtual player that was not visible to the players but could follow them freely in the environment.

In the first empirical study (Article I), the data consisted of students' face-to-face discussions in Finnish and their contributions in the web-based learning environments in English. The face-to-face discussions were videotaped to study metatalk during the course, which formed the data for the quantitative content analysis. In 1999, the small group encounters were recorded with a rather large static VHS video camera standing on a tripod in the corner of the seminar room at the Faculty of Education. During the data analysis, the VHS video tapes were watched from a separate TV and VHS tape recorder, and the transcripts and notes were recorded on a computer standing next to the TV. The transcription work proceeded slowly, and the VHS tapes had to be rewound and forwarded many times. At the time, this procedure was standard in studies using video data. The web-based work took place in the ProTo (Project Tools for Learning) learning environment, which was the common platform for all participants. ProTo was a web-based learning environment developed at the University of Oulu and was the predecessor of environments such as Discendum Optima, and Blackboard. All

contributions were automatically saved to the environment, which made it easy to analyse the web-based activity of the students.

The second data collection took place in November 2003 (Articles II and III) in the current V-Lab of the University of Oulu, which at that time was a TV studio. The plans for the game experiment were ambitious in relation to the resources and types of computers available. The set up of the computers for playing the game and video recording each player and their screens took a great deal of planning and coordination. All the players were seated in the same room and separated from each other with screens and curtains. The researchers and developers from the Game Research and Development Unit brought their own work computers from their faculty to ensure a fluent game experience for the participants. Smaller digital video cameras were used to tape the view of each player and their screen. The videotapes of four players were combined into one video first by bringing the video streams to four TVs set up next to and on top of each other, and second by taping the views of those four TV screens with another video camera. In addition, the game was videotaped from inside the game world by a so-called invisible player who was following the players in the game but whom the players could not see in the virtual game environment. The voice was recorded separately and matched afterwards to the video. In the data analysis, the video was on DVD format, and it could be watched from the computer screen simultaneously with the transcription and coding work.

In the third empirical study (Article IV), the Gate game experiment was set up in May 2007 in the Faculty of Computer Sciences, Game Design and Research Unit. Again, the plans for the game experiment were ambitious in relation to the resources. The work computers of the researchers and developers from the Game Design and Research Unit were once more reserved for the players' use; the practical arrangements for the distributed team setting took one weekend to complete. Each player was seated in a separate room in the department and the game world was recorded with the same invisible player technique as in the second research experiment. In the Gate study, however, the main data were the individual interviews, which were carried out right after the game with the method of stimulated recall. Photos from the game situations were shown to remind and stimulate the players to remember different situations of the game.

4.5 Analytic framework

The methodological approach employed for the analysis of the data of this thesis was qualitative and based on the situated approach of learning, which emphasizes the understanding of collaborative discourse as group thinking made visible (Greeno, 2006b). The data collected from real collaborative activity is referred to as "messy data" (e.g., verbal explanations and videotapings). 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).

Content analysis, "a research technique for making replicable and valid inferences from data to their context" (Krippendorff, 1980, p. 21) has been largely adapted as a method for studying social interaction in CSCL contexts (Strijbos, Martens, Prins, & Jochems, 2005). 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 (Weber, 1990; Tesch, 1990). The categories in the empirical studies of this thesis were both theory and data driven, meaning that the categories arose from the data, but were also established in the theoretical framework of collaborative learning and CSCL. An attempt was made to study collaborative learning in small groups on both individual and group levels (see Table 1.). A small group, "an ensemble" was seen as a group of people who directly interact with one another during the collaborative activity (Granott, 1998). At the same time, individual cognition was not forgotten but treated as a part of a complex social process of collaborative interaction (Thompson & Fine, 1999).

The units of analysis, a central characteristic of the content analytic approach, were chosen based on the type of data in each empirical study. For verbal data, the defining cut can occur at many points (Chi, 1997). The relatively slow paced face-to-face discussion data (Article I), consisting of longer elaborations from individual students, called for analysis in episode levels. On the other hand, the data from the game activity (Articles II, III) were very quickly paced and context dependent, resulting in short and continuous utterances from the participants. In the interview data (Article IV), a natural choice for the unit of analysis was one answer. In the second and third empirical studies, the unit of analysis was defined based on the non-content features (turn taking), whereas in the first empirical study, an episode was defined based on the semantic features of the discussion.

The boundaries between the episodes were drawn based on the contents of the situations (Chi, 1997). Defining the boundaries based on the semantic features of small group discussions was clearly more challenging and time consuming, adding significantly to the analytic work (Strijbos, Martens, Prins, & Jochems, 2005). The choice of the unit of analysis nevertheless should be made according to the data as well as to the aims of the study.

Table 1. Overview of the empirical study articles and the methodology of each.

Article Empirical Study	Subjects	Research Aim	Data Sources	Quantitative Content Analysis
Article I Empirical Study 1	Teacher Education Students –group (N=6)	Types and role of metatalk as context in web-course	Videotaped F2F discussions and web actions	Episode level of students' discussion
Article II Empirical Study 2	Higher Education Students –group and individual (N=24)	Elements of game collaboration and shared problem-solving	Video data from the game	Utterance level of players' discussion + solution critical times
Article III Empirical Study 2	Higher Education Students – group and individual (N=24)	Individuals role for group composition and collaboration	Video data from the game and questionnaire	Utterance level of players' discussions+ experience and relations
Article IV Empirical Study 3	Participants from companies and organisations – individual (N=24)	Aspects of collaborative game-activity	Individual interviews and questionnaire	Response level of interview data

Table 1 presents an overview of the three empirical studies and four articles constituting this thesis. Video data of the small group interaction were collected in each empirical study. However, in the third empirical study the individual interviews were the focus of the analysis. After analysing the actual collaborative interaction in the first and second empirical study, it seemed important to study the participants' points of view of the collaboration, providing a more complete account of the game situation.

4.6 Issues of the validity and reliability of the study

The decision to focus to the interview data in the last empirical study also can be seen as a methodological choice related to the validity and reliability of this thesis.

Triangulation of the data sources is an acknowledged way of confirming the findings of qualitative studies. Its aim is to support the findings by showing that independent measures of it are in agreement or do not contradict (Miles & Huberman, 1994; Silverman, 2001). Because the empirical studies reported in this thesis have been carried out in larger research projects, multiple types of data were collected, analysed, and reported in the context of each research project. Although only some of those data were reported in this thesis, the reliability concerns also have been addressed at the project level.

In the first empirical study, the classroom discussion data were accompanied by the data collected from the web-based learning environment. In the second empirical study, the video data from the game environment were supported by the background questionnaires of the participants. Moreover, the participants were interviewed in the same groups immediately after the game. The interview data was not directly utilised in the second or third article included in this thesis. However, I conducted a separate study on the group interviews as a thesis for a minor subject in the Department of English Philology at the University of Oulu (Bluemink, 2009). In the third empirical study, although the interviews were the main data, the video data of the games was utilised for interpreting the situations that the participants described. Moreover, I have been closely involved in master's thesis work carried out in this research project, where the analysis was based on the video data (Veijola, 2008).

The experience of analysing the video data in the first two empirical studies was a practical experience in the laborious nature of analysing multiparty discussion (Korolija, 1998). Videos from the synchronous group discussion contained much more information than just the voice; for example, the non-verbal interaction and participant's positions in relation to each other were included in the data. For studying the collaborative discussion in context, it was also necessary to record the interaction and later transcribe it. As Silverman (2001) stated, "it is within the sequences, rather than in single turns of talk, that we make sense of conversation" (p. 162). However, some non-verbal information was lost in the transcription phase and has not been utilized in the analysis. On the other hand, my personal participation as an observer in all data collection events has formed a strong background and frame of reference for interpreting the data in its original contexts, which adds to the validity of this thesis.

The validity of qualitative studies always is largely dependent on the researcher's skills of handling and reporting the data. As Huberman and Miles (1994) astutely observed, qualitative analysis can be "evocative, illuminating,

masterful—and wrong" (p. 262). Documenting the research process is a means to establish validity, where the aim is to explain the research procedure openly and thoroughly (Silverman, 2001). For this thesis, the documentation was carried out in the framework of each empirical study with to the purpose of describing the setting, data, and data analysis process. In the analysis phase, the reliability of the coding, or "the degree of consistency with which instances are assigned to the same category by different observers or by the same observer on different occasions" (Hammersley, 1992, p. 67) was checked by an independent coder. In addition, through reliability measures, the descriptions of each category evolved by explaining and justifying the analysis categories to an outsider.

5 An overview of the empirical studies

5.1 Bluemink, J. & Järvelä, S. (2003). Face-to-face encounters as contextual support for Web-based discussions in a teacher education course. *The Internet and Higher Education, 7*, 199–215.

The focus of the study that was reported in Article I was to study the role of face-to-face encounters as support for collaboration in a web-based university level course. Specific emphasis was placed on analysing the type of interactions that appeared in face-to-face collaboration during the course. In addition, student activity related to the contextual features of the course was explored. It has been pointed out that, besides studying the students' interaction in web-based environments in CSCL, it is essential to recognize the importance of the contextual setting in which learning takes place in order to obtain a comprehensive picture of the students' learning processes (Lipponen, 2000).

Based on the SHAPE pedagogical model, the English language reading and writing course for teacher education students was planned to combine face-to-face meetings and web-based discussions in order to elicit students' reflections during the course (Järvelä, & Häkkinen 2002; Saarenkunnas, et al., 2000). The design of the course was based on the idea of electronic case mentoring, which means that students wrote their cases to the discussion area of the web environment on a topic or a problem interesting to them; during the course the other students and mentors commented on the cases. (Bonk, Malikowski, Angeli, & East, 1998). The course was conducted in international co-operation with four universities, and there were 83 subjects in the study. The number of students at the University of Oulu was 19. The more detailed video analysis reported in this study focused on one group of students from the University of Oulu (N=6). Small group collaborative interactions in the face-to-face encounters supporting the web-based activities were videotaped and analyzed with content analytic methods by categorizing the episodes into six data and theory driven categories: explaining, sharing knowledge, providing critique, reflection, joint engagement, and off-task interactions. At the same time, the students' activity in posting messages to the web-environment was traced and calculated.

The results of this study showed that the students were engaged in a rich variety of interactions in the face-to-face encounters. All six main categories used for the analysis of the video data (excluding the category of off-task interactions)

appeared with substantial numbers. The highest percentages of episodes were categorized as explaining (25%), joint engagement (23%), sharing knowledge (19%), and reflection (18%). Furthermore, the students' activity in the web-based environment stayed at the same level until the end of the course; a clear dependence between the dates of postings and face-to-face meetings was detected. It was concluded that as contextual support for students' learning and engagement in web-based courses, face-to-face encounters could be essential for enabling richly different interactions to take place between all course participants.

5.2 Bluemink, J. & Järvelä, S. (2011). Elements of collaborative discussion and shared problem-solving in a voice-enhanced multiplayer game. *Journal of Interactive Learning Research, 22 (1), 23–50.*

Article II focuses on investigating the nature of small group collaborative interaction in a voice-enhanced multiplayer game called eScape. The aim was to analyse the elements of small group collaborative discussion and to explore the nature of the players' shared problem solving activity during solution-critical moments in the game. The eScape game, a social action adventure, was developed as a part of this study to examine a multiplayer game as a space for collaboration. It was hypothesised that by designing problem-solving situations that require genuine participation from all participants, the game could support and mediate social interaction among a distributed team (Hämäläinen, Manninen, Järvelä, & Häkkinen, 2006; Manninen, & Korva, 2005).

The data were collected from an optional course entitled "Innovative Technology and Research: Collaboration in a 3D Virtual Environment," which was organised with higher education students (N=24). As part of the course, the students played the eScape-game in randomly divided groups of four. After the game, a group interview was conducted as a means for generating reflection on the game experience. The games were videotaped and the players' collaboration was analysed in two phases. First, the players' discussion throughout the entire game was categorised by using content analytic methods, and second, the discussion and activity were explored in the context of solution-critical times in shared problem solving situations. The data and theory driven categories for analysing the discussion during the game were Question, Content Statement, Social Statement, Suggestion, Instruction or Order, Encouragement, and Response. This analysis alone, however, was not adequate to capture the

complexity of the collaborative activity in the problem-solving contexts of the game. Therefore, a decision was made to explore the conditions in which shared problem solving could take place and how much the players shared the problem solving activities at solution-critical times (Barron, 2000, 2003) of the problem-solving situations.

In the analysis, from the 4886 utterances in all discussions during the games, 26% were coded as content statements, 22% as questions, 19% as instructing others, and 19% as responses. The students' discussion was vivid and contained many elements of social interaction that have been found effective for learning such as explaining and asking questions. Based on the analysis of solution-critical moments in problem solving, it was found that half the groups were engaged in shared problem solving in all tasks of the game and the other half in tasks at the end of the game. For the conditions of shared problem solving, it was crucial that all group members participated in the activity, which showed as partaking in the discussion and in the physical activity and location of the avatar. It was concluded that, based on this study, voice-enhanced multiplayer games can be a potential tool for supporting the formation of teams and for providing team members with a shared team experience.

5.3 Bluemink, J., Hämäläinen, R., Manninen, T., & Järvelä, S. (2010). Group-level analysis on multiplayer game collaboration: How do the individuals shape the group interaction? *Interactive Learning Environments, 18 (4), 365–383.*

In Article III, the aim was to continue the analysis carried out in Article II by examining how individuals interacting in a virtual multiplayer game shape group collaboration. This further analysis was carried out by studying the participants' collaborative discussion in the game as well as their prior social ties and experience in gaming. Earlier research on small group composition and collaboration largely focused on pre-defined group consistency based on, for example, division of ability, group size, or gender (e.g., Webb, 1982; 1984). Researchers have, however, gradually concluded that all these factors have an effect on the key element of social interaction of the group (Kreijns, 2004). Furthermore, in modern technology-supported learning and working contexts, it is often not possible to assemble pre-defined groups to work together.

The data were collected from a voice-enhanced eScape-multiplayer game (see Article II), which was played by six randomly divided groups of four university

students for about one hour. After studying the discourse functions of the students' discussions during the games, the analysis was continued on the group and individual levels. Special emphasis was placed on examining how the participants' prior social ties and experience with gaming varied among the groups and individuals as well as how these variables affected discourse functions and participation percentage. The data- and theory-driven categories for analysing the discourse functions during the game were Question, Content Statement, Social Statement, Suggestion, Instruction or Order, Encouragement and Response.

The results showed that all groups were heterogeneous with regard to prior social ties, experience in gaming, and discussion participation percentage. In many cases, the most experienced player, who possibly had prior social ties with one or more players, dominated the discussion. The groups differed not only with respect to time spent but also in the way and order of solving the problems. From the discourse function point of view, it was found that Content Statement, Question, Response, and Instruction or Order were the largest discourse function categories in all groups except one. One meaningful difference in the number of utterances between the groups was found in the Content Statement percentage; half the groups had approximately 10% more content statements than the other half. A large number of content statements can be interpreted as a positive sign regarding the quality of collaborative activity since, based on the category description, these groups talked more about their observations and explained and justified their ideas and behaviour. Based on the overall results, it was concluded that unequal participation of individual students weakens the group's possibilities to develop a shared understanding of both their social interaction and the game.

5.4 Bluemink, J. & Leinonen, P. (2011). How do members of distributed teams manage the aspects of collaborative game activity in a voice-enhanced multiplayer game? Manuscript.

The aim of this study was to examine how the members of distributed teams manage the different aspects of collaborative game activity during a virtual multiplayer game. The analysis focused on an individual player's descriptions of the collaborative game situations and distributed collaborative activities during the roughly two-hour voice-enhanced team game. The "Gate for Collaboration" team game was modified as a part of the study by designing tasks that would promote participants' awareness of social processes in team situations. The game and tasks were developed based on the findings of the eScape-study to require

participation that is equal and focus the players on shared problem-solving activities. Earlier studies observed that team-skills training enhances collaborative learning (Prichard, Stratford & Bizob, 2006).

The interview data were collected from an experimental study in which six groups of four participants (N=24) from companies and organisations played the Gate game in a distributed setting for two to three hours. Immediately after the game, all players were interviewed individually by the method of stimulated recall. The data were analyzed by content analytic methods and categorized into three data-driven categories, which were task-related aspects (T), social aspects (S) and avatar activity (A). It was typical (TAS 47%) that all three aspects of collaborative game activity—task, social, and avatar—were intertwined in the players' descriptions, revealing the complexity of an individual player's reality during the game. Therefore, it seems that individual agency in the game collaboration context is concerned with managing these three interwoven aspects of collaboration. The avatar activity was important for sharing knowledge, exploring the environment, monitoring the status of other players, and participating in the problem solving tasks. It was found that the avatar activity reinforced individual agency in the collaborative game context.

It was concluded that in future, when combined with an after-game reflection, purposefully designed multiplayer games could function as "awareness games" for distributed teams and team training to increase awareness of collaborative processes in working life contexts. Furthermore, the scripting of multiplayer games augments accountable positioning and increases individual agency in participation in collaborative activity.

6 Main findings and general discussion

The main aim of this doctoral thesis is on enriching collaborative learning through pedagogically scripted multiplayer games. Collaborative learning was examined in the synchronous discussions of small-group problem-solving activities in both face-to-face and virtual game settings. Moreover, the particulars of the multiplayer game context for small-group collaborative activity were investigated. The game environments were designed as part of the empirical studies to determine what kind of game environment scripting can enrich collaboration. The approach of the study emphasized the contextual and situated nature of learning and collaboration. Overall, this thesis aims to contribute to the "research gap" in the field of serious games by reporting findings from two empirical studies conducted in game contexts.

From the methodological perspective, the aim was to discuss methodological issues surrounding the study of social interaction and collaborative learning in 3D voice-enhanced multiplayer games. The main data analysis in Articles II and III focused on studying the elements of synchronous discussion in the small groups during the game. However, it was found that this approach alone was not enough to capture the complexity of the collaborative situation during the game; therefore, an analysis of the solution-critical moments in collaborative problem-solving activity was conducted. Furthermore, the methodological approach in Article IV was changed to the individual interviews to complement the picture formed by the video data of the actual game collaboration.

Due to the time span between the empirical studies reported in this thesis, there is inconsistency in the terminology of the articles, which, however, also reveal the development of thinking and understanding in the CSCL field. Concepts such as collaborative discussion, discourse elements, shared activity, shared understanding, and collaboration aspects were developing elements within this study for several years and may seem repetitive and vague, yet at the same time illuminating the complex and multifaceted nature of the phenomenon.

The findings of this study are presented in four sections, highlighting the main empirical results through critical discussion and issues related to the validity and limitations of the empirical studies. First, the findings from the perspective of small-group discussions and collaborative learning are discussed. Second, the particulars of collaborative game activity and shared collaborative problem-solving situations are introduced. Third, the points of view of enriching collaborative learning through structuring collaborative learning environments

and serious games are summarized. Fourth, the methodological perspectives evaluating the forms of data collection and analysis in relation to the aims of this thesis are discussed. The practical implications and need for further research conclude the discussion.

6.1 The elements of synchronous small-group discussion

This thesis built on the research carried out in the CSCL field to show that in collaborative situations, the key to learning is in building and maintaining a shared conception of a problem or task (e.g., Dillenbourg, 1999; Stahl, 2006). As many studies define collaborative learning on a rather general level such as "mutual engagement of participants in a coordinated effort to solve the problem together" (Roschelle & Teasley, 1995, p.70), the goal was to examine the macro and micro level elements of this "mutual engagement" and "coordinated effort" in synchronous small-group discussions in CSCL contexts. In order to promote and enrich collaborative learning, it seemed essential to determine the specific constituents of social interaction and collaborative activity in certain learning contexts, namely games.

The results of the first empirical study showed that the face-to-face discussions consisted of explaining, sharing knowledge, providing critiques, reflecting, and joint engagement. The coding was carried out on an episode level, resulting in macro-level elements of collaborative small-group discussion. These elements have been also earlier recognised as key constituents in collaborative learning (Roscoe & Chi, 2008; Weiss & Dillenbourg, 1999; Barron, 2000, 2003) Less research interest, if any, has been shown in the micro-level elements of the players' discussion during a voice-enhanced multiplayer game, which were studied in the second empirical study. It was found that the discussion consisted of questions, content statements, social statements, suggestions, instructions or orders, encouragements, and responses, which demonstrated that the players were engaged in vivid discussions containing multiple elements of discourse. In both studies, these elements appeared in large numbers and for outside observer in random order. Certain patterns in the order of appearance of these elements could not be found even though they were studied in both cases. Patterns of participation also were the focus of earlier CSCL studies (e.g., Lipponen et al., 2003; Hudson & Bruckman, 2004); however, in most cases, they concentrated on analysing written contributions, the writing and reading activity of notes, or chatting in discussion areas.

This thesis focused on analysing synchronous small-group discussions, which earlier studies found to have social advantages compared to asynchronous settings in CSCL (Andriessen, Baker & Suthers, 2003). Small groups may be more motivating for participants, and thus facilitate interpersonal negotiations. This social advantage is evident in the data of this thesis, where synchronous discussion was dense, consisting of nearly continuous communication concentrating on the topic or problem at hand.

In retrospect, it seems that the focus, especially in the game discussion, should have been on the content of the utterances, instead of on the types of discourse functions in the discussion (Greenbaum & Quirk, 1990). As the studies carried out in argumentation in collaborative discourse (Andriessen, Baker & Suthers, 2003; Jonassen & Kim, 2010) have shown, a different approach would give more valuable insights into problem-solving activities and the joint construction of knowledge during the game. It became obvious that through quantitative content analysis, in other words, counting the number of elements related to learning from the small-group discussion, it was not possible to capture the actual process of collaborative learning, shared understanding, or temporal development (Suthers, 2006). However, the content analytic approach was useful in that it helped to recognise these elements. Although the number of occurrences in each category finally had no clear meaning or indication, the fact that the students were engaged in the interactions as distributed in the categories is valuable. Quantitative content analysis is the method used in CSCL studies in recent years, which partly explains the choice for this approach (Strijbos et al., 2005). In order to determine whether the students really developed shared understanding or participated in shared collaborative activities, the analysis was continued in the second empirical study. The focus was placed on actual collaborative problem-solving situations, particularly solution-critical moments (Barron, 2003), which will be described in the next section.

6.2 Through equal participation to shared collaborative activity

Recent studies have emphasized the importance of individuals' equal participation in joint knowledge construction (Gresalfi, et al., 2009; Kumpulainen, et al., 2010). It has been found that the manner of participation influences the quality of social interaction, which then has a crucial influence on the groups' problem-solving processes (Hudson & Bruckman, 2004). After the first empirical study, a decision

was made to enrich collaborative activities and productive social interaction in small groups by voice-enhanced 3D multiplayer game environments.

It was hypothesised that by scripting such tasks in game environments that require genuine participation from all participants, the game could support and mediate social interaction among distributed teams (Hämäläinen, Manninen, Järvelä, & Häkkinen, 2006; Manninen & Korva, 2005). In the first eScape-game experiment, the data from the game world and the players' discussions were first analysed through content analytic methods as discussed in the previous paragraph. To determine whether the problem-solving situations of the players were actually shared and all players participated, the analysis was continued by focusing on the solution-critical times during the problem-solving activities. To illustrate this situation, Figure 2 presents one example of collaborative activity in a game situation.

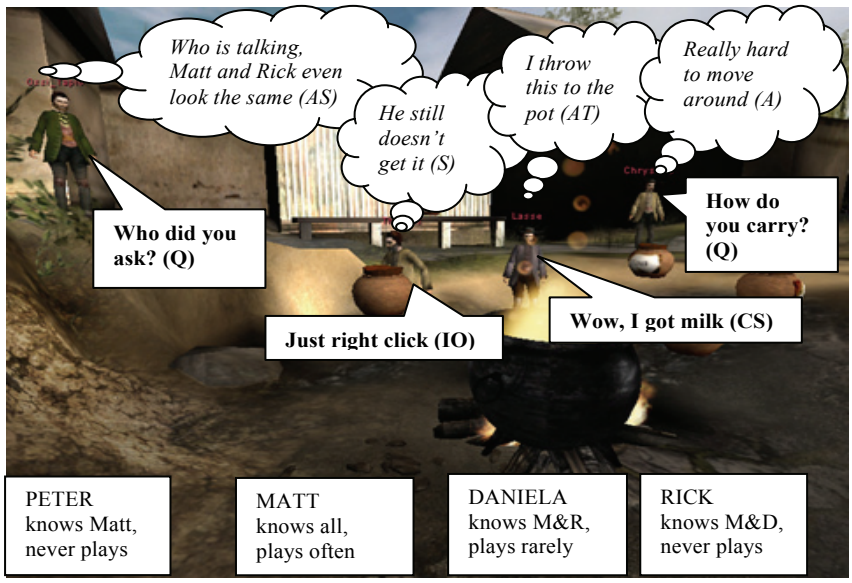

Fig. 2. Is this shared collaborative activity? The discussion and situations before and after this "snapshot" were analysed to study collaboration in the context.

At the bottom of Figure 2, each player and his or her familiarity with the other group members and previous gaming experience is indicated. The focus of Article III was to study how the role of individual players' backgrounds and relations to others affected the collaborative activity. In the middle of the picture, each players' utterances in the discussion are presented, and the category is shown in the

brackets (Q=Question, IO=Instruction, Order, CS=Content statement). The focus and aim of the Article IV also are included in Figure 2. As discussed earlier, the approach in the last article was focused on individual interviews to complement the picture formed by the video data of the actual game collaboration. Thus, the thinking bubbles in Figure 2 represent the individual player's descriptions in the interviews, pointing out the context from an individual player's point of view during the game situations, which were not externalised. The categorisations of the players' descriptions are also shown in brackets, and point to aspects of collaborative game activity (T=task-related aspects, S=social aspects, and A=aspects of the avatar activity). The individual interviews in the last empirical study greatly helped to complement the observations of shared problem-solving situations during the game.

To determine whether the solution-critical times of problem solving were shared, a criterion was formed (see Article II). In retrospect, this criterion also strongly related to the categorisation of the last empirical study reported in Article IV and indicated the importance of participation and avatar activity. In order for collaborative activity to be shared in the game context (see Article II): "The student had to be aware of the group's intentions in the problem-solving situation and participate by talking and / or acting through the avatar. Continuous part taking in the discussion was not required, but the student had to be engaged in the problem-solving situation as evidenced by the physical presence of the avatar or as participation in the discussion."

A main finding of this study is that avatar activity reinforces individual participation in collaborative activity. This study also extended participation in the collaborative activity by providing additional ways for sharing knowledge, mediating actions, and instructing others. The avatar activity had a significant role in helping others to find locations, coordinating problem solving in the tasks, showing examples to others, and monitoring the status of others during the game. Through game playing in small groups, individuals experience active participation. The additional value of avatars in technology-mediated collaboration also was noted in recent studies (Petrakou, 2010; Falloon, 2010), which pointed out that virtual worlds provide enhanced interactivity because they allow for synchronous communication by placing the student in a spatial dimension.

Interaction via avatars also relates strongly to the concept of agency in studies of collaborative learning and transfer (Greeno, 2006a; Bandura, 2001; Spada, 2010). The participants in group activity can be viewed as agents; moreover, the

situation greatly affects the distribution of the agency. The way the learner acts or does not act in collaborative situations and how the learner's actions contribute to the joint action of the group are keys for successful collaboration. The degree of participation might depend on the degree of competence, authority, and accountability attributed to the agent by the group or themselves. (Greeno, 2006b; Gresalfi, et al., 2009.) The accountable positioning of collaborative agents reinforced through scripting of serious games is a significant area for further research.

6.3 Structuring collaborative learning environments and serious games

The main aim of this thesis as well as other CSCL studies was aptly summarized Crook (2000,), who pondered, "how the circumstances for a potential collaboration are made more optimal: how they are designed and engineered, with expectations that putative collaborators can more readily fall into them to productive effect" (p. 167). The pedagogical structuring of the learning environments studied in this thesis reflected both the development and maturity of the CSCL field (Dillenbourg, Järvelä, & Fischer, 2009). Despite the differences in the technological settings of the empirical studies, they are similar in design. In all study settings of this thesis, there was "the activity" itself (web-based discussions and games) in addition to "after talk," which provided an occasion for reflecting on the experiences and situations of the activity. The reflective activity was in the form of face-to-face discussions (Empirical Study 1), group interviews (Empirical Study 2), and individual interviews (Empirical Study 3). Reflection was not the focus of the data analysis in the second empirical study, but it was an integral part of the design of the game experiment.

More specifically, from the perspective of pedagogical structuring, the aim in the first empirical study was to study how the SHAPE-pedagogical model in the web-based course promoted productive collaboration (Saarenkunnas et al., 2000). The focus was on studying face-to-face discussions that were seen as metalevel activity supporting the international web-based case discussion. Based on the results of the study, the students were involved in reflective activity about one third of the time in the face-to-face discussion (Reflection, Self Reflection, and Providing Critique); thus it can be seen that the scripting was successful. Earlier studies found that reflective activities, on both individual and group levels, supported learning (Kneser & Ploetzner, 2001).

In the second and third empirical studies, multiplayer games were chosen as learning environments in order to explore the enrichment of collaboration and create a sense of co-presence through game technology. Games were chosen as a medium to determine how the scripting of games could stimulate and activate the activities important for collaborative learning. The game environment was also a methodological choice, drawing attention to distributed collaboration in a voice-enhanced 3D multiplayer game environment. A social action adventure was chosen as the game content although other content areas such as natural sciences were also considered. In retrospect, this choice also contributed to the scripting for shared understanding, since it set the participants in an equitable situation in relation to prior content knowledge. Inevitably, prior gaming experience is advantageous in navigating the game environment (Petrakou, 2010); however, the difficulty of the actual tasks was related not to individual gaming skills but to the problem-solving ability of the group.

Regarding the game design, results showed that pedagogical scripting for collaboration must be effective in order that all players participate actively in the problem-solving activities (Hämäläinen, Oksanen, & Häkkinen, 2008). This applied to a situation in which only four players played in one game session. It was found that the attraction of the game world is strong, tempting players solve the tasks individually. Only by careful design was it possible to support equal participation, which then led to shared problem-solving activities. Earlier studies have shown that equal participation has fostered more discussion on task procedure and content, which then has enhanced individual learning (Prichard, Stratford, & Bizo, 2006). It was also found that the extent of equal participation depended largely on shared understanding of both the task and one another (Prichard, 2002). Therefore, scripting for equal participation is also likely to result in shared understanding among the participants.

Limitations of the eScape or Gate games were that they did not teach the players interpersonal and team skills. However, they provided a scene for collaborative activity. In addition, “aftertalk” was a crucial part of the game experience. In the game experiment settings, the group discussions (Empirical study 2) and individual interviews (Empirical study 3) served as reflection activities at the same time providing data for the analysis of game collaboration. Future research could combine the game with specific reflective tools for evaluating team performance (Phielix, Prins, & Kirschner, 2010) and thus create a powerful tool for effective collaboration in teamwork.

6.4 Methodological perspectives of studying social interaction in small-groups

The methodological choices made for this thesis have made possible an examination of the nature of social interaction in synchronous small-group settings in two different data collection contexts and in three different analytical approaches. The first empirical study showed that by carrying out a macro level content analysis of synchronous discussion, it was possible to pinpoint the elements of which the discussion consisted. As a unit of analysis, an episode enabled categorisation of the discussion from naturally occurring chunks of data. The macro level approach, however, did not allow focusing on the utterance level contributions of the collaborators, raising the question of whether it would be possible to define the critical moments of shared understanding in collaborative activity using a micro level analysis. Therefore, in the second empirical study, the micro level approach was chosen for the analysis of the synchronous discussion during the game play. It was hypothesized that when analysing the discussion on the utterance level, it might be possible to recognise certain patterns in the discourse functions that could be related to the construction of shared understanding.

However, results showed that it was not possible to recognise critical moments in shared understanding. Neither was it possible to determine specific patterns in the utterances based on micro level categorisation of the discourse functions (Suthers, 2006). The reason was that it was not possible to analyse issues related to the content of the talk based on formal categories drawn for the discourse functions of the talk (Barnes & Todd, 1977; Greenbaum & Quirk, 1990). The results showed that in practise the shared understanding in small-group discussion is constructed over longer episodes (Weiss & Dillenbourg, 2002). Although shared understanding might be lost from time to time, it can be regained at solution-critical moments in problem solving (Barron, 2003). Shared understanding also is partly implicit and may not be recognisable afterwards (Barnes & Todd, 1977; Mercer, 2008). Thus, despite the different context, the findings confirmed the conclusion asserted by Barnes and Todd (1977):

> *"Meanings for what is going on in the conversation are constructed not from any one utterance on its own, but from cycles of utterances, perhaps over quite lengthy sections of the interaction. Now these cycles are not readily*

isolable: they adhere to the interaction between utterances, and the speaker-hearer's intentions for, and interpretations of, these utterances. (p. 17)"

Therefore, the analysis was continued to determine criteria for shared collaborative activity in the game context. Solution-critical times (Barron, 2003) in problem solving were studied in order to determine whether the activity was shared among the players at those times (see Figure 2.). This choice was methodologically relevant, indicating that only by looking at the problem-solving situation as whole was it possible to determine criteria for shared problem-solving activity. Since the game as a context provided a specific setting for distributed, synchronous, and voice-enhanced collaboration, it was crucial for the analysis to consider the whole discussion, individual contributions, and avatar activity in the moment just before the tasks were solved. Multiplayer games provided a challenging context from the individual perspective, since it was very difficult to analyse the different players' cognitive, spatial, and social points of view at specific moments in time. However, this analysis was necessary for grasping the interaction and discussion since much was unsaid although obvious to the players due to the shared ongoing game and implicit references (Mercer, 2008).

The outcome of the analysis of solution-critical times was inspiration to focus on individual descriptions of the game activity in the third empirical study. Focus on the interview data in the third empirical study was a useful methodological choice that resulted in detailed accounts of the game activity and provided evidence of the particulars of collaborative game activity. As all data have limitations, the interview data revealed aspects that were not explicit in the interaction data and vice versa.

Studies that use the group as a unit of analysis can provide new information on why some discussions more than others lead to more fruitful collaboration and provide opportunities for learning (Hausmann, Chi, & Roy, 2004). On the other hand, because the group consists of individuals, the individual perspective, especially in small-groups, should not be ignored. Therefore, in this thesis, the analysis was conducted on both the group and the individual. Most of the data analysis focused on synchronous collaborative activity to examine how people in groups make sense of situations and each other (Suthers, 2006).

A clear limitation of the empirical studies conducted in game environments is the short and one-time nature of the game experiments. Furthermore, some groups came together only for the game experiments. Thus, they had no other reason to work towards a shared goal except the game (or short course). Therefore, it can be

claimed that the situation of the collaborative activity was not natural or real for the participants of the two latter empirical studies. In this respect, the first empirical study conducted among the teacher-education students formed a more natural and longitudinal context of collaboration for students who already had a shared history. Moreover, data from a one-to three-hour game provides a small amount of evidence, which is certainly a valid concern and a limitation of this thesis in addition to the small sample size. However, the situation in the game experiment, at least to some extent, resembles real life working life situations where teams are quickly put together and expected to be immediately productive. Additionally, as the results have pointed out, the game was, despite its short duration, an intensive experience for the players because it consisted of focused and continuous collaboration compared with the single face-to-face encounter in the first empirical study. Finally, it should also be recognised that the amount of detail in the qualitative analysis of the data was unwieldy because the data source was multiple speakers in group discussions.

6.5 Practical implications and aspects for further research

Work on this thesis raised questions such as "what is really learnt" and "how would it be possible to find out if there really is shared understanding among the players," which have been reconsidered many times. Although definite answers were not found, a deep understanding of the complexity of these questions emerged. In retrospect, it might have been better to employ a self-scoring instrument to measure shared understanding (Mulder, 1999). This measurement would have been used for questions such as "At this moment, this team has a common understanding of the task at hand." However, answers also would elicit the perspectives of the players, who most likely would have different criteria for deciding whether the understanding was shared. Perhaps combining this instrument with an observer's analysis could add to the study—perhaps.

Conducting learning research always entails a compromise and decisions that must be made on the measures that are taken to trace learning. When studying learning on content knowledge, which is often the case, it is still possible for the researcher to measure, through pre- and post-tests, the content knowledge to determine that learning has taken place (e.g., Stegmann, Weinberger, & Fischer, 2007). However, when studying collaborative activity, interaction (e.g., Arvaja, 2005), and how people participate, measurement is highly complex, especially if it includes the period in which the participatory behaviour of people changed.

Thus, the main area of further study is clearly the metacognitive aspect of the game play combined with its transfer in after-reflection. Study of these matters in an authentic longitudinal context, would make it possible to observe whether the game experience changes participants' behaviour in real work situations. It has been asserted recently that the area of metacognition is ripe for studies on questions such as "do people become better able to reflect on complex social interactions and recognise when crucial aspects of joint work are not functioning well (such as joint attention or differences in using terms)?" (Bransford, et al., 2006, p. 29). Results showed already that in a classroom context, short-term combined training in self-regulatory and problem-solving strategies was effective for enhancing self-regulatory competences (Perels, Guertler, & Schmitz, 2005). Directly related to aspects of metacognition is a view that draws focus to the interplay of transfer and accountable positioning of the learners. It was asserted that transfer never occurs without conscious effort by the individual, who can therefore be seen as an active agent in transfer situations (Bandura, 2001; Spada, 2010). Studies on transfer to new situations found that it is essential not only to remember certain facts and contents but also to remember the experience of oneself as an active agent and subject (Greeno, 2006a). The focus is thus shifted to the kinds of practices in which people have opportunities to participate in collaborative situations, including the ways people relate to each other within a particular setting (Gresalfi, et al., 2009).

The results of this thesis show that pedagogically scripted game environments create a promising potential context for accountable positioning of participants in (distributed) collaborative situations (Greeno, 2006a). Collaborative learning promotes not only the engagement that game contexts have to offer but also active participation in the social interaction of the small group, which can be reinforced by avatar activity (Falloon, 2010). Voice-enhanced multiplayer game contexts can therefore provide experiences of active agency using a wide variety of game contents. For this finding to aid, for example, the working life or classroom activities in practise, more research is needed urgently to study the impact of multiplayer games in authentic and longitudinal contexts. The field of serious games is new and calls for both defining the research agenda and establishing methods of analysing game activities (Gee, 2006; Sawyer, 2007; Aldrich, 2009). It is not enough for educators and learning scientists to be visionaries; empirical data also must be examined and healthy criticisms of our claims must be maintained. Otherwise, non-evidence based claims can easily lead

to simplistic interpretations (Barab, 2003), which are a clear danger in the current field of serious games.

The need for technological applications such as serious games is apparent, since global companies and organisations have an increasing need to support the social architecture of employees. Knowledge intensive work is often carried out in project-based and global teams, and the expectations for collaborative activity are high (van den Bossche, Gijselaers, Segers, & Kirschner, 2006). Small teams of experts brought together for a limited period of time may suffer from the illusion that collaboration is a recipe that automatically leads to improved performance (Salas, Rosen, Burke, Goodwin, & Fiore, 2006; Mulder, 2004). The distributed and multicultural settings of everyday working life, however, add to the difficulty of collaboration in solving complex problems. In addition, studies (e.g., Weick, 2001) of team collaboration in organisations have observed that "the newfound urgency to understand improvisation and learning is symptomatic of growing societal concerns about how to cope with discontinuity, multiple commitments and interruptions" (p. 297). It is obvious that modern work also needs a mode of thinking that fits with the social structures of networking and teamwork (Brown & Duguid, 2000).

To conclude, the findings of this thesis showed that pedagogically scripted 3D multiplayer games provide a fruitful context for team training by stimulating the active participation and engagement of the participants. In the future, the individual's ability to be metacognitive about social engagement will be more important than ever before (O'Donnell, 2006). Therefore, pedagogically scripted game environments combined with sufficient prompts for reflection will be prominent technological tools, raising the awareness of the importance of small group and interpersonal skills in an attractive manner.

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Original articles

This thesis is based on the following articles, which are referred in the text by their Roman numerals:

I Bluemink, J. & Järvelä, S. (2003). Face-to-face encounters as contextual support for Web-based discussions in a teacher education course. *The Internet and Higher Education, 7*, 199–215.

II Bluemink, J. & Järvelä, S. (2011). Elements of collaborative discussion and shared problem-solving in a voice-enhanced multiplayer game. *Journal of Interactive Learning Research, 22 (1), 23–50.*

III Bluemink, J., Hämäläinen, R., Manninen, T., & Järvelä, S. (2010). Group-level analysis on multiplayer game collaboration: How do the individuals shape the group interaction? *Interactive Learning Environments, 18 (4), 365–383.*

IV Bluemink, J. & Leinonen, P. (2011). How do members of distributed teams manage the aspects of collaborative game activity in a voice-enhanced multiplayer game? Manuscript.

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

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ACTA UNIVERSITATIS OULUENSIS

ISBN 978-951-42-9422-8 (Paperback)
ISBN 978-951-42-9423-5 (PDF)
ISSN 0355-323X (Print)
ISSN 1796-2242 (Online)

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