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UNIVERSITY OF JYVÄSKYLÄ
FINNISH INSTITUTE FOR
EDUCATIONAL RESEARCH

Serious Game Design: Supporting Collaborative Learning and Investigating Learners' Experiences

Finnish Institute for Educational Research
Studies 31

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Abstract

Computer-supported collaborative learning (CSCL) is a type of collaborative learning that uses technological solutions to support collaborative learning. Collaborative serious games can be considered as one promising way to use technology to support collaborative learning. However, they are not a self-evident solution leading to successful productive social interaction, collaborative knowledge construction, or learning. Thus, to take advantage of the full potential of collaborative serious games, there is a need for the better use of the theoretical knowledge about collaborative learning and game design as a foundation for game development. In addition, attention should be paid to whether gameplay really constitutes favorable conditions for social interaction or contributes to collaborative knowledge construction.

This study focused on designing a collaborative serious game, supporting collaborative learning, and investigating learners' experiences. The overarching aim of the study is to find and investigate new ways to support collaborative learning in serious games through game design and instructional design. The general aims of the study are 1) to design a collaborative serious game based on the theoretical knowledge of collaborative learning and game design; 2) to investigate the learners' subjective experiences generated by a collaborative serious game as a sociable CSCL environment as well as a game; and 3) to determine the teachers' role from the perspective of collaborative knowledge construction in game settings.

This study applied a design-based research (DBR) approach. The study consists of one theoretical sub-study (Article I) and three empirical sub-studies (Articles II–IV). The theoretical sub-study focused on utilizing game mechanics in designing a 3-D collaborative serious game (Article I). The developed game was further investigated in empirical sub-studies (Articles II–IV), which focused on investigating the learners' subjective experiences generated by a collaborative serious game as a sociable CSCL environment as well as a game, and determining the teachers' role in collaborative knowledge construction in game settings. Research data were collected by using self-report questionnaires and recording the groups' discussions during the gaming sessions. The data were analyzed by using statistical methods as well as quantitative and qualitative content analysis.

In this study, a collaborative serious game was designed and implemented based on the theoretical knowledge of collaborative learning and game design (Article I). The findings of the empirical sub-studies showed game mechanics to be an essential dimension in the design of collaborative serious games. By applying game mechanics in an appropriate way, collaborative serious games have the potential to engage the learners' attention, to structure their collaborative knowledge construction, and to support their socio-emotional processes to enable them to achieve productive, collaborative knowledge construction. The findings of the study showed that the sociability of the game was rated rather high, and mostly higher than the sociability of the asynchronous learning environment (Article II). Further, during the gameplay, the learners felt a strong sense of social presence (Articles II and III) along with fairly positive and engaging game experiences (Article III). Solving the puzzles of the game gave birth to the social interaction and collaborative knowledge construction among the learners (Article IV). These results indicate that playing the game captured the learners' attention, creating a genuine need for the learners to collaborate and build shared knowledge to solve the puzzles. Thus, decisions made in the game-design stage can be proposed to improve the possibility of productive, collaborative knowledge construction occurring. The results of the study also indicate that in addition to the game's internal guidance, teachers have a critical role in structuring collaborative knowledge construction.

To conclude, this study showed that by combining the theoretical knowledge on collaborative learning and game design, it is possible to find new ways to support collaborative knowledge construction in serious games. Especially game mechanics appear to be a potential way in which to generate and support social interaction and collaboration among the learners in the game context. In addition to the game's internal guidance, the teachers' real-time orchestration during the collaboration situation plays a crucial role in achieving productive, collaborative knowledge construction. For the future research and development of collaborative serious games, there is a need to develop a shared vocabulary and understanding among professionals in the fields of education and game design further.

Keywords: Collaboration, collaborative serious game, computer-supported collaborative learning, design research, educational games, game design, game mechanics, serious game experiences

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OPPIMISPELIEN SUUNNITTELU: YHTEISÖLLISEN OPPIMISEN TUKEMINEN JA OPPIJOIDEN KOKEMUSTEN ARVIOINTI

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Tiivistelmä

Yhteisölliset oppimispelit ovat yksi tapa hyödyntää teknologisia ratkaisuja tietokoneavusteisen yhteisöllisen oppimisen tukemisessa. Pelit itsessään eivät kuitenkaan välttämättä johda onnistuneeseen tuottavaan vuorovaikutukseen ja edelleen yhteisölliseen tiedonrakentamiseen sekä oppimiseen. Yhteisöllisiin oppimispeleihin sisältyvän potentiaalin lunastamiseksi on tärkeää, että pelit pohjautuvat teoreettiseen tietämykseen yhteisöllisestä oppimisesta ja niissä hyödynnetään pelisuunnittelun mahdollisuuksia. Tämän lisäksi on olennaista, että pelin pelaaminen luo suotuisat edellytykset sosiaaliselle vuorovaikutukselle ja johtaa yhteisölliseen tiedonrakentamiseen.

Väitöskirjatutkimus keskittyi oppimispelien suunnitteluun, yhteisöllisen oppimisen tukemiseen ja oppijoiden kokemusten arviointiin. Tutkimuksen yleinen tavoite oli löytää ja tutkia uusia keinoja tukea yhteisöllistä oppimista oppimispeleissä pelisuunnittelun sekä opetuksen suunnittelun kautta. Tutkimuksen päätavoitteet olivat: 1) Kehittää yhteisöllinen oppimispeli, joka pohjautuu teoreettiseen tietämykseen yhteisöllisestä oppimisesta, ja jonka suunnittelussa hyödynnetään pelisuunnittelun tuomia mahdollisuuksia. 2) Tutkia millaisia kokemuksia yhteisöllisen oppimispelin pelaaminen synnytti pelaajissa. 3) Selvittää opettajan roolia yhteisöllisissä tiedonrakentamisen prosesseissa.

Tutkimuksessa toteutettiin design-tutkimuksen lähestymistapaa. Väitöskirja koostuu yhdestä teoreettisesta (artikkeli I) ja kolmesta empiirisestä (artikkelit II–IV) osatutkimuksesta sekä niiden yhteenvedosta. Teoreettinen osatutkimus keskittyi pelisuunnitteluun ja erityisesti pelimekaniikkojen hyödyntämiseen yhteisöllisten oppimispelien suunnittelussa. Lisäksi siinä kuvataan tutkimuksessa kehitetyn pelin suunnittelussa käytetyt pelimekaniikat ja niiden käytännön toteutus. Empiirisissä osatutkimuksissa selvitettiin kuinka kehitetty peli toimii käytännössä. Tutkimusaineisto kerättiin itsearviointikyselyillä sekä

tallentamalla peliryhmien pelin aikana käymät keskustelut. Aineiston analysoinnissa käytettiin tilastollisia menetelmiä sekä määrällistä ja laadullista sisällönanalyysiä.

Tutkimuksessa kehitetty peli pohjautuu teoreettiseen tietämykseen yhteisöllisestä oppimisesta, ja sen suunnittelussa hyödynnettiin pelisuunnittelun mahdollisuuksia. Empiiristen tutkimusten perusteella pelimekaniikat ovat erityisen tärkeässä asemassa yhteisöllisten oppimispelien suunnittelussa. Tarkoituksenmukaiset pelimekaniikat voivat ″koukuttaa″ oppijoita, ohjata heidän yhteisöllistä tiedonrakentamistaan, sekä tukea heidän sosioemotionaalisia prosesseja tuottavan tiedonrakentamisen aikaansaamiseksi. Tutkimuksen tulokset osoittivat, että peli koettiin sosiaalisemmaksi ympäristöksi verrattuna perinteisiin asynkronisiin virtuaalisiin oppimisympäristöihin. Lisäksi pelaajat kokivat vahvaa sosiaalisen läsnäolon tunnetta yhdessä melko positiivisten ja vetovoimaisten pelikokemusten kanssa. Pelissä olevien tehtävien ratkaiseminen synnytti pelaajien välistä sosiaalista vuorovaikutusta sekä yhteisöllistä tiedonrakentamista. Nämä tulokset osoittavat, että pelin pelaaminen kiinnitti pelaajien huomion ja loi todellisen tarpeen toimia yhdessä sekä rakentaa yhteistä tietämystä pelitehtävien ratkaisemiseksi. Pelisuunnittelussa tehdyillä ratkaisuilla voidaan siis edistää tuottavan yhteisöllisten tiedonrakentamisen muodostumista. Pelisuunnittelun lisäksi opettajan reaaliaikaisella ohjauksella on merkittävä rooli yhteisölliselle tiedonrakentamiselle.

Kaiken kaikkiaan tutkimus osoitti, että yhdistämällä yhteisöllisen oppimisen teoreettista perustaa ja pelisuunnittelua voidaan löytää uusia tapoja tukea yhteisöllistä tiedonrakentamista oppimispeleissä. Erityisesti erilaisia pelimekaniikkoja hyödyntämällä voidaan synnyttää ja tukea sosiaalista vuorovaikutusta ja yhteisöllistä toimintaa oppimispeleissä. Peliin sisältyvän ohjauksen lisäksi opettajan reaaliaikaisella ohjauksella pelin aikana on merkittävä rooli tuottavan yhteisöllisen tiedonrakentamisen saavuttamisessa. Tulevaisuuden haasteena on kehittää yhteistä sanastoa ja ymmärtämystä oppimisen ja pelisuunnittelun asiantuntijoiden kesken laadukkaiden yhteisöllisten oppimispelien kehittämiseksi.

Asiasanat: Tietokoneavusteinen yhteisöllinen oppiminen, yhteisöllinen oppimispeli, pelisuunnittelu, pelimekaniikat, oppimispelit, oppimispelikokemus

List of original papers

The study is based on the following original publications, which are referred to as "Articles" in the text and numbered with the Roman numerals I–IV:

Article I Oksanen, K. & Hämäläinen, R. (2014). Game Mechanics in the Design of a Collaborative 3D Serious Game. *Simulation & Gaming, 45* (2), 255–278.

Article II Oksanen, K. & Hämäläinen, R. (2013). Perceived Sociability and Social Presence in a Collaborative Serious Game. *International Journal of Game-Based Learning, 3* (1), 34–50.

Article III Oksanen, K. (2013). Subjective Experience and Sociability in a Collaborative Serious Game. *Simulation & Gaming, 44* (6), 767–793.

Article IV Hämäläinen, R. & Oksanen, K. (2012). Challenge of supporting vocational learning: Empowering collaboration in a scripted 3D game – How does teachers' real-time orchestration make a difference? *Computers & Education, 59* (2), 281–293.

The study as a whole has been reported in one single author (Article III) and three jointly authored articles (Articles I, II, and IV). The work reported in the three jointly authored articles (Articles I, II, and IV) was primarily carried out by the first author. The first author had significant responsibility for planning and design, conducting analyses, and reporting the findings. Additionally, the author of the thesis has played a significant role in the design of the game used in the empirical sub-studies (Article I).

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Acknowledgements

When I was a little boy, we used to gather together with friends to play Rolemaster in a small hut in the backyard of our house. At that time, I obviously did not think of any deeper meaning when playing games other than having fun and taking a break from the outside world for a while (or rather, for countless hours and days). During this PhD journey, I have had the opportunity to explore the deeper essence of gameplay. I share the same enthusiasm and interest for these two aspects of games in the different stages of my life. The difference is that the role-playing game never really ended for me, but the journey concludes in this thesis. However, in terms of role-playing games, I have only just created my character, and now the real game can begin. I am deeply grateful to all those who have helped and supported me in creating my own character and gathering experience points as a researcher.

First, I am grateful to the Finnish Institute for Educational Research for offering the resources and an excellent "hut" in which I have been able to do this research. However, the environment itself is not enough; good game masters are also needed. Thus, I want to express my deepest gratitude to my supervisors Adjunct Professor Raija Hämäläinen, Professor Päivi Häkkinen, and Professor Helena Rasku-Puttonen. Raija, it has been a great pleasure working with you. During the years that we have been working together, you have shared your expertise, and given me your sincere support and advice whenever needed, and this has proven to be on countless occasions. Päivi, you have always encouraged me both before and during this journey, for which I am grateful. Helena, besides your other duties, you have always found time to read and comment on my writing. Your feedback and expertise have been very valuable for this thesis. I would also like to thank Professor Raine Koskimaa for his valuable comments during this journey. I really hope this collaboration will continue with all of you. Additionally, I want to express my gratitude to the reviewers of the thesis, Senior Research Fellow, Adjunct Professor Timo Lainema and Associate Professor Karel Kreijns; your invaluable comments, questions, and feedback have helped me in completing this thesis.

As in role-playing games, big battles cannot be won alone; you need a team around you. This journey would not have been possible without the help from numerous colleagues and supporters. Thus, I would like to thank all of these people for their support and assistance during the different phases of this thesis. I would first like to thank the entire Game Bridge team, especially Birgitta Mannila and Tony Manninen. Our project is living proof of collaboration at its best. Birgitta, you were the one who infused the rest of the team with the faith to find the answers to the game design and development issues. Tony, you and your Ludocraft team did an incredible job throughout the project. Besides our project team, I have had help and support from numerous people in facing all kinds of challenges. I am grateful to our system analyst Sari Emaus-Valkonen, Professor Antero Malin, researcher Kari Nissinen, and translator Tuomo Suontausta. Special thanks also to the FIER Publication and Information Unit, the Financial Secretary Seija Mannila, and Executive Secretary Susanna Routti.

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Matti for their encouragement throughout this journey. Sincerest thanks to my parents, Ulla and Erkki, my brother Miikka, and my sister Sanna. Even though we have not kept in daily contact, you have always been there for support. And, finally, Stina, thank you for being by my side, and bringing love and joy into my everyday life.

Helsinki 26.8.2014
Kimmo Oksanen

1
Introduction

The focus of this study is on designing a collaborative serious game, supporting collaborative learning, and investigating learners' experiences. In the light of a growing number of studies, it seems that collaborative serious games are one promising way in which to use technology to support collaborative learning (e.g. Whitton, 2010; Hummel, van Houcke, Nadolski, van der Hiele, Kurvers, & Löhr, 2011). However, the game itself is not an obvious solution or a "silver bullet" that undoubtedly leads to successful social interaction, and further, to collaborative knowledge construction; in other words, to collaborative learning (Hämäläinen, 2011). Thus, to harness the full potential of collaborative serious games, it is central to make better use of the theoretical knowledge about collaborative learning and game design as a foundation for the development of such games (Wu, Hsiao, Wu, Lin, & Huang, 2012). Currently, the integration of these perspectives in the design of collaborative serious games is rare (Echeverría, García-Campo, Nussbaum, Gil, Villalta, Améstice, & Echeverría, 2011). Further, it is essential to pay attention to whether the game constitutes favorable conditions for social interaction and collaboration (Nussbaum et al., 2011; Kreijns, Kirschner, & Vermeulen, 2013), or if playing the game contributes to collaborative knowledge construction and learning (e.g. Van Eck, 2006).

Collaborative serious games can be considered as a specific type of computer-supported collaborative learning (CSCL) environment. Thus, limitations and challenges related to the design and use of CSCL environments in general largely apply to games as well. Recent studies have revealed multiple challenges related to collaborative group work; these challenges include, for example, problems with social interaction and group dynamics (Kreijns, Kirschner, Jochems, & Buuren, 2007), the learners' lack of engagement (Whitton, 2010), and the teachers' lack of knowledge about how to structure and support learning processes (Arvaja, Hämäläinen, & Rasku-Puttonen, 2009).

Collaborative serious games offer opportunities for facing these challenges through game design and instructional design. From the game-design perspective, combining the theoretical knowledge on collaborative learning and game design is essential (Echeverría et al., 2011). The main aim of integrating these two perspectives is to find ways to take advantage of game-design elements to support collaboration (Echeverría et al., 2011). This aim is in line with the notion that to achieve productive collaborative activities, it is necessary to guide learners to enter into situations where collaborative knowledge construction is needed (e.g. Collazos, Guerrero, Pino, Ochoa, & Stahl, 2007; Hämäläinen, Oksanen, & Häkkinen, 2008; Bluemink, Hämäläinen, Manninen, & Järvelä, 2010). Besides structuring knowledge construction, it is essential to offer support for the learners' socio-emotional processes (such as group development) to improve the possibility of productive social interaction and knowledge construction occurring (Wegerif, 1998; Kreijns et al., 2013). For example, collaborative scripts, predefined roles, and different kinds of task structures have been indicated as useful ways for supporting collaboration and enhancing social interaction in CSCL environments (Hämäläinen, 2008a; Hämäläinen et al., 2008; Hummel et al., 2011). Especially in the game context, game mechanics appear to be a potential way to make use of game design in the development of serious games (Aleven, Myers, Easterday, & Ogan, 2010; Mariais, Michau, & Pernin, 2011). However, collaborative games are extraordinarily difficult to design (Zagal, Rick, & His, 2006), and require an expanded view of group dynamics, social roles, and interaction between the players (Kim, 2000; Manninen & Korva, 2005).

From the perspective of instructional design, the teachers' real-time orchestration has been proposed as one possible way in which to address the previously mentioned challenges (e.g. Dillenbourg, Järvelä, & Fischer, 2009; Kollar, Hämäläinen, Evans, De Wever, & Perrotta, 2011). Thus, teachers are supposed to have a meaningful role, not as a distributor of information, but more as a fellow collaborator or a facilitator. The main aim of the teachers' real-time orchestration is to maintain balance between the instructions, free-collaboration processes, and the contextual nature of collaboration (Kollar et al., 2011). To sum up, the aim of the game-design perspective for collaborative serious games is to support collaborative learning by capturing the learners' attention and structuring their knowledge construction, and to support the learners' socio-emotional processes. In addition, the teachers' role in supporting collaborative learning is to design and orchestrate the structure of the knowledge construction during collaboration situations.

There have been promising attempts to bridge the gap between instructional design and game design by integrating educational and game-design principles in the design of serious games (e.g. Quinn, 1994; Kiili, 2005; Dickey, 2005; Echeverría et al., 2011; Bedwell, Pavlas, Heyne, Lazzara, & Salas, 2012). Besides the integration of these perspectives in the game-design phase, it is also important to evaluate and understand the learners' experiences of acting in such games. This is because emotional experiences are, in the end, the ones that determine what learners do in the game, and how much they are willing to invest in what they are doing (Nacke & Lindley, 2009). Thus, learners may not always act as the designer intended them to act (Dillenbourg & Jermann, 2006). In practice, this could mean that if learners find playing a game boring and unpleasant, they may not bind to the achievement of the objectives of the game. Conversely, pleasant and engaging experiences deepen commitment and encourage players to continue playing and solving ever-more challenging tasks. Further, Whitton (2010) proposed that the real value of serious games is in their ability to engage learners through meaningful tasks and interaction with the game as well as with other players.

Against this background, the overarching aim of this study is to find and investigate new ways to support collaborative learning in serious games through game design and instructional design. More precisely, the general aims of the thesis are:

1) To design a collaborative serious game based on the theoretical knowledge of collaborative learning and game design (Article I).
2) To investigate the learners' subjective experiences generated by a collaborative serious game as a sociable CSCL environment as well as a game (Articles II and III).
3) To determine the teachers' role from the perspective of collaborative knowledge construction in game settings (Article IV).

Due to the multidisciplinary nature of the research, this thesis is located at the crossroads of educational sciences and computer sciences (especially game design). The multidisciplinary approach of the study is reflected in the integration of the theoretical knowledge on collaborative learning and game design in the design of the collaborative serious game (Article I) that was used and investigated in the empirical sub-studies (Articles II–IV).

2
Theoretical background

In this section, the starting points and main concepts of the study are introduced. The intention is to position the thesis within the previous studies related to designing collaborative serious games (e.g. Echeverría et al., 2011; Zagal et al., 2006), supporting collaborative learning in CSCL environments (e.g. Kreijns et al., 2007, 2013), investigating game experiences (e.g. Poels, De Kort, & IJsselsteijn, 2008), and determining the teachers' role in collaborative knowledge construction (e.g. Kollar et al., 2011). First, the main concepts of the study are defined. Second, the premises and challenges for collaborative learning in the context of serious games are discussed. Third, the theoretical grounding of supporting collaborative learning and applying game design to promote collaborative learning are presented. Fourth, understanding the learners' subjective experiences in serious games is discussed. Finally, at the end of this section, the theoretical framework of this study is summarized.

2.1 Collaborative learning and serious games

Collaborative learning is often defined by describing it as a construction of shared knowledge through activities with others (collaborative knowledge construction), where the participants are committed to or engaged in shared goals and problem solving (e.g. Dillenbourg, 1999). Thus, members of the group are not only engaged in individual activities, but also in group interactions such as negotiation and knowledge sharing (Roschelle & Teasley, 1995). In collaborative learning, members of the group are expected to join forces, with each member's views and resources contributing to a shared workspace in which to solve complex problems (Weinberger, 2003). According to Winne et al. (2010), each member of the group brings three essential resources to the collaboration situation. First, there is prior knowledge, and especially those with less knowledge may benefit from others' prior knowledge. This knowledge may be about the task, the content, or the collaboration itself. Second, there is information that is not anyone's knowledge, but which may be processed to joint knowledge through collaborative knowledge construction. Third, there are different kinds of learning strategies and tactics that can complement each other in a collaborative learning situation.

Thus, social interaction between group members is a prerequisite for collaborative learning (Arvaja, Häkkinen & Kankaanranta, 2008). However, all interaction does not lead to learning and the quality of the interaction is crucial. The guiding principle in collaborative learning is that, for example, through joint creation of understanding (e.g. Barron, 2003), construction of common knowledge (e.g. Crook, 2002), coordination (e.g. Barron, 2000), negotiation of shared meaning (e.g. Miell & Littleton, 2008), and mutual explaining (e.g. Webb & Palinscar, 1996), the group is able to build new collaborative knowledge that exceeds what any individual could have achieved on their own (Stahl, 2004). In order to provoke such high-quality interactions, it is essential to create favorable conditions for collaboration and social interaction (Nussbaum et al., 2011). CSCL is a type of collaborative learning that uses technological solutions to support collaborative learning (Koschmann, 1996). Thus, CSCL research integrates research areas focusing on collaborative learning (Koschmann, 1996) and information and communication technologies (e.g. Arvaja, Häkkinen & Kankaanranta, 2008).

Concepts of collaborative learning and cooperative learning are sometimes used interchangeably by mistake (Zagal et al., 2006). However, in cooperative learning, a problem-solving task is often split into sub-tasks, and each participant is responsible for a portion of the problem solving (Dillenbourg, 1999). In a collaborative situation, in turn, participants share the task of solving problems; new knowledge must be built on others' ideas and thoughts (Arvaja et al., 2007). Thus, the idea is that successful collaboration leads to a situation where the group, through collaborative knowledge construction, creates something together that exceeds what any one individual could achieve alone (Stahl, 2004). To achieve this goal, it is important to structure the learners' knowledge construction, and to support their socio-emotional processes to promote their development as well as their performance in a team (Wegerif, 1998; Kreijns et al., 2013). Marschak and Radner (1972) define a team as an organization in which the information each member holds may differ, but where the members' interests and beliefs are the same.

Even though the concept of serious games was developed in 1970 (Abt, 1970), it continues to be defined in many ways. Common to most of the presented definitions is that serious games are concerned with the use of games and gaming technology for other purposes than mere entertainment (e.g. Susi, Johannesson, & Backlund, 2007). The term "serious games" is sometimes used synonymously with educational games or edutainment games (Crookall, 2010). However, what makes the difference between these concepts is the purpose of the game. While educational games are mostly developed for use in K-12 education to teach a particular piece of curricular textbook knowledge (Breuer & Bente, 2010), serious games can be used for various purposes such as education, training, health care, and marketing (Susi et al., 2007).

2.2 Collaborative serious games

Collaborative serious games are one way to use technology to support collaborative learning. A growing number of studies on collaborative serious games has indicated that, at their best, such games can be helpful, for example, in visualizing things which would be impossible to demonstrate in classroom settings (Hämäläinen, 2008a), in knowledge creation (Burton & Martin, 2010; Hummel et al., 2011), in motivating and promoting teamwork (Susaeta et al., 2010), in developing decision-making processes (Amory, Naicker, Vincent, Adams & McNaught, 1999; Kennedy-Clark & Thompson, 2011), and in improving learning motivation and attitudes (Sung & Hwang, 2013). Thus, games are one way to use technology to support collaborative learning (e.g. Whitton, 2010) and to promote the learners' ability to face future challenges (Salpeter, 2003).

Applying elements of games to inform instruction is not a novel idea. For example, Malone (1980) studied motivational aspects of games and identified four elements (fantasy, challenge, curiosity, and control) that motivate players. Further, Bowman (1982) stated that motivational support in games can be adapted for instruction by providing learners with clear goals, roles, responsibilities, and freedom of choice, and by balancing learners' skills with progressive challenges. Further, it has been shown that playing games supports intrinsic motivation and learning by providing feedback, fantasy, and challenges (Rieber, 1996). However, only through recent technological development has the collaborative mechanism become prominent in computer games, and, at the same time, interest in utilizing them to support learning has increased (Zagal et al., 2006). Thus, applying collaborative learning (Crook, 1998; Minnaert, Boekaerts, de Brabander, & Opdenakker, 2011) in digital game settings can be seen as one of today's innovations. Some earlier studies related to collaborative serious games can be found. For example, Bruckman (1998) and Turkle (1995) studied multiuser environments with aspects of role-playing and community. Bruckman (1998) found that these game-like virtual environments enabled community support and the development of social relationships. Turkle's (1995) study, in turn, showed that these environments offered learners a safe, nonthreatening space in which to expand, explore, and reflect on different aspects of themselves.

Collaborative learning and shared problem solving are overlapping processes, and, in practice, game design may apply knowledge produced in CSCL research. Additionally, collaborative learning (Roschelle & Teasley, 1995; Sawyer, 2007) and shared problem solving in games (Burton & Martin, 2010; Hummel et al., 2011) take place by distributing the learners' thoughts and expertise, by listening to and elaborating on the views of others, and through collaborative knowledge construction to reach common goals. Through sharing perspectives, experiences, and understandings, learners are able to develop and debug new ideas, and to notice the complexities in the concepts and skills (Leemkuil, de Jong, de Hoog, & Christoph, 2003). Thus, at their best, collaborative serious games encourage creative collaboration that includes elements whereby students need to make choices based on evidence, consider alternative solutions, investigate a variety of clues under different conditions, and explore new and even counterpoint issues before a particular solution can be reached (Reiser, 2004; Ruiz-Primo, Fugueroa, & Gluckman, 2001). However, the game itself is not an obvious solution for the challenges of achieving collaborative learning, as discussed in more detail in the next section.

2.3 Challenges of collaborative learning in serious games

Many factors may lead to the failure of successful collaborative learning in serious games. These problems may be related to the difficulty of designing such games (e.g. Zagal et al., 2006; Manninen & Korva, 2005; Kim, 2000), integration of the games into the pedagogical process of the class (e.g. Echeverría et al., 2011), or supporting learning processes in such games (e.g. Dillenbourg et al., 2009; Kollar et al., 2011; Hämäläinen & Vähäsantanen, 2011). This study focused on three challenges that were especially relevant in the context of serious games: the learners' lack of engagement, problems with social interaction and group dynamics, and the teachers' lack of knowledge on how to structure and support the learners' knowledge-construction processes.

The first challenge deals with the learners' lack of engagement. The use of games for educational purposes is often justified by the perception that games are engaging and motivating by their very nature. However, it has been argued that serious games do not engage players (Van Eck, 2006) and that they are not necessarily self-motivating (Whitton, 2010). Whitton (2010) argues that the real value of serious games, instead of their motivational benefits, lies in their ability to engage learners through challenging and meaningful tasks, and through social interaction with other players. Thus, serious games have a potential to be engaging and support learning, but only if they are well designed and pedagogically relevant, which means that the desired learning outcomes are closely aligned with the goals of the game (Whitton, 2010). Through engagement, players are actively seeking clues and combining existing knowledge to solve large problems or tasks to move forward in the game (Amory et al., 1999; Gee, 2007). In collaborative games, deeper engagement might lead to more productive social interaction, which is an obvious cornerstone of collaborative knowledge construction and learning. Thus, there is a need to develop an understanding of the learners' experiences of playing serious games. Within this study, engagement is approached and evaluated mainly from the perspective of game experience (see Section 2.5). As a response to this challenge in this study, the meaning of the sociability of the game and the sense of social presence for the game experience and game engagement are identified (Article III). This is a step forward in understanding serious game experiences and will further improve engagement in serious games.

The second challenge relates to social interaction and group dynamics. A decade ago, Kreijns et al. (2003) proposed that one main reason for failure in collaborative learning was because the emergence of social interaction in CSCL environments was taken for granted. Subsequently, it has been found that merely offering tools for interaction is not enough, and to achieve successful interactions and enhance learning, it is necessary to structure the learners' knowledge-construction processes in CSCL environments, for example, through collaboration scripts (e.g. De Wever, Schellens, Van Keer, & Valcke, 2008; Hummel et al., 2011). Social interaction is also important for another reason; it is a dominant factor in group-forming and group dynamics (Bales, 1999; Kreijns et al., 2013). Thus, social interaction promotes the learners' socio-emotional processes and enables group members to develop into a well-performing team (Wegerif, 1998). This means that there is a strong sense of social presence, positive interdependence, and trust among members of the group. This type of solid atmosphere enables open social interaction, which is beneficial for collaborative knowledge construction (Kreijns et al., 2013). Without a sense of social presence among the learners, they may not openly share their ideas and prior knowledge among themselves (Rourke, 2000). This view is supported by the indication that prior ties between the learners also affect the nature of social interaction in collaborative serious games (Bluemink et al., 2010). According to Hobaugh (1997), problems with group dynamics is often the major cause of ineffective group action. Despite these findings, the social aspects such as a sense of social presence and the sociability of the environment are still rarely studied in the context of collaborative serious games (see Section 2.4.2). As a response to this challenge, new ways of taking advantage of game mechanics (see Section 2.4.3) to structure collaborative knowledge construction and support socio-emotional processes are presented (Article I). Further, this study investigates the learners' experiences of collaborative serious games as sociable CSCL environments (Article II).

Thirdly, even though, for example, collaboration scripts have been indicated to be an effective way to support collaborative learning (Hummel et al., 2011; Hämäläinen et al., 2008), collaborative serious games challenge teachers to find new ways to support collaborative knowledge construction. This is because although the game design can be used to structure the learners' activities in the game, knowledge-construction processes need to be guided based on situational and timely needs (Hämäläinen & Vähäsantanen, 2011). Hämäläinen and Vähäsantanen (2011) further state that it is essential to find a balance between the freedom and structuring of collaborative knowledge-construction processes. In relation to this challenge, the role of the teachers' real-time orchestration (see Section 2.4.1) for collaborative knowledge construction is investigated (Article IV).

2.4 Promoting collaborative learning in serious games

To harness the full potential of collaborative serious games, both the theoretical grounding for collaborative learning and the game-design perspective should be taken into consideration in the design of such games. These perspectives should not be seen as separate, but rather as mutually reinforcing. According to Echeverria et al. (2011), the gameplay perspective is the subject of the educational point of view in the game design. Further, to serve as a sociable CSCL environment, both cognitive (structuring knowledge construction) and emotional aspects (supporting socio-emotional processes) should be taken into account in the design of collaborative serious games (Kreijns et al., 2007). Thus, the integration of these perspectives aims to find new ways to take advantage of game-design elements (such as game mechanics) to structure the learners' knowledge construction, and to support their socio-emotional processes to improve the opportunity for productive interaction and collaboration to emerge. In addition to the game's internal guidance, it is essential to pay attention to the instructional design, such as the role of the teacher in structuring the knowledge-construction processes. Within this section, structuring knowledge construction and supporting socio-emotional processes are discussed. Section 2.4.3 focuses on taking advantage of game-design elements (especially game mechanics) in designing collaborative serious games.

2.4.1 Structuring knowledge construction

The game as an interactive medium offers many ways in which to engage players and structure their activities in the game (e.g. Dickey, 2005). Previous studies have indicated, for example, how the use of collaboration scripting and predefined roles can be effective pedagogical techniques to structure knowledge-construction processes in CSCL environments (Hummel et al., 2011; Bluemink et al., 2010). Especially in the context of serious games, the importance of game mechanics has been highlighted (Aleven et al., 2010; Zagal et al., 2006). From the instructional design point of view, the teachers' real-time orchestration has been proposed to be an effective pedagogical technique to facilitate and structure collaborative knowledge construction (e.g. Hämäläinen & Vähäsantanen, 2011; Dillenbourg et al., 2009)

Collaboration scripting is a pedagogical technique that aims to engage learners in social and cognitive activities, which otherwise would occur rarely, or not at all, and to improve collaboration through structuring the learners' knowledge construction (Kobbe et al., 2007). In the context of serious games, collaboration scripting refers to game design, and especially to defining the game tasks and mechanics (see Section 2.4.3), which requires the participation of several players, and necessitates collaborative knowledge construction (Bluemink et al., 2010). According to Hummel et al. (2011), scripted collaboration seems to improve the quality of the learning output, and thus they stressed collaboration scripting to be an interesting pattern of gameplay to be examined in serious gaming research.

The roles in CSCL can be divided into scripted, predefined roles, and emergent roles, which emerge naturally in the collaboration situation (Strijbos & De Laat, 2010). In general, the roles in CSCL refer to more or less defined functions or responsibilities that guide the learners' behavior and regulate social interaction in the group (Hare, 1994). From the game-design perspective, the focus is on predefined roles. Roles have been traditionally used to structure online discussions in asynchronous CSCL environments (e.g. De Wever et al., 2008). However, games as an interactive (and increasingly synchronous) form of media offer new possibilities for the use of roles. Game design allows players to set a variety of diverse roles in joint problem-solving tasks. In the game context, roles can be defined, for example, which determine the challenges and actions that the game sets and offers to each player (e.g. Hummel et al., 2011; Hämäläinen et al., 2008). In practice, this can mean, for example, giving different information for the different players or allowing them to use different tools when problem solving (Article I). However, as mentioned before, players may not always act in the way in which the designers thought they would act (Nacke & Lindley, 2009). In CSCL, this refers to the situation where learners behave differently to what has been predicted (Strijbos & De Laat, 2010).

Rapid development of CSCL environments has led to the situation where the teachers' role in promoting learning has received less attention (Hämäläinen & Oksanen, 2013).

New types of CSCL environments challenge teachers to find new ways to support collaborative learning. The aim of the teachers' real-time orchestration in CSCL environments is to maintain the balance between the instructions, the free-collaboration processes, and the contextual nature of collaboration (Kollar et al., 2011). More precisely, the role of the teacher is to design and orchestrate the structure of the learning processes, while the activities rest on the curriculum, and on the game's internal guidance structure for collaboration (Hämäläinen & Vähäsantanen, 2011). In practice, orchestration in collaborative serious games can be, for example, teachers' participation in the game, and teachers asking questions and highlighting real-life scenarios during the problem-solving stages (Article IV).

2.4.2 Supporting socio-emotional processes

In addition to structuring knowledge construction, it is essential to also support the learners' socio-emotional processes (such as group formation, building trust, and a sense of community), which have been identified as essential for the emergence of social interaction (Wegerif, 1998; Kreijns et al., 2013), and which contribute to perceived learning (Abedin, Daneshgar, & D'Ambra, 2012). This is because learners are not only information processors, but also social beings with social and emotional needs (Sproull & Faraj, 1997; Kreijns et al., 2007). The sociability of the environment and a sense of social presence have been identified as important contributors for the learners' socio-emotional processes (Abedin et al., 2012; Kreijns et al., 2007) as well as game experiences (e.g. Ducheneaut, Moore, & Nickell, 2007; Poels et al., 2007).

The sociability of the environment refers to the ability of a CSCL environment to facilitate the emergence of a sound social space for social interaction, a strong sense of togetherness, and good working relationships (Laffey, Lin, & Lin, 2006; Kreijns et al., 2007). Previous studies have shown the sociability of the environment to be strongly related to the learners' enjoyment, the level of learner participation, and the effectiveness of the learning (e.g. Abedin et al., 2012; Muilenburg & Berge, 2005). Further, the sociability of the environment has been found to be associated with the emergence of a sense of social presence (Kreijns et al., 2007). Sociability can be approached from two different perspectives. Thus, it can be seen as an attribute of the socio-technological system (Kreijns et al., 2013) or as an attribute of the social system (Preece, 2000). From the former perspective, sociability is determined by social affordances, which are properties of the environment that act as facilitators or triggers for the social interaction. Social affordances can be either tangible (e.g. group-awareness delivering tools) or intangible (e.g. the policies and rules in the CSCL groups) (Kreijns et al., 2013). In the context of collaborative serious games, this refers, for example, to designing game tasks that require social interaction and collaboration among players to be solved. In massively multiplayer online games (MMOGs), sociability can be encouraged, for example, through the available player interdependencies, game space, and interaction system (Ducheneaut et al., 2007). Even though the characteristics of CSCL environments (or games) do not directly affect the quality, content, and intensity of the social interaction, they can be designed in a way that promotes the emergence of social interaction (Ducheneaut et al., 2007; Kreijns et al., 2013).

From the latter point of view, sociability is determined through three factors: community purpose, the people who participate, and policies (Preece, 2000). To enhance sociability, these factors should be defined carefully. In the context of CSCL, this means that the purpose of the collaborative learning activity should be clearly stated so that group members have the same expectations of what has to be done, thereby preventing frustration. In addition, collaborative learning can be promoted by setting different roles for the group members (people) to support positive interdependence among group members and one's individual accountability. From the policies' perspective, CSCL policies are no different to policies in other online communities, covering, for example, similar general rules for behavior (Kreijns et al., 2013; Preece, 2000).

A sense of social presence, in turn, has been defined as "the perceived degree of illusion that the other in the communication appears to be a 'real' physical person in either an immediate or delayed communication episode" (Kreijns et al., 2007, 180). In the research on game experiences, a sense of social presence is divided into three sub-categories: positive (empathy) and negative (negative feelings) psychological involvement, and behavioral involvement (Poels, De Kort, & IJsselsteijn, 2008). This categorization makes sense, since the degree of the sense of social presence itself does not reflect the nature of social presence. Kear (2010) found that a lack of a sense of social presence is a major drawback in asynchronous, text-based learning environments, since they do not offer either visual or auditory cues for communication, and besides, there might be a delay between the messages. Further, she proposed that the sense of social presence is influenced by the participants' behavior and interaction, as well as by the characteristics of the environment. For example, making group members visible to each other and enabling synchronous social interaction may increase the sense of social presence (Kear, 2010; Haythornthwaite, Kazmer, Robins, & Shoemaker, 2000). Additionally, prior ties between participants influence the sense of social presence (Rettie, 2005).

Supporting the learners' socio-emotional processes improves building a good basis for productive social interaction and knowledge construction. This enables students to get to know each other, to build trust, and to form a sense of community. This may further facilitate the emergence of a sound social space. As Rourke (2000) proposes, the emergence of fruitful social interaction requires certain conditions such as a sense of community and mutual trust. Without such conditions, the learners may not share tentative ideas with their peers or critique each other's ideas, and may interpret criticism as a personal insult rather than as a valuable resource. A sense of social presence is also important from another point of view; namely, game experiences, as discussed in Section 2.5.

2.4.3 Applying game mechanics to promote collaborative learning

In a traditional game theory approach, games are divided into two categories: competitive and cooperative games (von Neumann & Morgenstern, 1947; Zagal et al., 2006). The scope of game theory is vastly large, and it focuses on understanding situations in which decision-makers interact (Osborne, 2004). Game theory can also be applied in situations where interdependency exists between two or more players.

In competitive games, players naturally compete against each other, and this requires them to form strategies that directly oppose the other players in the game (Zagal et al., 2006). Many traditional board games (such as chess) can be characterized as competitive games (Jones, 2000). Cooperative games, in turn, refer to the form of games in which two or more players' interests are neither completely opposed nor completely coincident (Nash, 2002). The classic example of cooperative games is the iterative version of the prisoner's dilemma, in which two players might not cooperate, even if it is in their best interest to do so (Osborne, 2004).

Thus, a cooperative game does not guarantee that players will benefit equally or that they will even benefit at all (Osborne, 2004). As it has been stated before, there is a fundamental difference between cooperative and collaborative games. In cooperative learning, a task is often split into sub-tasks, and participants are responsible for a portion of the task-solving (Dillebourg, 1999). Collaborative learning, in turn, is based on the idea that participants share task-solving, and through equal participation, achieve something that any one individual could not achieve on their own (Stahl, 2004). The focus of this study is on collaborative games, and not on games in which an individual is going to win or optimize in terms of their profit from the game. Collaborative games can be considered as a third category of games (Zagal et al., 2006). Thus, instead of using a game theory, and focusing on a mathematical point of view to locate the optimal solution for one's profit from the game, it is essential to focus on game mechanics that promote social interaction and collaborative knowledge construction.

Nussbaum et al. (2011) have proposed the conditions that should be met to improve the emergence of social interaction that enables collaborative knowledge construction to occur. These favorable conditions for collaborative learning include: 1) a common goal, 2) positive interdependence, 3) coordination and communication, 4) individual accountability, 5) awareness, and 6) joint rewards.

Members of the group need to have a common goal that they strive to achieve (Dillenbourg, 1999). This goal aims to generate social interaction and collaborative knowledge construction between the members of the group (Roschelle & Teasley, 1995). Positive interdependence is an essential element in effective collaboration (Collazos, Guerrero, Pino, & Ochoa, 2003; Wang, 2009). A common goal is one way to promote positive interdependence among group members (Wang, 2009). Interdependence links group members. No one can achieve this goal alone; all members must make the effort (Brush, 1998; Johnson & Johnson, 1999). Coordination and communication involve the group members communicating with one another and managing their interdependent activities to achieve a goal (Malone & Crowston, 1990; Nussbaum et al., 2011). By doing this, group members can reconcile their individual prior knowledge and information (Winne et al., 2010). At best, this activity leads to a situation in which joint understanding and knowledge are built on others' ideas and thoughts (Arvaja et al., 2007).

Individual accountability is one of the principal characteristics of collaborative learning. Each member of the group must have a meaningful role in knowledge construction (Slavin, 1996). In an ideal collaborative situation, each member plays a critical role and makes a significant contribution to the group's work instead of one member working for all (Wang, 2009). By awareness, Nussbaum et al. (2011) mean that to collaborate successfully, group members must be aware of their peers' current state of mind and engage in mutual feedback that promotes decision-making. Finally, joint rewards create a feeling of winning or losing together, as a group (Axelrod & Hamilton, 1981). These encourage members to maximize their joint effort (Zagal, Rick, & His, 2006).

Combining the theoretical knowledge on collaborative learning and game design aims to find ways to take advantage of game-design elements to promote collaborative learning (Echeverría et al., 2011). Schell (2008) classifies game-design elements into four categories: story, aesthetics, technology, and mechanics. The story describes a series of events that make up the game's narrative. Aesthetics is about how the game looks and sounds, including graphics, design, sound, and music. Technology determines the materials and interactions that make the game possible. Mechanics are the factors that distinguish the game from other forms of media, because they determine the game's interactivity, for example, through the procedures and rules of the game.

Designing collaborative games has been identified as being extraordinarily difficult (Zagal et al., 2006), requiring an expanded view on group dynamics, social roles, and interaction between the players (Kim, 2000; Manninen & Korva, 2005). Game mechanics has been found to be directly affected by the learning objectives of the game (Aleven, Myers, Easterday, & Ogan, 2010), and, additionally, they can be designed according to the desired activity or expected goal (Mariais, Michau, & Pernin, 2011; Peppler, Danish, & Phelps, 2013). Schell (2008) further divided mechanics into sub-categories: 1) space; 2) objects, attributes, and states; 3) actions; 4) rules; 5) skill; and 6) chance.

Space defines the "magic circle" in which the game takes place (Schell, 2008). In line with that concept, Manninen and Korva (2005) found that placing players in different locations out of the line of sight and with no cognitive distractions (*spatial isolation*) encouraged them to start social interaction. Sharing the area where collaboration takes place (*shared space*) creates interdependence among the players (Johnson & Johnson, 1994) and increases the level of awareness of each other's state of mind (Nussbaum et al., 2011).

Objects, attributes, and states bring content to the game's space (Schell, 2008). Objects are things that can be seen or manipulated in the game. Attributes are categories of information related to the objects; each attribute has a current state. Objects can be used to generate collaboration and social interaction among the players through shared objects with which multiple players need to interact to complete the game or task (*shared object*) successfully. Limiting the information that different players get from the attributes and their states (*encrypted information*) may promote collaboration and emphasize individual accountability in collaborative knowledge construction (Nussbaum et al., 2011).

Actions determine what the players can do in the game. In general, two types of actions exist: operative actions (concrete actions) and resultant actions (strategic choices) (Schell, 2008). Actions are related to the players' roles, and to how players coordinate and communicate with one another (Nussbaum et al., 2011). Although the use of roles is not a novel idea in instructional design (Dickey, 2005), games offer new possibilities for using roles. In practice, the players' actions or roles may be complementary; players cannot solve the problem alone, and each member of the group plays an important role in problem solving (*complementary action*). Thus, positive interdependence exists among the players (Nussbaum et al., 2011). Complementary operative actions also help resultant actions emerge and encourage group members to stay aware of their peers' current state of mind. Actions can also be combined with limited access to information by providing someone with information that requires another player to act (*indirect action*).

Rules can be seen as the most fundamental type of mechanics. They bring other mechanics to life and give them meaning by, for example, defining the consequences of the players' actions, the constraints on the actions, and the goals of the game. In the context of rules, establishing a common goal (cf. promoting collaboration; Nussbaum et al., 2011) is vital. Such a goal requires effort and commitment from several players to complete the game successfully. It must also be challenging enough to engage the players' attention and to give them a feeling of success in the form of joint rewards (Nussbaum et al., 2011). Rules should not guide and limit players' activities too much (Dillenbourg, 2002), but should permit the selection and development of knowledge construction and problem-solving strategies (*flexible strategies*).

Skill refers to the skills (physical, mental, and social) that games require players to exercise or have. Game tasks need to be complex enough to require players to combine forces, and to contribute views and resources to achieve a common goal. Finding a balance between the required skills and existing skills is crucial for engagement and motivation (Hromek & Roffey, 2009). Initially, it is vital to open up social interaction among the players. Later, however, it is important to increase the level of challenge (Howland, 2002; Zagal et al., 2006). Finally, chance refers to the unforeseen and uncertain events of the game, and it is very important in terms of the game being fun. The practical implementation of the described sub-mechanics (including spatial isolation, shared space, shared object, encrypted information, complementary action, indirect action, and flexible strategies) is presented in more detail in Section 4.3.

2.5 Understanding serious game experiences

Game experiences are a less studied but rising area of research in the field of serious games (e.g. Admiraal, Huizenga, Akkerman, & ten Dam, 2011; De Grove, Van Looy, & Courtois, 2010; Whitton, 2010; Kiili & Lainema, 2008). One reason for this increasing interest may be that positive and engaging game experiences are indicated to have a positive effect on learning (e.g. Jacques, Preece, & Carey, 1995; Kiili & Lainema, 2008; De Grove et al., 2010; Whitton, 2010). Due to the growing number of multiplayer games, the social aspects of gaming, including the sociability of the game and the sense of social presence, have been increasingly taken into account when it comes to game experiences (e.g. Ducheneaut et al., 2007; Poels, De Kort, & IJsselsteijn, 2007; Kallio, Mäyrä, & Kaipainen, 2011).

Engagement is one of the most discussed and studied issues in the research on game experiences (e.g. Malone & Lepper, 1987). Especially in the context of serious games, Whitton (2011) proposed engagement to be a result of five factors: 1) challenge, 2) control, 3) immersion, 4) interest, and 5) purpose. Challenge refers to the activity that requires skills, and is defined by clear rules involving achievable but not trivial goals (Csikszentmihalyi, 1992; Malone, 1980). A sense of control arises from the fact that one is able to make choices related to the activity and to get feedback from these choices (Malone, 1980). Immersion refers to a gradual, time-based, progressive experience that includes the suppression of all surroundings, along with attention and involvement within the sense of being in a virtual world (Brown & Cairns, 2004; Ermi & Mäyrä, 2005; Jennett, Cox, Cairns, Dhoparee, Epps, Tijs, et al., 2008). Interest, in turn, refers to having an intrinsic urge for the subject of an activity and thus provides the basis for engagement for its own sake (Deci & Ryan, 1987). The last factor, purpose, is especially relevant for adult learners, and it refers to the perceived value of the activity for learning (Knowles, 1998; Whitton, 2011).

In more general terms, the most often-used concepts related to game experiences are flow (e.g. Csikszentmihalyi, 1975; Sweetser & Wyeth, 2005) and immersion (Ermi & Mäyrä, 2005). However, these concepts alone are too limited to cover game experience, which should be viewed from a broader perspective, and dealt with rather as a multidimensional phenomenon. Within this thesis, game experience is viewed through the framework that consists of elements of the core game experience and a sense of social presence (Poels et al., 2008). According to the proposed framework, the core game experience consists of 1) flow, 2) sensory and imaginative immersion, 3) competence, 4) challenge, 5) positive affect, 6) negative affect, and 7) tension. A sense of social presence, in turn, consists of 1) positive psychological involvement (empathy), 2) negative psychological involvement (negative feelings), and 3) behavioral involvement.

Flow is considered as a central concept of the user experience in many studies related to the engagement and enjoyment of digital games (e.g. Admiraal et al., 2011; Fu, Su, & Yu, 2009; Kiili & Lainema, 2008; Sweetser & Wyeth, 2005). It refers to the feelings of enjoyment that result from the balance between an individual's skills and the challenge in the process of performing an intrinsically rewarding activity (Csikszentmihalyi, 1975, 1996). Past research has shown flow to have a positive effect on learning (Webster, Trevino & Ryan, 1993; Kiili & Lainema, 2008). As mentioned before, another closely related concept to engagement is immersion. Even though there are many similarities between the concepts of flow and immersion, it is reasonable to distinguish between these concepts. Briefly, while the concept of flow can be considered as the involvement in an activity, immersion refers more to one's sense of presence in a mediated environment. According to Weibel and Wissmath (2011), flow is more closely related to the characteristics of tasks, while immersion is more concerned with the technological characteristics of a medium.

The concepts of competence and challenge are closely related to each other, as well as to flow and immersion. It has been stated that it is only possible to experience flow when the players' skills match with the challenges set by the game (e.g. Sweetser & Wyeth, 2005; Kiili & Lainema, 2008). In addition, both of these must also exceed a certain threshold, and thus, to maintain the opportunity to experience flow, it is crucial for the game to offer constantly challenging tasks. By positive and negative affect, Poels et al. (2008) refer to more general positive (such as fun and enjoyment) and negative (such as boredom and lack of concentration) feelings as a part of the experience. Finally, the last dimension of this categorization is tension, which is closely connected to the negative affect, and refers to feelings such as irritation, frustration, and a sense of pressure.

From the perspective of the sense of social presence, distribution across different dimensions makes sense, since, what is even more important than knowing which level of social presence exists is recognizing the quality of the sense of the social presence. In the light of previous studies, the relationship between a sense of social presence and the core game experience is, to some extent, contradictory. On the one hand, it has been proposed that social interaction during the game can potentially interrupt flow and immersion by taking players out of their fantasy worlds (Sweetser & Wyeth, 2005). On the other hand, social interaction and a sense of social presence have been highlighted as strong elements of enjoyment, and thus, these aspects should be incorporated into player-experience models (Gajadhar, Nap, De Kort, & IJsselsteijn, 2008). In collaborative serious games, a sense of social presence has a particularly important role in promoting the emergence of social interaction and collaborative knowledge construction. The rationale behind this idea is that good sociability in an environment together with a positive sense of social presence has been proposed to form a safe and supportive space for social interaction and collaboration (Abedin et al., 2012; Muilenburg & Berge, 2005; Kreijns et al., 2007). This further encourages learners to share and critique tentative ideas without interpreting criticism as a personal insult, but rather as something valuable (Rourke, 2000). In addition, as Whitton (2010) proposes, the real value of serious games is not in their motivational benefits, but in their ability to engage learners through challenging and meaningful tasks, and interaction with the game and other players. Thus, it is essential to identify the meaning of the sense of social presence and the sociability of the game for the core game experiences.

2.6 Summarizing the theoretical framework

The theoretical framework of the study centers on six elements, as depicted in Figure 1: sociability; social presence; pedagogical techniques (including game design and teachers' real-time orchestration); social interaction; knowledge construction; and game experience. The framework of the study is largely based on the work by Kreijns et al. (2007, 2013). However, the framework has been modified in regard to the following: It has been extended to cover the game-experience perspective, the pedagogical techniques are specified to include game design and real-time orchestration, and further social interaction has been considered as a prerequisite for collaborative knowledge construction.

Social interaction is the cornerstone of collaborative learning and knowledge construction (Vygotsky, 1978; Hiltz, 1994). It serves two purposes: First, it is required, so that learners can learn from and with each other (knowledge construction), and second, it is necessary for supporting socio-emotional processes (such as group formation and building trust) (Kreijns et al., 2007, 2013). According to the proposed framework, three factors affect the emergence of social interaction in CSCL environments: 1) the sociability of the environment, 2) a sense of social presence, and 3) the pedagogical techniques that are employed.

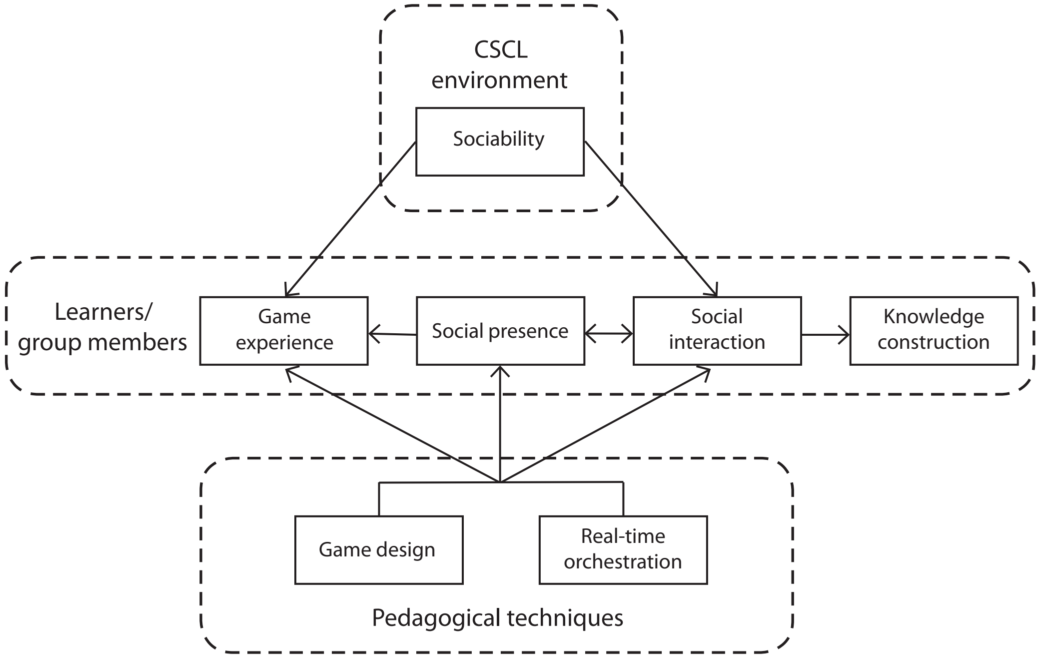

Figure 1. *Theoretical framework of the study*

Sociability is defined as the ability of a CSCL environment to facilitate the emergence of a sound social space for social interaction (Laffey, Lin, & Lin, 2006; Kreijns et al., 2007). Social presence refers to "the perceived degree of illusion that the other in the communication appears to be a 'real' physical person in either an immediate or delayed communication episode" (Kreijns et al., 2007, 180). Pedagogical techniques structure the learners' collaborative knowledge construction and support socio-emotional processes during the collaboration situation. Within this thesis, pedagogical techniques refer to game design (including collaboration scripting) and the teachers' participation in the gameplay as external orchestrators.

Relationships between the elements of the original framework have been studied before (Kreijns et al., 2013). Previous studies have indicated that social affordances (characteristics of the environment) are connected to the sociability, and, further, to the emergence of social interaction in social networking websites, such as Facebook and LinkedIn (Keenan & Shiri, 2009). In addition, the sociability of the environment has been found to strengthen the sense of social presence (e.g. Yang, 2007; Kear, 2010). The relationship between the pedagogical techniques and the sense of social presence has been discussed before as well. However, even though recommendations and guidelines to improve the sense of social presence have been presented (Whipp & Lorentz, 2009; Scollins-Mantha, 2008), this relationship has not been confirmed with empirical results. Social interaction, instead, has been proven to have a positive relationship with the sociability of the environment (Keenan & Shiri, 2009), the sense of social presence (e.g. Tu & McIsaac, 2002; Shen, Yu, & Khalifa, 2006), and the pedagogical techniques such as pedagogical scripting and pre-defined roles (e.g. Dillenbourg & Tchounikine, 2007; Fischer, Kollar, Stegmann, & Wecker, 2013; Strijbos & De Laat, 2010).

Game experiences refer to the players' subjective emotions about the gaming session. Previous studies have also shown the sociability of the game and the sense of social presence to be associated with the players' game experiences (Ducheneaut et al., 2007; Poels et al., 2007). Besides, the real value of serious games has been proposed to be in their ability to engage the learners through game tasks and interaction with the game and with other players (Whitton, 2010). Especially in the context of collaborative serious games, it is noteworthy that the sociability of the game together with a positive sense of social presence prompts open discussion among the group members (Kreijns et al., 2007; 2013; Rourke, 2000). It has been proposed that game experiences are ultimately the ones that define what players do in the game and how much they are willing to invest in what they do (Nacke & Lindley, 2009). Thus, pleasant and engaging game experiences may also encourage social interaction and collaborative knowledge construction among players. From this basis, the game-experience point of view was considered as a necessary aspect to include in the theoretical framework.

Even though there is some empirical evidence about the interrelations between sociability, social presence, pedagogical techniques, and social interaction, as described above, previous studies have mainly been conducted in the context of asynchronous, text-based virtual (learning) environments. In addition, relationships between sociability, social presence, and game experiences have been examined in the context of entertainment games. In the light of the current knowledge, there are no studies in which these issues are examined in the context of collaborative serious games. Collaborative serious games can be considered as a specific type of CSCL environment in which group members are visible to each other and where the environment enables visual and auditory interaction and collaboration. Thus, there is a need to conduct research in this specific context as well.

3

Research task and aims of the study

Overall, the practical inquiry of this thesis consists of three empirical sub-studies (Articles II–IV), in which the developed game (Article I) was used in practice. The overarching aim of this study is to find and investigate new ways to support collaborative learning in serious games through game design and instructional design. The general aims of the thesis are:

1) To design a collaborative serious game based on the theoretical knowledge of collaborative learning and game design (Article I).
2) To investigate the learners' subjective experiences generated by a collaborative serious game as a sociable CSCL environment as well as a game (Articles II and III).
3) To determine the teachers' role from the perspective of collaborative knowledge-construction processes in game settings (Article IV).

All of the empirical sub-studies approached the general aims of the thesis from different angles. More precisely, each of the empirical sub-studies had their own aims and research questions, as reported in Articles II–IV (see Table 1). Article II focused on the collaborative serious game as a sociable CSCL environment, and especially on the sociability of the game, and the sense of social presence generated by the game. Article III turns the focus toward assessing the learners' subjective game experiences in a collaborative serious game, and the meaning of the social aspects of gaming for the core game experiences. Article IV, in turn, focuses on the role of the teachers' real-time orchestration during the gaming session for collaborative knowledge construction.

4

Methodological approach

4.1 Design-based research

This study applied a design-based research (DBR) approach (e.g. Wang & Hannafin, 2005). There is a continuous, growing interest in and use of DBR in the field of educational research (Anderson & Shattuck, 2012). CSCL is one domain in which DBR is widely utilized (e.g. Hoadley, 2002). This thesis is a part of a larger research entity that investigates the potential and challenges of designing and implementing serious games for CSCL in vocational education (e.g. Hämäläinen et al., 2008, Hämäläinen, 2008a; Oksanen, Hämäläinen, Mannila, & Manninen, 2010; Hämäläinen, 2011). The research entity has been ongoing since 2004, and it is implemented in close cooperation with national and international research groups as well as a variety of professionals from different areas (vocational colleges, research institutes, working life, and technical implementers). Thus, this study is one case study (Yin, 2003) as a part of a larger whole implementing a DBR approach.

DBR has shown great potential in integrating traditional instructional design or instructional system design and research on shared processes involving professionals in different fields. Through this collaboration, DBR enables reciprocal development of the theory, implementation of the virtual environments, and practice in the field of education (Wang & Hannafin, 2005; Kester, Kirschner, & Corbalan, 2007). Thus, DBR is an inter-disciplinary, mixed-method research approach that serves both applied and theory-building purposes (Reimann, 2011). The aim of DBR is to increase the impact, transfer, and translation of educational research to improve educational practices (e.g. Anderson & Shattuck, 2012; Oh & Reeves, 2010; Wang & Hannafin, 2005). Hence, DBR aims to go beyond merely designing and testing particular interventions (Design-Based Research Collective, 2003). The main idea in DBR is to perform research to test and refine educational design based on theoretical principles (Collins, Joseph, & Bielaczyc, 2004). DBR is a series of approaches aiming to produce new artifacts, theories, and practices that account for and potentially impact learning and teaching in authentic settings (Barab & Squire, 2004).

Originally, DBR was centered on a combination of design experiments, where new, theoretically constructed models to support learning were designed and tested in authentic settings (Brown, 1992). Thus, DBR seeks to integrate the empirical research from learning with a particular design for instruction, and may also include software design (Hawkins & Collins, 1992; Hoadley, 2002). This means that DBR aims both to develop effective learning environments, and use them in authentic settings in learning and teaching (Sandoval & Bell, 2004). Design experiments in authentic settings are carried out to find out what works in practice. This obviously means giving up the traditional psychological research tradition based on controlling variables (Collins, 1999).

The problem with studies carried out in the laboratory is that they do not reach educators, and do not, for the most part, affect teaching practices (Reimann, 2011). In relation to this problem, DBR is a form of learning research that does take place, to a large extent, within an authentic setting, involving close cooperation between educators, students, and researchers (Reimann, 2011). When the research is about educational technology, then technology developers are also closely involved. Thus, the main motivation behind DBR is to connect learning research more closely to classroom practices.

DBR differentiates from traditional psychological studies in various ways (Barab & Squire, 2004; Collins, Joseph & Bielaczyc, 2004). One central distinction is in the focus of the research. The focus of psychological experimentation is on identifying a few variables and holding them constant, while DBR focuses on understanding the messiness of real-world practice, with context being a core part of the story. In addition, DBR involves design revision, multiple dependent variables, and active social interaction among participants. Further, participants in DBR are not treated as subjects, but more as co-participants. Finally, DBR involves multiple perspectives of the design and focuses on developing a profile or theory that characterizes the design in practice.

Wang and Hannafin (2005) outline how DBR is 1) pragmatic; 2) grounded; 3) interactive, iterative, and flexible; 4) integrative; and 5) contextual by its very nature. Being pragmatic means that DBR refines both theory and practice. Theory in DBR is closely related to practice, linking it back to the origins of the design research as a means of increasing the relevance of the theory to practice (Brown, 1992). Further, the value of the theory is appraised by the extent to which principles inform and improve practice. DBR is grounded in relevant research, theory, and practice. In addition, it is also grounded in real-world contexts rather than in laboratory settings isolated from everyday practice. For example, learning is not considered as a separate phenomenon from the environment, but more as a sum of the environment and the content. As Barab and Squire (2004) state, cognition is not a thing located within the individual, but a process distributed across the learner, the environment in which knowing takes place, and the activity in which the learner participates. Interaction and collaboration among researchers, practitioners, and participants is emphasized throughout the processes in DBR (Cobb et al., 2003). DBR is further characterized by an iterative cycle of design, implementation, analysis, and redesign (Design-Based Research Collective, 2003). Flexibility means that collaborators in DBR seek to improve an initial design plan through implementation. Being integrative means that mixed research methods are used to maximize the plausibility of the research. Further methods vary during the process as new needs and issues emerge, and the research focus evolves. Finally, DBR is contextual, meaning that the results of the research are connected to the design process and the setting.

As DBR typically integrates expertise from different fields, there are different perspectives on the DBR approach such as design experiments (e.g. Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003), design research (e.g. Edelson, 2002), development research (e.g. van den Akker, 1999), and developmental research (e.g. Richey, Klein, & Nelson, 2003). The underlying goals and approaches of these perspectives are similar, but each has a slightly different focus. To underline the similarities and distinctions among DBR and other related perspectives, Wang and Hannafin (2006, pp. 6–7) outline DBR as "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories".

To sum up, DBR is typically characterized by five characteristics (Design-Based Research Collective, 2003). First, the central goals of designing learning environments and developing theories are intertwined. Second, development and research progress through continuous cycles of design, enactment, analysis, and redesign (Cobb, 2001). Third, research on designs leads to sharable theories that help communicate relevant implications to practitioners and other educational designers. Fourth, research is transferable to different authentic learning settings. Fifth, the development relies on methods that can connect (and document) processes of enactment to outcomes of interest.

In this study, game design and development (Article I) has been combined with empirical research on how decisions made in the game design work in practice (Articles II–IV). Empirical sub-studies are not conducted under laboratory conditions, but in the most natural situations possible; there is not even an attempt to limit the impact of the environment on learning. In this study, empirical sub-studies were carried out in authentic classrooms that were equipped with the necessary hardware and software. The design and implementation of the game used in the empirical studies were carried out in close cooperation with professionals from different fields (e.g. researchers, teachers, and game designers). This study, as a part of a larger research entity, follows the iterative and flexible structure of DBR in the sense that the improvements made on previous interventions interact with the design of the games. Within this study, empirical sub-studies (Articles II–IV) have been carried out using the last version of the game. As is often the case in DBR, this study also employed both qualitative and quantitative research methods (see Table 1).

Despite optimistic notions, there are also challenges and limitations related to DBR. According to Wang and Hannafin (2005), issues that are particularly challenging in DBR are an immature methodology, applicability, and feasibility, a paradigm shift, and data utilization. Thus, methodological development is needed for rigor and to account for the importance of the local context (Design-Based Research Collective, 2003). From the applicability and feasibility perspective, the problem may be that DBR may not satisfy the decision-makers' requirements for scientifically based research (Cobb, 2001). Further, teachers and administrators may prefer to take advantage of existing products and approaches rather than becoming deeply involved in their development (Wang & Hannafin, 2005). A paradigm shift requires changes in how designers design and implement system approaches and how they interact with collaborators. As DBR has been characterized as over-methodologized, the gap between the methodology used to collect data and its meaningful utilization needs to be decreased (Wang & Hannafin, 2005).

4.2 Research design of empirical studies

This thesis consists of three empirical sub-studies (Articles II–IV). The main goal of these empirical studies was to investigate the learners' subjective experiences generated by a collaborative serious game as a sociable CSCL environment as well as a game, and to determine the teachers' role from the perspective of shared knowledge-construction processes in game settings. More precisely, the first sub-study (Article II) focused on the game as a space for social interaction and collaborative activities; in other words, a sociable CSCL environment (Kreijns et al., 2007). The second sub-study (Article III) focused on evaluating the learners' subjective game experiences created by a collaborative serious game, and the meaning of the social aspects of gaming for the core game experiences. The third sub-study (Article IV), in turn, concentrated on the role of the teachers' real-time orchestration for shared knowledge-construction processes in game settings.

All of the empirical sub-studies were conducted in an authentic classroom setting, although in the third sub-study (Article IV), an authentic classroom was partly modified in terms of research equipment (an audio recording system was set up). In practice, this means that each group played the game with no experimental manipulation; features of the game were not controlled during the experiment. Sub-studies I (Article II) and III (Article IV) were conducted in the context of vocational education, but sub-study II (Article III) was partly conducted in the context of higher education (Table 1).

All of the empirical experiments followed the same procedure. Experiments included a one- to two-hour gaming period in the collaborative serious game "Game Bridge" (GB). To avoid compromising the research setting, the participants were physically isolated from one another. Cubicles were arranged so that the participants were not disturbed from outside the game world and could communicate only through the VoIP speech system and chat. No specific instructions were given to the participants before the gaming period and none of participants had played the game before. In the case of sub-studies I (Article II) and II (Article III), the participants were asked to fill out an electronic questionnaire immediately after the gaming period.

Participants in the empirical sub-studies consisted of students and teachers. Group formation in sub-study I (Article II) was implemented in a way that participants (N = 69) of the study were randomly divided into 14 groups of four to five persons. In sub-study II (Article III), participants (N = 86) were randomly divided into 18 groups of four to five persons, with the exception that students and teachers were consciously placed into different groups to evaluate the groups' experiences while playing the game with their peers. In sub-study III (Article IV), 18 students were randomly divided into four groups, but two teachers were intentionally placed in different groups to form varied working conditions (N = 20). During the experiment, two groups with and two groups without teachers' real-time orchestration solved scripted puzzles in GB.

Game Bridge was designed and implemented as a part of a development project coordinated by the college of Jyväskylä, Finland. The development of the game was supported by EU Structural Funds and nationally by the Centre for Economic Development, Transport, and the Environment of Central Finland. GB was designed and developed as a joint effort between three parties (the Finnish Institute for Educational Research, College of Jyväskylä, and LudoCraft Ltd.).

Table 1. *Outline of the sub-studies*

The focus of the sub-study	Research questions	Data and participants	Data analysis
I ***Collaborative serious game as a sociable CSCL environment (Article II)***	1) What was the level of perceived sociability of the collaborative serious game "Game Bridge"? 2) What was the level of social presence of the collaborative serious game "Game Bridge"?	Self-report questionnaires with 45 students and 24 teachers (total N = 69) in vocational education gathered in 2011.	Descriptive statistics and bivariate correlation
II ***Learners' experiences about the collaborative serious game (Article III)***	1) What kinds of game experiences are generated by the players by playing a collaborative serious game? 2) How are social presence and core game experiences generated from a collaborative serious game connected to each other?	Self-report questionnaires with 62 students and 24 teachers (total N = 86) in vocational and higher education gathered from 2011–2012.	Descriptive statistics, one-sample t-test, analysis of variance (ANOVA), and bivariate correlation
III ***Teachers' real-time orchestration for knowledge construction processes in a game setting (Article IV)***	1) What are the main differences in knowledge-construction processes between the settings with and without real-time teacher orchestration?	Observational notes and players' discussions with 18 students and two teachers (total N = 20) in vocational education gathered in 2011.	Qualitative and quantitative content analysis

4.3 Case: Game Bridge (Article I)

4.3.1 Game-design process and description of the game

The idea behind GB is to create favorable conditions for collaborative learning (see Section 2.4.3), to structure learners' collaborative knowledge construction (see Section 2.4.1), and to support socio-emotional processes (see Section 2.4.2) to raise and maintain social interaction and collaborative activities. The idea for the game comes from working-life needs (Salpeter, 2003). The game design was based on eight (N = 8) themed interviews (e.g. Gubrium & Holstein, 2002) with instructors who worked in different industries, for example, the customer service and metal industries. The reason behind the interviews was to enable the development of a valuable game that addressed the requirements of future working lives. Based on these interviews, human sustainability was selected as a key substantive element of the game. This is in line with the notion that future working life is increasingly based on inter-professional expertise and the shared construction of new knowledge. Thus, there is a need to improve communication to reach understanding, processes, and work principles in interagency work (Collin, Paloniemi, & Mecklin, 2010). In addition, job diversification and growing requirements for effectiveness affect human sustainability (e.g. Feldt, 1997). The added value of GB becomes evident as human sustainability is essential in work life, but teaching it can be very challenging. Therefore, the game had added value, offering the potential of illustrating, in a new way, the working-life community, social relations, haste, flow of information, and leadership. To conclude, based on the themed interviews, the goal of the game was set to emphasize the importance of shared work between professionals of different areas and relevance in real life, to create productive collaborative knowledge construction among the players, and to expand their awareness of human sustainability.

The game-design process lasted about six months, and professionals from different fields (e.g. teachers, researchers, game designers, and programmers) participated in it. GB is a 3-D-multiplayer game (Manninen, 2004; Manninen & Korva, 2005) that offers each player a first-person-view, shared game world (*shared space*). In a synchronous 3-D-game setting, each group member is visible to the others. This visibility may promote individual accountability, decrease "free riding," and increase the level of awareness (Toups et al., 2009; Strijbos & De Laat, 2010; Nussbaum et al., 2011). The game's story (Adams, 2010) is that players work as volunteers at a charity concert for human sustainability. Through three pedagogically scripted levels (or multiplayer puzzles), they are supposed to make sure that customers are satisfied and that everything is ready for the band's gig. The aesthetics are designed to support the narrative of the game. The game lacks background music. Sound effects are used only when necessary so players can talk among themselves without audio interference.

Table 2 summarizes the game mechanics used in the design of GB to create favorable conditions for collaborative learning, and to raise and maintain social interaction and collaborative activities. The dimensions of the game mechanics are based on the classification by Schell (2008). Sub-mechanics are proposed ways to take advantage of game mechanics in the design of collaborative serious games. The following sub-sections describe how these sub-mechanics have been implemented in practice at different levels of the game.

Table 2. *Summary of game mechanics used in Game Bridge*

Mechanic	Sub-mechanic	Target condition	Game levels	Argument
Space	Spatial isolation	Coordination and communication	I	Spatial isolation with no cognitive distractions encourages social interaction (Manninen & Korva, 2005)
	Shared space	Positive interdependence, awareness	I, II, III	Sharing synchronous 3D space for collaboration generates spatial interdependence (Johnson & Johnson, 1994) among the players, and further increases the level of awareness (Nussbaum et al., 2011)
Objects, attributes, and states	Shared object	Coordination and communication, individual accountability	I, III	Shared object with which multiple players need to interact for successful completion promotes social interaction and emphasizes individual accountability (Nussbaum et al., 2011). This also makes "free riding" more difficult (Toups et al., 2009; Strijbos & De Laat, 2010)
	Encrypted information	Coordination and communication, individual accountability, awareness	I, II, III	Encrypted information promotes collaboration and highlights individual accountability so that players are aware of each other's state of mind (Nussbaum et al., 2011) and prior knowledge (Winne et al., 2010; Arvaja, 2012), which forms the basis for the new shared knowledge (Stahl, 2004)
Actions	Comple-mentary action	Common goal, positive interdependence, individual accountability	II	Complementary actions emphasize the critical role of each player in problem solving, since no one can solve the problem alone (Wang, 2009). Complementary actions may also lead to the emergence of resultant actions, which encourage group members to stay aware of their peers' current state of mind (Schell, 2008, 140–142)
	Indirect action	Common goal, coordination and communication, joint reward	II	Indirect action refers to the situation where some of the players are given information that requires another player's action. Thus, these players have a common goal, and they need to collaborate and coordinate their actions with each other for a joint reward (Nussbaum et al., 2011). Joint reward further encourages group members to do their best (Zagal et al., 2006)
Rules	Flexible strategies	Coordination and communication	I, II, III	Flexible strategies allow players to select and develop their working and problem-solving strategies through collaboration. Too strict guidelines may disturb natural interaction and problem-solving processes and increase the cognitive load (Dillenbourg, 2002)

4.3.2 Description of the multiplayer puzzles

Level I: Gate – aiming for coordination among players

The first level of the game acts as an introduction to the gameplay, and the general aims of the level are to practice moving and performing actions in the game, and to facilitate group-forming and an opening discussion among players. In terms of collaboration, the aim of the level is to promote coordination involving personal responsibility, dependency among players, and control of an aggregate of individuals (Barron, 2000).

At the beginning of the first level, players were locked up for a while in truck containers and had no cognitive distractions (*spatial isolation*). The only thing players could do was to communicate with one another. After a time limit, they could leave the container and get a job in the catering tent check-in. However, a locked gate prevented players' access to the area. The gate could be opened only by entering a password in its electronic lock. Each player had a part of the password (*encrypted information*), and these parts had to be entered in correct order to open the lock (*shared object*). Each player had an equal right to use the keypad, regardless of the other players. However, only the player who was entering the password was aware of the state of the keypad (*encrypted information*). To reconcile their information and to organize their actions, players could discuss matters through VoIP and chat. Thus, each player had an active role, because solving the puzzle required effort from all of them. They shared the required information because they were jointly responsible for solving the problem. For example, one player could enter the entire password, but that player still needed to get the required information from other members of the group through discussion (*flexible strategies*). If any mistakes occurred while entering the code, players had to start over. Figure 2 illustrates how the players' actions affected the state of the keypad.

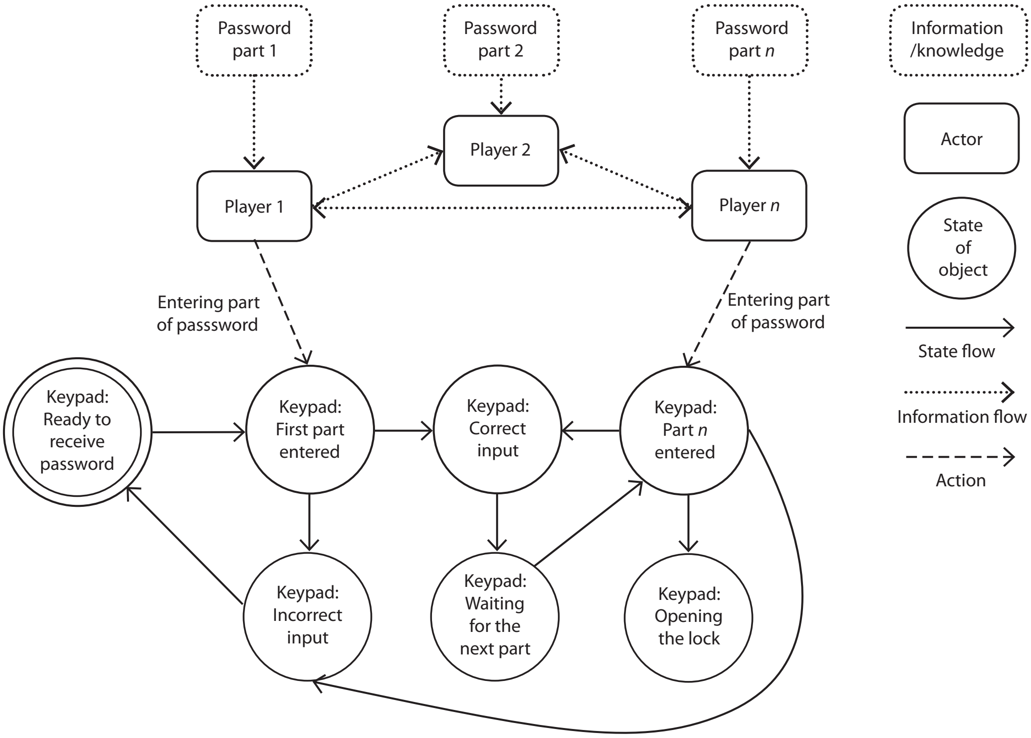

Figure 2. *Event chart of the Gate level*

Level II: Restaurant – aiming for distributed expertise and mutual dependency among players

The second level of the game is more complex compared to the first one. The general aim of the level is to encourage players to share information with each other and to keep others aware of their own position and doings. In terms of collaboration, the aim of the level is to create dependency among group members by distributing different knowledge and resources to each of the players (Price, Rogers, Scaife, Stanton, & Neale, 2003).

For the second level, the players were supposed to keep customers and band members satisfied by serving them in the catering area. Players had supplementary inter-professional roles: cook, waitress, receptionist, and serviceman. These roles (De Wever et al., 2008; Hoadley, 2010) determined the challenges and actions the game established and offered to each player. Each role had its own responsibility area, and players were supposed to integrate and synchronize their individual tasks in a timely manner (*complementary actions*) to keep the customers satisfied. Despite the predefined roles, players still had a degree of freedom to choose their own working strategy. For example, they could agree that the serviceman mainly took care of cleanliness in the restaurant area or that the waiters could alternate in taking breaks (*flexible strategies*). At the end of the task, band members had lunch in the restaurant. One band member had a nut allergy, but he still wanted to have a portion of food that normally included nuts. Information about the allergy was available only to the receptionist (*encrypted information*). However, the receptionist could not directly interact with the customer; thus, this worker would inform the waiters and the cook about this specific requirement (*indirect action*) to solve the puzzle.

To maintain the balance between the players' skills and required skills, the puzzle included additional tasks that hampered problem solving. Some of the tasks needed to have been performed within a certain time limit; limited resources also impeded integration (Howland, 2002). Each player also had a certain amount of energy available. To increase their energy, players needed to take breaks and to synchronize their breaks between the tasks. This further increased the players' need to collaborate continuously. Running out of energy or failing to perform tasks caused players to take a forced break. In a forced break, players were moved to the break tent. There, they had time to reflect on what had happened and to try to develop their working strategy.

Figure 3 demonstrates how the players' actions were tied together and affected the state of the customer. As shown, the receptionist first invited the customer to the restaurant and

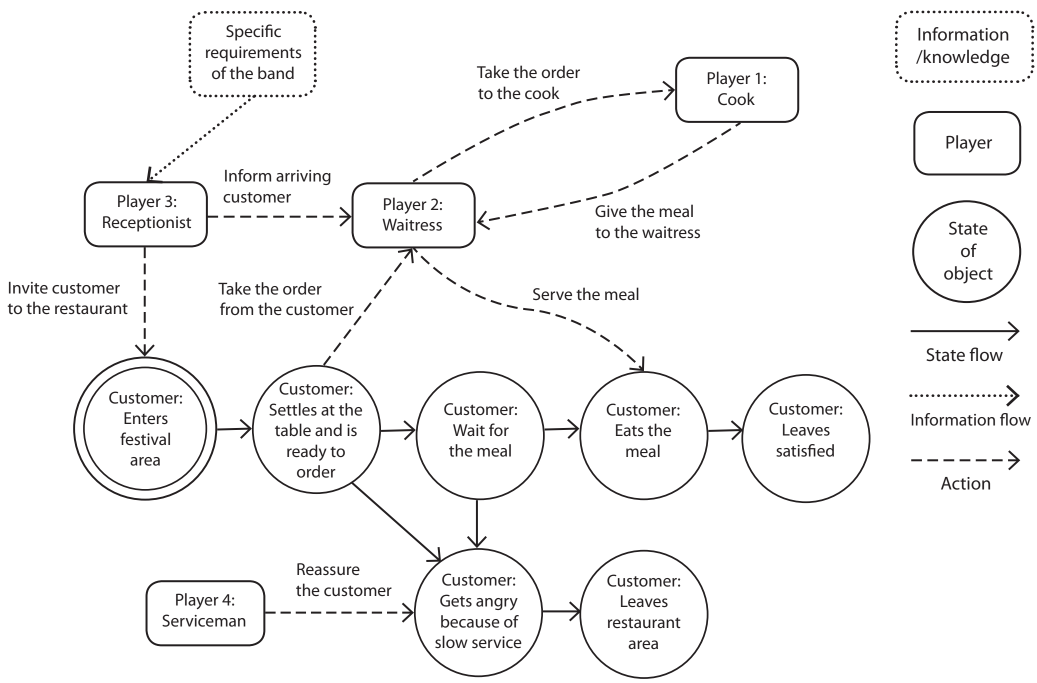

Figure 3. *Event chart of the Restaurant level*

informed the waitress about the incoming customer. After the customer settled in at the table, the waitress was supposed to take the order from the customer and send it to the cook. The cook prepared the meal and gave it to the waiter, who then served the meal to the customer.

Level III: Stage – aiming for solving cognitive conflict

The structure of the third level is simple; similar to the first level of the game. The general aim of the level is to prompt players to share their individual information with each other in order to build a shared understanding of all the available information. In terms of collaboration, the aim of the level is to enter learners into a socio-cognitive conflict situation (Chan & Chan, 2001) and then guide them to solve the conflict. Socio-cognitive conflict is created by giving learners partly contradictory information at the same time, which, without proper coordination, causes an unsolvable problem.

For this level, the players were supposed to identify each band member and organize the band's equipment in the right place on the stage. Identification was based on the tips provided by roadies and pictures on the boxes. Overall, five roadies were in the area, and each one gave unique tips to each player (*encrypted information*). This meant that no one had more information than the other players did, but all the information was needed to solve the puzzle. The large number of tips, however, posed challenges for reconciling individual information to create joint understanding. Piles of boxes were on the stage, and all of the players had an equal right to change the owner of each pile of boxes (*shared object*). The game gave them the freedom to decide on their own working strategy (*flexible strategies*). For example, the players may have decided that only one of them should change the boxes' owners, whereas others could explore pictures on the boxes. Eight piles of boxes existed, of which five belonged to the band members, and the rest belonged to the warm-up band. One by one, the players were supposed to identify the band members and recognize which piles of boxes belonged to the warm-up band. The game did not give continuous, immediate feedback from correct answers. Instead, every 10 minutes, the game gave the players this feedback. This is because, otherwise, players could find the correct answer just by trying different options.

Figure 4 visualizes how the task was structured. As the figure shows, the structure of the task itself was simplified, but the challenge came from the players' collaboration and building of a shared understanding based on individual information.

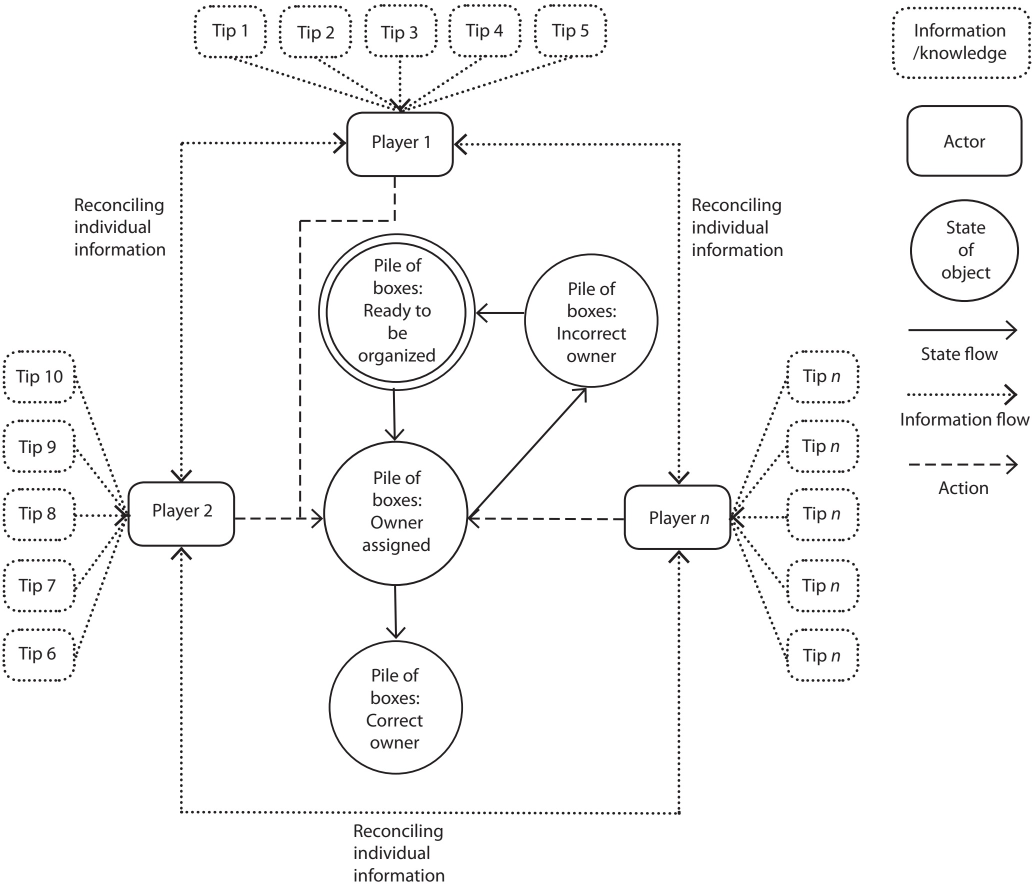

Figure 4. *Event chart of the Stage level*

4.4 Data sources

The aim of the empirical sub-studies was to investigate the learners' subjective experiences generated by a collaborative serious game as a sociable CSCL environment as well as a game (Articles II and III), and to determine the teachers' role from the perspective of knowledge-construction processes in game settings (Article IV). In relation to these aims, research data were collected by using self-report questionnaires (sub-studies I and II; Articles II and III), and by recording the groups' discussions (sub-study III; Article IV) during the gaming session (see Table 1).

Survey data were gathered by using the game-experience questionnaire (GEQ) (Poels et al., 2008) and the sociability scale (Kreijns et al., 2007). The GEQ is intended to cover a range of digital game experiences and included its own modules for core game experience and social presence. The core module covered the following dimensions of the game experience: 1) flow, 2) immersion, 3) competence, 4) challenge, 5) positive affect, 6) negative affect, and 7) tension. The social presence module comprised 1) empathy, 2) negative feelings, and 3) behavioral involvement. Overall, the questionnaire included 59 statements. Each statement was evaluated on a five-point scale, ranging from one (*not at all*) to five (*extremely*). Example statements of the dimensions are as follows, "I felt completely absorbed" (flow), "It was aesthetically pleasing" (immersion), "I felt skillful" (competence), "I had to put a lot of effort into it" (challenge), "I enjoyed it" (positive affect), " I felt bored" (negative affect), "I felt pressured" (tension), "I found it enjoyable to be with the others" (empathy), "I felt jealous about the others" (negative feelings), and "My actions depended on the others' actions" (behavioral involvement). The reliabilities (Cronbach's alpha) of the dimensions of the GEQ (N = 86) were as follows: flow (0.895), immersion (0.865), competence (0.864), challenge (0.636), positive affect (0.901), negative affect (0.823), tension (0.812), empathy (0.867), negative feelings (0.546), and behavioral involvement (0.896).

The sociability scale is intended to measure the perceived sociability of a CSCL environment (Kreijns et al., 2007) and comprises ten statements. The original questionnaire was modified for one item because the original statement "This CSCL environment enables me to make close friendships with my teammates" was considered irrelevant due to the short duration of the gaming sessions. The original statement was replaced by another: "This CSCL environment helped me to understand the perspective of other group members," which was considered more relevant in this context. Each statement was evaluated on a five-point scale, ranging from one (*not applicable at all*) to five (*totally applicable*). A sample statement of the scale is, "This CSCL environment enabled me to get a good impression of my teammates". The reliability (Cronbach's alpha) of the sociability scale (N = 86) was 0.926.

In addition, the questionnaire that was used contained questions about the participants' background as well. The background variables included the educational context (vocational education or higher education), the status of the participant (student or teacher), age, gender, and gaming activity (daily, a few times a week, one to four times a month, less than once a month, or never).

Within the third sub-study, an audio recording system was used to capture all the required data from the collaboration situations. The groups' discussions (6016 transcribed utterances) were recorded straight from the VoIP speech system using the software "Audacity". From the perspective of fidelity, transcripts were coded independently by two researchers. The Cohen's k for inter-judge agreement was 0.97. After discussion between the coders, 98.6% of the coding could be agreed on. However, it has to be noted that high agreement is influenced by the fact that both of the coders had been actively involved in developing methods to analyze collaborative knowledge construction according to different means of activity.

4.5 Data analysis

DBR does not limit the use of research methods, and typically, both qualitative and quantitative methods are used (Wang & Hannafin, 2005). Thus, in this study, both quantitative and qualitative methods were used. The overarching aim of this thesis was to find and investigate new ways to support collaborative learning in serious games through game design and instructional design. In relation to this goal, statistical methods have been used to analyze the gathered survey data (Articles II and III), while in the analysis of the groups' discussions, quantitative and qualitative content analysis were used (Article IV) (see Table 1).

The first sub-study (Article II) focused on the learners' experiences about the game as a sociable CSCL environment, focusing especially on the sociability of the game and the sense of social presence generated by the game. More precisely, the aim was to measure the level of the perceived sociability of the game and the learners' sense of social presence generated by the game, and to find out how these dimensions were connected to each other. In order to respond to these questions, basic descriptive statistics and bivariate correlation were used as a method of analysis.

The second sub-study (Article III) focused on evaluating the learners' subjective experiences about the gaming session in a collaborative serious game, and the meaning of the social dimension of gaming in terms of the core game experiences. More precisely, the sub-study aimed to find out what kinds of game experiences playing the GB generated for the players, and how the perceived sense of social presence and the sociability of the game were connected to the core game experiences. To answer these questions, statistical methods of analysis were used. Basic descriptive statistics and a one-sample t-test with the midpoint of the scale were used to give an overview of the data being analyzed, and to determine whether a participant's ratings deviated from the scale midpoint significantly. In addition, analysis of variance (ANOVA) was used to determine how background variables were related to the game experience. To clarify the meaning of the social dimension of gaming, including the sense of social presence and the sociability of the game, in terms of the core game experiences, bivariate correlation was used as a method of analysis.

The third sub-study (Article IV) concentrated on the role of the teachers' real-time orchestration for shared knowledge-construction processes in a game setting. In more detail, the aim was to determine the main differences in knowledge-construction processes in game settings with and without real-time orchestration. To answer this question, quantitative and qualitative content analysis were used to analyze the research data (for a detailed description of the analysis, see Article IV). Data analysis was implemented in four phases: (1) revising the data, (2) comparing the time used, (3) analyzing collaboration with content analysis, and (4) comparing the differences between the learning settings. In revising the data, all of the gathered data were re-examined and utterances unrelated to shared knowledge construction with others were excluded (e.g. overlapping speech acts, laughing, and individual soliloquy). After the revision, 5386 utterances out of 6016 were categorized to include activities of shared knowledge construction. Comparing the time used was aimed at revealing whether there were differences in the times for completing the game with and without the teachers' orchestration.

Analyzing the groups' discussions with quantitative content analysis (phase 3) aimed to determine whether there was a difference between the settings with and without real-time orchestration. The aim of the qualitative content analysis (phase 4), in turn, was to understand the nature of their differences. An utterance, typically one turn of speech of transcribed data, was chosen as the unit for analysis (Chi, 1997). At first, the utterances were categorized into six theory-based main categories (e.g. Berger & Calabrese, 1975). The main categories were based on the functional roles of the participant's utterances (Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001). The classification had a theoretical grounding in Vosniadou et al.'s (2001) work on teacher–student interaction and our previous studies on the analysis of collaboration in vocational 3D-learning contexts (Hämäläinen et al., 2008; Hämälänen, 2008a). The main categories used in the analysis were as follows: 1) providing knowledge, 2) contextual questions, 3) shared problem solving, 4) management of interaction, 5) summing-up/discovering a solution, and 6) other inputs. Organizing utterances into these main categories was aimed at creating a holistic picture of knowledge-construction activities in different settings and at finding indicators to illustrate the quality of knowledge-construction processes.

Further, to find qualitative differences within the knowledge construction processes, the utterances were further categorized into 25 different data-driven sub-categories within the six main categories according to more detailed functions of interaction. The sub-categories used in the analysis were as follows: 1) providing knowledge (piece of advice – contextual, piece of advice – technical, new information, explaining one's own situation, justifying an opinion, and not justifying an opinion); 2) contextual questions (new openings, technical, specifying, reasoning, and opinions); 3) shared problem solving (continues one's work, answers, disagrees/argues, and reasons); 4) management of interaction (group organization, planning upcoming activity, organizational questions, and support); 5) summing-up/discovering a solution (based on groups' activities, one's own activities, and unknown reasons); and 6) other inputs (related to task-solving, describing technical problems, and off-task knowledge construction related to the environment). These sub-categories were developed to ascertain whether knowledge construction really was based on others' ideas and thoughts. As such, that knowledge can be further used to identify the nature of the knowledge-construction processes as well as to illustrate the differences in various types of learning settings (with and without the teachers' real-time orchestration).

5

The findings of the empirical sub-studies

Within this section, the main findings of the empirical sub-studies (Articles II–IV) will be presented. The game used in each sub-study is the same (GB) (for a detailed description of the game, see Section 4.3), but each of the empirical studies had their own research focus. The first sub-study (Article II) focused on investigating a collaborative serious game as a sociable CSCL environment. The second sub-study (Article III), in turn, focused on assessing the learners' subjective game experiences, and the meaning of the social dimension of gaming for the core game experiences. The third sub-study (Article IV) deals with the role of the teachers' real-time orchestration for the knowledge-construction processes in game settings.

5.1 The game as a space for social interaction and collaboration (Article II)

The aim of the first sub-study (Article II) was to create new knowledge about collaborative serious games as a means of creating a sociable CSCL environment. More specifically, the aim was to answer the following research questions: 1) What was the level of perceived sociability of the collaborative serious game "Game Bridge"? 2) What was the level of social presence of the collaborative serious game "Game Bridge"?

Results of the study showed that participants rated the sociability of the game environment to be fairly high ($M = 3.62$, $SD = 0.85$). From the perspective of social presence, results showed that playing the game generated strong behavioral involvement ($M = 3.49$, $SD = 0.84$) and positive psychological involvement ($M = 3.39$, $SD = 0.77$), in other words, empathy, among the learners. Negative feelings were much less severe and less frequently experienced ($M = 1.95$, $SD = 0.52$). In addition, the sociability of the game and the dimensions of social presence were strongly connected to each other. The strongest correlation was found between the feeling of empathy (positive psychological involvement) and behavioral involvement ($r = .783$, $p < .001$). This indicates that interdependence among the members of the group was positively toned. The sociability of the game and empathy also correlated significantly with each other ($r = .689$, $p < .001$). This indicates that playing the game facilitated and supported the players' socio-emotional processes, such as trust building and a sense of belonging together. This is important, since the learners' socio-emotional processes are essential for the emergence of social interaction and collaborative activities. Thus, the findings of this study are in line with the notion that the sociability of the environment reinforces the players' socio-emotional processes. Further, it is worth noting that the dimensions of psychological involvement (empathy and negative feelings) also correlated with each other ($r = .456$, $p < .001$). This may be due to the fact that the more socially present the other person is, the stronger their mutual influence on each other's feelings, both positive and negative.

To deepen the understanding of serious games as a setting for collaboration, the results of this study were compared to the original study by Kreijns et al. (2007), in which the sociability scale was developed and used in the context of asynchronous virtual environments. This comparison revealed that the level of perceived sociability was largely higher in game settings than in asynchronous virtual environments. Two major differences between these settings can be found. First, the game environment allowed for more spontaneous, informal conversations than the asynchronous environments did. Second, the game environment regenerated a stronger sense of community than the asynchronous virtual environment did. However, it should be noted that the game environment and traditional (asynchronous) virtual environments were experienced as equally comfortable spaces for collaborative activities, and should not necessarily be considered as intrinsically motivating.

In the light of these results, collaborative serious games seem to have extraordinary potential to support the social and psychological aspects of collaborative learning. Even though a positive and stable atmosphere during the gameplay does not necessarily make players feel more comfortable, it still encourages them to collaborate and to have productive social interactions. This is because in such a supportive atmosphere, the learners feel more confident in expressing their opinions (also critical ones), and arguments, which are a prerequisite for productive, collaborative knowledge construction. To conclude, the results of this study may indicate that "Net Generation" learners find game environments inherent spaces for social interaction and collaboration. This creates possibilities for the future, as rehearsing socio-emotional processes is becoming an increasingly important skill to have in the 21st century. Additionally, at their best, collaborative serious games (as a specific type of sociable CSCL environment) may be applied more and more often to support productive knowledge construction and collaborative learning.

5.2 Understanding learners' experiences (Article III)

The second sub-study (Article III) aims to narrow the knowledge gap in the understanding of collaborative serious game experiences and the relationship between the social dimension of gaming and core game experiences. More precisely, this study aims to answer to the following research questions based on empirical study: 1) What kinds of game experiences are generated by the players by playing a collaborative serious game? 2) How are the social presence and core game experiences generated from a collaborative serious game connected to each other? 3) How is the sociability of a game environment connected to the core game experiences?

From the perspective of the core game experience, the results showed that there was a significant deviation in the players' ratings from the scale midpoint of each dimension, except for competence ($t(85) = 1.70$, $p = .093$) and flow ($t(85) = -0.54$, $p = .588$). Two dimensions of the core game experience, positive affect ($M = 3.44$, $SD = 0.77$) and competence ($M = 3.12$, $SD = 0.67$), received higher values than the scale midpoint. The deviation in positive affect from the scale midpoint was significant ($t(85) = 5.28$, $p < .001$), which indicates that the players enjoyed playing the game. From the engagement point of view, the players reported an average level of flow ($M = 2.95$, $SD = 0.93$) as well as immersion ($M = 2.79$, $SD = 0.79$). From these dimensions, immersion was rated significantly lower than the scale midpoint ($t(85) = -2.42$, $p = 0.18$). Because, flow has been defined as involvement in an activity, and is thus related to the characteristics of the game tasks (Weibel & Wissmath, 2011), this indicates that the engagement in the game was more about the nature of the tasks than the technological characteristics of the game. Negatively toned experiences, such as negative affect ($M = 1.98$, $SD = 0.74$) and tension ($M = 2.00$, $SD = 0.71$), were much less severe and less frequently experienced. This is supported by the fact that both negative affect ($t(85) = -.12.81$, $p < .001$) and tension ($t(85) = -13.09$, $p < .001$) were rated significantly lower than the scale midpoint.

The results also indicated that the participants' backgrounds slightly affected their game experiences. In light of the fact that teachers most often played less than students, teachers ($F\ (1, 84) = 11.03$, $p = .001$) and older participants ($F\ (4, 81) = 2.85$, $p = .029$), rated the level of challenge as significantly higher than students did. Further, gaming activity was connected to the feelings of challenge ($F\ (4, 81 = 4.86$, $p = .001$) and competence ($F\ (4,$

81) = 3.07, $p = .021$). More precisely, active gamers felt a higher degree of competence than those who played games less frequently did. In the case of the level of challenge, the relationship was not so clear, but in general, active gamers reported a lower level of challenge, and participants who played games one to four times a month reported the lowest level of challenge. The participants' background did not have a significant influence on ratings of the feeling of social presence and the sociability of the game environment.

Besides, the results showed that the dimensions of the core game experience, the sense of social presence, and the sociability of the game are strongly linked to each other. From the perspective of social presence, positive psychological involvement (empathy), and behavioral involvement correlated most strongly with flow, positive affect, and immersion. The strongest correlation was between empathy and positive affect ($r = .705$, $p < .001$), followed closely by empathy and flow ($r = .685$, $p < .001$). Negative psychological involvement (negative feelings) correlated significantly only with tension ($r = 457$, $p < .001$) and negative affect ($r = .288$, $p < .01$). These results indicate that behavioral involvement, especially empathy among the group members, appears to strengthen the positive dimensions of the core game experience (such as immersion, flow, and positive affect). Conversely, negative psychological involvement reinforces the negative aspects of the experience (such as tension and negative affect).

In addition, the participants' ratings about the sociability of the game environment were strongly connected to the core game experiences. Sociability correlated significantly with every other dimension of the core game experience but tension. The correlation was mostly positive, except with negative affect, which correlated negatively ($r = -.359$, $p < .01$) with sociability. The strongest positive correlation was between sociability and positive affect ($r = .638$, $p < .001$). In addition, correlations between sociability and immersion ($r = .579$, $p < .001$) and flow ($r = .548$, $p < .001$) were very strong.

To sum up, the results of this study intimate that collaborative serious games have the potential to engage players, especially through meaningful and sufficiently challenging tasks. Compared to students, the teachers (usually with lower gaming activity) may feel the gameplay to be more challenging, but that does not necessarily mean that the game experience would not be positive and engaging. According to the findings of this study, it also seems that game engagement, especially in collaborative games, may be strengthened by positive feelings toward teammates and collaboration with them. Finally, the results of this study suggest that the sociability of the game can be considered as a potential factor in the emergence of pleasant serious game experiences, at least in the context of collaborative games.

5.3 The teachers' role in collaborative knowledge construction in game settings (Article IV)

The third empirical sub-study (Article IV) focused on the role of the teachers' real-time orchestration during the gaming session for collaborative knowledge-construction processes. More precisely, the aim of the study was to determine the main differences in knowledge-construction processes in 3D game settings with and without real-time orchestration.

The results of this sub-study in general revealed that in playing GB with teacher real-time orchestration, knowledge construction mainly involved providing knowledge, shared problem solving, and asking contextual questions. In more detail, between the conditions involving studying with (2405 utterances) and without (2981 utterances) teachers' real-time orchestration, the findings indicated two main differences in knowledge-construction activities in the categories "providing knowledge" and "other input". With respect to the discussions, the amount of "providing knowledge" was much higher while playing with teachers' real-time orchestration (42% of utterances), compared to the setting without real-time orchestration (24% of utterances). A more detailed investigation showed that the main difference in the discussions concerned the understanding of the task's interprofessional nature, and the meaning of explaining one's own activities as part of solving puzzles. Groups playing with real-time orchestration used 18% of their utterances to explain their own situation, while groups playing without orchestration only used 6% of their utterances for this aspect. Thus, when playing with teachers' real-time orchestration, explaining one's own activities was used more actively to develop joint knowledge, and to solve the scripted puzzles than in the setting without real-time orchestration.

Another main difference between playing with and without real-time orchestration concerned the level of other inputs. Groups playing with real-time orchestration used 13% (315 utterances, of which 35 were off task) of their utterances for this, while groups playing without real-time orchestration used 36% (1077 utterances, of which 452 were off task) for other inputs. Thus, the main problem while playing without the teachers' real-time orchestration concerned the use of off-task discussions. Students studying without real-time orchestration seemed to become more easily distracted and discuss other topics when the same problem occurred.

In conclusion, the teachers' real-time orchestration seems to have the potential to improve shared knowledge-construction processes in scripted 3D games. This is supported by the fact that the orchestrated setting had more knowledge-construction processes that can be considered as productive.

6
General discussion

The unrevealed potential of collaborative serious games was the driving force behind this study (e.g. Echeverría et al., 2011; Whitton, 2010; Hummel et al., 2011). Better use of the theoretical knowledge on collaborative learning and game design as a foundation for the design of such games is one option to address this issue (Wu et al., 2012; Zagal et al., 2006). Further, to evaluate the relevancy of made decisions, attention should be paid to whether the game constitutes favorable conditions for social interaction and collaborative activities (Nussbaum et al., 2011; Kreijns et al., 2013), or if playing the game contributes to productive knowledge construction and learning (e.g. Van Eck, 2006). This study focused on designing a collaborative serious game, supporting collaborative learning, and investigating learners' experiences. The overarching aim of the study was to find and investigate new ways to support collaborative learning in serious games through game design and instructional design. Collaborative learning was supported through game design (including collaboration scripting) and instructional design. From the game-design perspective, the aim was to find new ways to utilize game mechanics in the design of collaborative games. From the instructional design point of view, the focus of the study was on the teachers' real-time orchestration of collaborative knowledge construction. The game used in the empirical sub-studies was designed and implemented as a part of a development project in cooperation with professionals from different fields of collaborative learning and game design (Article I). The aims of the empirical part of this thesis were twofold. First, to investigate the learners' subjective experiences generated by a collaborative serious game as a sociable CSCL environment, as well as a game. Second, to determine the teachers' role from the perspective of shared knowledge-construction processes in game settings.

6.1 Designing collaborative serious games

Inter-professional cooperation plays a crucial role in the design of collaborative serious games (e.g. Hämäläinen, 2008b; Echeverría et al., 2011). The failed integration of educational and game-design principles has been proposed to be one of the biggest problems in serious games (Kiili, 2010). Thus, there is a need to combine the expertise from the fields of collaborative learning (such as teachers and researchers) and game design (such as game designers, programmers) in the design of collaborative serious games. The main idea in combining these perspectives is to find ways to take advantage of game-design elements to promote collaboration and interaction (Echeverría et al., 2011). Thus, the first aim of this thesis was to design a collaborative serious game (GB) based on the theoretical knowledge of collaborative learning and game design. This approach enabled taking into account the specific needs of collaborative learning, the latest research in this field, and the possibilities of game design in supporting social interaction and collaborative knowledge construction (Article I).

The findings of this study (Article I) are in line with the notion that the synergistic advantage brought about through the combination of the theoretical knowledge on collaborative learning and game-design perspectives is often left untapped (Echeverría et al., 2011). This is despite the fact that, in principle, the objectives of the research on collaborative learning and game design are similar to a certain extent (Article I). For example, the main goal of game design is to find solutions to engaging the players in the gameplay and guiding their activities in a way that they are able to proceed in the game. One main goal of the research on collaborative learning, in turn, is to enlist learners in reaching common goals, and to structure their activities to achieve these goals. A lack of combining these perspectives may be due the fact that collaborative games are extraordinarily difficult to design (Zagal et al., 2006), and require an expanded view of group dynamics, social roles, and interaction between the players (Kim, 2000; Manninen & Korva, 2005). Further, problems related to multidisciplinary design teams, such as a lack of a common vocabulary and understanding, make it difficult to design collaborative serious games (Kiili, 2010).

In this study, previous research from collaborative serious games and game design formed the basis for the design of the game (GB) used in the empirical sub-studies (Articles II–IV). In previous studies, educational and game-design perspectives were combined in different ways and to different degrees. On the one hand, the influence of the theoretical knowledge on collaborative game design varied between the studies. On the other hand, in terms of purely game design, the studies had wide variation as well (Article I). This supports the view that finding a shared vocabulary and understanding between the instructional and game designers might be problematic. Thus, this thesis is a step forward in developing a common vocabulary and understanding to strengthen cooperation between instructional and game designers in designing serious games.

GB was designed and implemented in close cooperation with professionals from the fields of collaborative learning and game design (Article I). The aim of the game was to create favorable conditions for collaborative learning, to structure the learners' collaborative knowledge construction, and support the socio-emotional processes to raise and maintain social interaction and collaborative activities. Finding out about and taking advantage of game mechanics – requiring collaboration and inter-professional knowledge construction – were paid special attention to in the game design. GB consisted of three multiplayer puzzles. In general terms of collaboration, the game's puzzles were designed to promote coordination (Barron, 2000), to encourage distributed expertise (Price et al., 2003), and to guide solving the cognitive conflict (Chan & Chan, 2001). To achieve these objectives, different sub-mechanics (including spatial isolation, shared space, shared object, encrypted information, complementary action, indirect action, and flexible strategies) were introduced and used to structure the activities of the players (Article I).

The results of the empirical sub-studies concerning the use of GB showed the proposed mechanics to be promising in the design of collaborative serious games. This is supported by the fact that the sociability of the game environment was rated relatively high (Articles II and III). Further, playing the game strengthened the players' sense of social presence (Article II and III), and generated social interaction and collaborative knowledge construction (Article IV) along with fairly positive and engaging game experiences (Article III). This indicates that playing the game captured the learners' attention, and created a genuine need for learners to collaborate and build shared knowledge to solve the puzzles. Thus, decisions made in the game design can be proposed to improve the possibility of productive collaborative activities taking place (Hummel et al., 2011; Kobbe et al., 2007). In addition, the game guided and helped groups to solve puzzles (Article IV). According to Hämäläinen (2008b), it might be easier to get learners to act according to the pedagogical script compared to textual environments because of more concrete tasks, and because the game's story also supports the roles of learners more efficiently.

Based on this study, it is possible to find new ways to support collaborative learning in game settings by combining the theoretical knowledge on collaborative learning and game design. As a main contribution of this study from the game-design perspective, seven ways to take advantage of game mechanics in the design of collaborative serious games are presented. The proposed sub-mechanics are spatial isolation, shared space, shared object, encrypted information, complementary action, indirect action, and flexible strategies. Despite this promising notion, this type of research is still in its infancy, and more research is needed to reveal the full potential of game design in supporting collaborative learning. Future research should focus on recognizing and describing collaborative game mechanics (as well as other game-design elements) in more detail to improve their general application. Another major line of research for the future deals with the game analytics. Due the development of new research methods for analyzing game statistics (Wallner & Kriglstein, 2013), it might be possible to gain a better understanding of how different decisions in game design affect the players' actions in the game. Thus, systematic research on game experiences with multiple methods might facilitate and promote recognizing game-design patterns that lead to engaging pleasant game experiences, which may further have a positive effect on learning (Nacke & Lindley, 2009; Kiili & Lainema, 2008; De Grove et al., 2010).

6.2 Collaborative serious games as sociable CSCL environments

CSCL environments, in general, have been criticized for the fact that they focus mostly on supporting acquiring knowledge and skills (knowledge construction), and supporting the learners' socio-emotional processes is generally neglected (Kreijns et al., 2013). When both of these aspects are taken into account in the design of environments, we can talk about sociable CSCL environments. Thus, the key characteristics of the sociable CSCL environment are structuring collaborative knowledge construction and supporting the learners' socio-emotional processes (Kreijns et al., 2013). Behind this study, there was an assumption that collaborative serious games have the potential to act as a specific type of sociable CSCL environment, which structures learners' knowledge construction, and supports their socio-emotional processes in an engaging and pleasant manner. However, the learners do not always act the way the designer intended them to act (Dillenbourg & Jermann, 2006). This is because the learners' experiences guide their decisions, and, in the end, determine what they do, and how much they are willing to invest in what they are doing (Nacke & Lindley, 2009). Thus, the second general aim of the thesis was to investigate the learners' subjective experiences generated by a collaborative serious game as a sociable CSCL environment as well as a game (Articles II and III).

The findings of the study revealed the potential of collaborative serious games as sociable CSCL environments. The empirical sub-studies showed that playing the game promoted collaborative learning by structuring the learners' knowledge construction (Article IV) and supporting their socio-emotional processes, which can help them to evolve as a well-performing team (Articles II and III). As a result, playing the game generated fairly positive game experiences (Article III), a strong sense of social presence (including psychological and behavioral involvement) (Article II), and shared knowledge construction among the learners (Article IV). It is worth noting that although a positive and stable atmosphere during the game does not necessarily make players feel more comfortable (Article II), it still encourages members of the group to collaborate, and to have productive social interactions. This is because in such a supportive atmosphere, learners feel more confident in expressing their opinions (especially critical ones) and arguments, which can be seen as a prerequisite for productive collaboration (Rourke, 2000). Besides, the positively toned psychological involvement that the players felt during the gameplay (Article II) reflects how the collaboration was not obnoxious; rather, the learners found it to be a pleasant way to solve the puzzles. This is important because if the learners feel that they are forced to work together, they might hinder rather than promote collaboration (Hämäläinen, 2008b).

The results of this study underline the meaning of the sociability of the game and a sense of social presence in collaborative serious games for two reasons. First, the sociability of the game seems to reinforce the learners' socio-emotional processes (Article II), which may have a positive impact for the emergence of social interaction and knowledge construction (Kreijns et al., 2013; Guzzo & Dickson, 1996). This finding is in line with the previous notion that the sociability of the CSCL environment and a sense of social presence are key factors in the emergence of social interaction, and further, in the formation of a safe and supportive space for collaboration (Kreijns et al., 2013). Second, the sociability of the game and a sense of social presence seem to be potential factors in the emergence of positive end engaging game experiences (Article III). Thus, this study challenges the previous assumption that the social nature of the game may disturb the core game experience, especially the feeling of flow (Sweetser & Wyeth, 2005). The results of this study highlight how a strong, positive sense of social presence during the game may lead to more enjoyable and engaging game experiences (Article III), which have been further proposed to have a positive impact on learning (Kiili & Lainema, 2008, Whitton, 2010; De Grove et al., 2010). On this basis, designing game mechanics that promote the sociability of the game and bolster the sense of social presence, along with collaboration, might lead to more positive game experiences, and a higher level of engagement (Article III).

In relation to the theoretical framework (Figure 1), this study indicates that the sociability of the game and the sense of social presence are strongly connected with each other, and, additionally, also to the subjective game experiences in collaborative serious games. It can also be assumed that the pedagogical techniques used in this study (game design and teachers' real-time orchestration) affect the game experience. However, due to the limited number of participants, this relationship cannot be statistically proved. Another thing that remains unclear is how the learners' experiences affect the emergence of social interaction and further collaborative knowledge construction. Thus, more research is needed to resolve these issues more precisely.

The results of the study seem promising, and strengthen the understanding of the potential of games to support collaborative learning. Despite this, the results also showed that games should not necessarily be considered as comfortable for all learners (Article II). This finding is in line with Whitton's (2010) proposition that serious games should not be seen as intrinsically motivating. Evaluating the learners' experiences in this study was based on self-report tools, and it is clear that through this route, it is not possible to gain a full picture of the learners' experiences and factors affecting the emergence of these experiences. To gain a deeper understanding of how the different characteristics of the game affect the game experiences, there is a need to combine different research methods. For example, the results from the self-report tools could be supported by systematically gathering and analyzing game analytics (Wallner & Kriglstein, 2013) in relation to the subjective experiences.

In addition to post-game assessment of the game experiences, it is essential to find and develop methods for analyzing experiences during the game in a timely manner. This is because people are not always fully conscious about their experiences. As the definitions of flow (Csikszentmihalyi, 1996; Sweetser & Wyeth, 2005) and immersion (Ermi & Mäyrä, 2005) maintain, the players' consciousness becomes distorted or even switched off. Psychophysiological methods (such as facial electromyography, skin conductance, and cardiac activity) appear to be one potential way to assess these unconscious experiences and emotions "on the fly" (e.g. Kivikangas et al., 2010). According to Lindley et al. (2008), unconscious emotions can be quantitatively characterized via physiological responses using psychophysiological methods. However, utilizing psychophysiological methods in game research is rare. This may be because there is a lack of a useful and widely accepted theoretical background, systematic research, and accumulated results between the studies (Kivikangas et al., 2010). Further, collecting psychophysiological data requires special hardware, and the interpretation of the results is very challenging because the results are influenced by many factors.

6.3 Real-time orchestration as an external support for collaborative learning

Rapid development of new technological learning environments has led to the situation where the teachers' role in the learning processes is ignored (Kollar et al., 2011). However, it has been proposed that the teacher has an important role in the emergence of productive collaboration processes (Tharp, Estrada, Dalton, & Yamauchi, 2000). Thus, the third general aim of this thesis was to determine the teachers' role from the perspective of collaborative knowledge-construction processes in game settings (Article IV).

From the real-time orchestration point of view, the results of this study revealed that the teacher's participation in the game, as an external orchestrator or fellow collaborator, enabled learners to focus on task-solving, develop a joint understanding of the inter-professional nature of the tasks, and explain their own situation and activities as a part of inter-professional task-solving. These results highlight the role of the teacher in structuring the learners' knowledge-construction processes. Teachers' real-time orchestration seems to be a plausible way of improving the collaborative knowledge construction and enhancing the productivity of collaboration in a game context, while simultaneously improving the internal guidance of the game. However, this does not mean traditional "teacher centrism," but the teachers' possibilities of being able to orchestrate learning and empower learning processes. In practice, this means, for example, the teachers' external support for collaborative learning (Kollar et al., 2011), or facilitating learning through collaborative knowledge construction in which the teacher and student work together on a common product or goal (Mercer, Hennessy, & Warwick, 2010). It is also worth noting that, in addition to the fact that the developed game gave guidance and helped students in puzzle solving, it had the potential to support the teacher's abilities to foster productive knowledge construction by providing new functional and sociable (Kreijns et al., 2007) learning spaces for knowledge construction, and to help teachers to orchestrate and monitor learning activities (Hämäläinen & De Wever, 2013).

Even though this study suggests the teachers' real-time orchestration to be relevant for structuring the learners' knowledge-construction processes, it still remains unclear how it affects the learners' socio-emotional processes. However, the study provides evidence that the teachers' real-time orchestration reduced the amount of off-task discussion (Article IV). This might indicate that within the groups playing with teachers' real-time orchestration, there was less space for learners' socio-emotional processes (such as group formation and trust building). Thus, further research is needed to resolve how the teachers' participation in the collaborative situation affects, for example, group formation, or trust building in collaboration situations. Besides, for future research, it is essential to pay attention to the role of the teacher before and after the gaming session. For example, the teacher's decisions with respect to the composition of the groups may be relevant, as learners' prior ties have been shown to affect the nature of the social interaction (Bluemink et al., 2010; Arvaja, 2012). Teachers also have a very important role in the post-game debriefing (Crookall, 2010), which has been identified as an essential element for game-based learning. Debriefing can be used, for example, to help learners to elaborate on their own collaboration processes and problem solving, to deepen their understanding about shared knowledge construction, and to integrate lessons learned into practice. Besides, from the debriefing point of view, it is essential to find and develop new work tools for teachers that produce knowledge of the learning processes (Hämäläinen & De Wever, 2013). Through these tools, teachers are able to form a better understanding about the learners' collaborative knowledge construction, and thus are able to direct debriefings on relevant issues.

6.4 Evaluation of the study

6.4.1 Methodological considerations

Currently, the theoretical knowledge about collaborative learning and game design has rarely been combined in the development of collaborative serious games (Echeverría et al., 2011). The strength of this study is that these perspectives have been integrated in the design of the game (Article I) and investigated in the empirical studies (Articles II–IV). Thus, both perspectives could be equally taken into account in the design of the game, and, additionally, enable the development of a shared vocabulary and understanding for instructional and game designers. Further empirical sub-studies were carried out into authentic settings to find out how the designed and implemented game worked in practice as a sociable CSCL environment. However, this approach also includes weaknesses. The limitations with regard to the usability of the findings of the empirical studies of this thesis are as follows. First, because only one game environment was used in the empirical sub-studies and only a rather small number of participants took part in the study, the results are not widely generalizable. Second, most of the statistics that were employed were correlational, but, for example, regression analysis could have been performed in order to find out the impact of social presence and sociability on core game experiences. Third, empirical studies could not confirm a linkage between the learners' subjective experiences and the amount and the quality of the social interaction that emerged during the game; therefore, conclusions are based on assumptions. Fourth, the sub-studies did not measure the actual learning outcomes of the game; instead, sub-study IV focused on evaluating the processes of collaborative knowledge construction during the gameplay session. Despite these limitations, the results of the sub-studies were promising and indicated that collaborative serious games have a particular potential to serve as sociable CSCL environments. Therefore, this direction of research can be considered as a step forward in taking advantage of combining the theoretical knowledge on collaborative learning and game design to improve the quality of such games.

The advantage of this study is that it takes into account the learners' experiences of the game as well as it being a space for social interaction and collaborative knowledge construction (a sociable CSCL environment), which has rarely been studied so far. However, learners' experiences (Article II and III) are investigated by using a self-report tool for measuring the learners' subjective experiences. Thus, evaluating the learners' experiences is based only on their own estimates of their experiences after the game. This aspect alone is not enough to give a comprehensive picture of the learners' experiences. The use of questionnaires in combination with other methods, such as interviews or systematic observation, would give a better, wider perspective of the learners' experiences of serious games. Another limitation related to the used questionnaires concerns the reliability of the GEQ. Even though the questionnaires used in this study seem to be a largely reasonable and reliable tool for measuring the learners' experiences, the reliability of two dimensions of the core game experience (challenge and negative feelings) was found to be weak. This may be because the questionnaire was not entirely suitable for use in the context of serious games. Another possible explanation is errors in language translation. However, based on this study, the low reliability of these two dimensions cannot be explained. In the analysis on the groups' discussions, a mixed approach employing qualitative and quantitative content analysis was applied in sub-study III (Article IV). The method of analysis that was employed is based on our earlier work within a long-term project that has been ongoing since 2004 (Hämäläinen et al., 2008; Hämäläinen, 2011; Hämäläinen & Oksanen, 2013). The method has been developed to gain insight into collaborative knowledge construction through analyzing the groups' discussions during the collaborative problem-solving phase. Previous studies have shown this method of analysis to be a valid way to assess the quality of collaborative knowledge construction.

With regard to the challenges and limitations of DBR (see Section 4.1; Wang & Hannafin, 2005), the advantages of this study are as follows. The game developed as a part of this study was designed in close cooperation with professionals from different fields including, for example, teachers, researchers, and game designers (Article I). Through this approach, teachers were involved in the design process, which may contribute to better applicability and feasibility of the game in authentic situations. Further, the author of this thesis participated closely and had a significant role in the design of the game used (Article I) in the empirical sub-studies (Articles II–IV). Due to this participation, the author of the thesis was fully aware of the decisions that were made in the game design. This further enabled the development of a shared vocabulary and understanding among the researchers and designers, and, additionally, this facilitated the integration of the research and design perspectives in the development of the tools to support learning.

To summarize, the main advantage of this study was in the integration of the theoretical knowledge on collaborative learning and game design in the development of a collaborative serious game and the close participation of the author of the thesis in this design process. The limitations of the study concerned the limited number of participants for the empirical sub-studies, investigating the learners' experiences by using self-report tools, and ignoring the measurement of actual learning outcomes. Thus, for future research, there is a need for more systematic empirical studies that focus on the meaning of game design and teachers' real-time orchestration for collaborative knowledge construction (and learning outcomes) on a more detailed level. Besides the integration of the theoretical knowledge on collaborative learning and game design in the development of collaborative serious games still being in its infancy, more studies including the design of such games are needed to reveal the full potential of serious games for collaborative learning.

6.4.2 Ethical issues of the study

This study was planned, conducted, and reported according to the research ethics guidelines of the Finnish Advisory Board on Research Integrity (2012) and the Academy of Finland (2003), and, therefore, it meets the characteristics of good scientific practice. This study followed the modes of action endorsed by the research community. Thus, integrity, meticulousness, and accuracy were taken into account in conducting the research, recording, and presenting the results of the research, and in evaluating the research and its results.

Participating in the study was voluntary and the experiment was carried out in school hours. Before the experiment, participants were informed about what would happen during the experiment. Participants were also informed about the aim of the study, the data-collection methods, and methods of reporting. All of the participants were asked to fill in and sign a written permission form for their participation. If a participant was under 18 years old, permission needed to be given by a parent/guardian. Participants were not given extra credit or a participant fee for their participation. The participants' privacy was also taken into account and the results of the study are reported in a way that individuals cannot be identified (pseudonyms were used in reporting when necessary). The collected data will be archived at the Finnish Institute for Educational Research, University of Jyväskylä.

Other researchers' work and achievements have been referred to in an appropriate way according to good scientific practice. The sources of funding and other associations relevant for the study were notified to the participants of the study, and were reported in the published articles included in this thesis, and in the summary of the thesis.

6.5 Conclusions

To conclude, the growing interest in serious games indicates that games will be increasingly used in future education. However, to improve the quality, relevancy, and usability of serious games, a shared vocabulary and understanding between professionals from the fields of education and game design need to be developed. Only in this way can new ways of utilizing game design to support and promote learning be found to exploit the full potential of serious games. This study strengthens the view that by combining the theoretical knowledge on collaborative learning and game design, it is possible to find new ways to support collaborative learning in serious games (Echeverría et al., 2011). This study highlights how game mechanics appear to be a potential way to give rise to social interaction and to structure collaboration among the learners in the game context. Through appropriate game mechanics, it is possible to structure the learners' knowledge construction, and support their socio-emotional processes, which facilitates group members to develop as a well-preforming team. Thus, this study supports the argument that the development of CSCL environments should take into account both educational, task-specific aspects (knowledge construction), and social, psychological aspects (socio-emotional processes) in order to provide the best possible opportunities for social interaction and productive knowledge construction to occur (Kreijns et al., 2013). In addition to the game's internal guidance, the teachers' real-time orchestration during the collaboration situation plays a crucial role in achieving productive knowledge construction. However, even if playing the game together formed a positive and supportive atmosphere for the collaboration, the game itself is not necessarily motivating or engaging, as has previously been observed (Whitton, 2010). Hence, both educational and gameplay viewpoints should be taken into account in the design of serious games. Especially in collaborative games, a sense of social presence and collaboration with teammates seem to be an essential part of engaging and pleasant game experiences. For the future research and development of collaborative serious games, there is a need to develop a shared vocabulary and understanding among professionals in the fields of education and game design further. Besides, a major future challenge is to find, implement, and describe the game-design methods employed with sufficient accuracy to improve their generalization. In addition, it is essential to pay attention to how decisions in the game design guide the players' actions in actual gameplay. To this end, there is a need to develop methods to assess the learners' experiences in real time and to better use game statistics to support other methods.

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Yhteenveto (Summary)

Tämän väitöstutkimuksen kolme päätavoitetta olivat: 1) Kehittää yhteisöllinen oppimispeli, joka pohjautuu teoreettiseen tietämykseen yhteisöllisestä oppimisesta, ja jonka suunnittelussa hyödynnetään pelisuunnittelun tuomia mahdollisuuksia. 2) Tutkia millaisia kokemuksia yhteisöllisen oppimispelin pelaaminen synnytti pelaajissa. 3) Selvittää opettajan roolia yhteisöllisissä tiedonrakentamisen prosesseissa.

Tutkimuksen yhteenveto koostuu kolmesta osiosta, joihin liittyy neljä väitöskirjan artikkelia. Ensimmäinen osio keskittyy tutkimuksen teoreettisiin lähtökohtiin. Siinä käsitellään oppimispeleissä tapahtuvan yhteisöllisen oppimisen haasteita, sekä sitä kuinka näihin haasteisiin voidaan vastata pelisuunnittelulla ja opettajan toiminnalla. Osiossa tarkastellaan pelisuunnittelua ja erityisesti sitä, kuinka pelimekaniikkoja voidaan hyödyntää yhteisöllisten oppimispelien suunnittelussa. Lisäksi ensimmäisessä osiossa kuvataan pelin suunnittelussa käytetyt pelimekaniikat, sekä se kuinka ne on käytännössä toteutettu. Yhteenvedon toisessa osiossa esitellään tutkimuksen metodologinen lähestymistapa sekä empiirisessä tutkimuksissa käytetty peli. Kolmannessa osiossa kerrotaan kolmen empiirisen osatutkimuksen tulokset sekä pohditaan tuloksia laajemmassa mittakaavassa. Osatutkimuksissa arvioitiin pelin synnyttämiä subjektiivisia kokemuksia ja opettajan roolia yhteisöllisen tiedonrakentamisen ohjaamisessa (engl. orchestration).

Teoreettiset lähtökohdat

Viimeaikaiset tutkimukset ovat osoittaneet, että yhteisölliset oppimispelit tarjoavat hyvät mahdollisuudet hyödyntää teknologiaa yhteisöllisen oppimisen edistämisessä (esim. Whitton, 2010; Hummel ym., 2011; Sung & Hwang, 2013). Parhaimmillaan nämä pelit helpottavat vaikeasti havainnollistettavien asioiden hahmottamista (Hämäläinen, 2008a), edistävät uuden tietämyksen luomista (Burton & Martin, 2010; Hummel ym., 2011), motivoivat ja edistävät ryhmätyöskentelyä (Susaeta ym., 2010), kehittävät päätöksentekoprosesseja (Kennedy-Clark & Thompson, 2011) ja parantavat opiskelumotivaatiota sekä asenteita (Sung & Hwang, 2013). Pelit voivat myös kannustaa oppijoita luovaan yhteisölliseen toimintaan, jossa heidän tulee tehdä päätöksiä olemassa olevan tiedon perusteella, punnita erilaisia ratkaisumalleja, tutkia erilaisia vihjeitä eri olosuhteissa, sekä selvittää monia asioita oikean ratkaisun löytämiseksi (Reiser, 2004; Ruiz-Primo ym., 2011). Yhteisöllisen oppimisen tavoitteena on, että ryhmän jäsenet saavuttavat yhteisen tiedonrakentamisen lopputuloksena jotain, johon kukaan heistä yksin ei yltäisi (Stahl, 2004).

Lupaavista tutkimustuloksista huolimatta peli itsessään ei kuitenkaan ratkaise yhteisölliseen oppimiseen liittyviä pulmia (esim. Hämäläinen, 2011; Hummel ym., 2011; Kreijns ym., 2013). Aiempien tutkimusten perusteella yhteisölliselle oppimiselle asettavat haasteita muun muassa ongelmat sosiaalisessa vuorovaikutuksessa (Kreijns ym., 2007, 2013), oppijoiden sitoutumisen puute (Whitton, 2010) ja opettajien tietämättömyys kuinka ohjata yhteisöllisen tiedonrakentamisen prosesseja (Arvaja ym., 2009). Lisäksi tietokoneavusteisen yhteisöllisen oppimisen (engl. computer-supported collaborative learning = CSCL) ympäristöjä on kritisoitu keskittymisestä lähinnä yhteisöllisen tiedonrakentamisen tukemiseen jättäen usein huomiotta oppijoiden sosio-emotionaaliset tarpeet, kuten ryhmäytyminen ja luottamuksen rakentaminen (Kreijns ym., 2007, 2013). Oppimispelit tarjoavat ainutlaatuisia mahdollisuuksia vastata näihin haasteisiin pelisuunnittelun sekä opetuksen suunnittelun kautta. Yhteisöllisten oppimispelien suunnittelussa on olennaista yhdistää toisiinsa yhteisöllisen oppimisen teoreettinen perusta sekä pelisuunnittelun tuomat mahdollisuudet. Tämä mahdollistaa pelisuunnitteluelementtien hyödyntämisen vuorovaikutuksen ja yhteisöllisen tiedonrakentamisen edistämisessä (Echeverría ym., 2011). Lisäksi opettajan ohjauksella on esitetty olevan merkittävä rooli yhteisöllisen tiedonrakentamisen tukemisessa (esim. Dillenbourg ym., 2009; Kollar ym., 2011).

Opetuksen ja pelisuunnittelun näkökulmia on aiemmin pyritty yhdistämään toisiinsa oppimispelien laadun parantamiseksi (esim. Kiili, 2005; Dickey, 2005; Bedwell ym., 2012). Näkökulmien yhdistäminen pelisuunnitteluvaiheessa ei kuitenkaan riitä, sillä oppijat eivät aina välttämättä toimi, kuten suunnittelija on ajatellut heidän toimivan (Dillenbourg & Jermann, 2006). Oppijoiden kokemuksilla ja tuntemuksilla on vahva merkitys sille, kuinka he toimivat ja kuinka paljon he ovat valmiita panostamaan siihen mitä ovat tekemässä (Nacke & Lindley, 2009). Näin ollen on tärkeää arvioida oppijoiden kokemuksia toimimisesta tällaisissa ympäristöissä. Tietokoneavusteisen yhteisöllisen oppimisen näkökulmasta aiempi tutkimus on keskittynyt pääosin asynkronisiin tekstipohjaisiin oppimisympäristöihin. Lisäksi pelaamisen sosiaalisen ulottuvuuden merkitykseen pelikokemukselle on syvennytty lähinnä viihdepelien osalta. Yhteisöllisistä oppimispeleistä tietokoneavusteisen yhteisöllisen oppimisen tilana on toistaiseksi olemassa vain vähän tietoa. Tämän tutkimuksen yleinen tavoite on löytää ja tutkia uusia tapoja tukea yhteisöllistä oppimista oppimispeleissä.

Tutkimuksen toteutus

Tutkimuksessa toteutettiin design-tutkimuksen lähestymistapaa (esim. Wang & Hannafin, 2005; The Design-Based Research Collective, 2003). Tutkimus on osa isompaa tutkimuskokonaisuutta, joka keskittyy selvittämään yhteisöllisten oppimispelien hyödyntämistä ammatillisessa koulutuksessa (esim. Hämäläinen ym., 2008, Hämäläinen, 2008a; Oksanen ym., 2010; Hämäläinen, 2011) Tutkimuskokonaisuus on jatkunut vuodesta 2004 alkaen ja se on toteutettu läheisessä yhteistyössä kotimaisten ja kansainvälisten tutkimusryhmien sekä eri alojen ammattilaisten kanssa. Näin ollen tämä tutkimus on yksi tapaustutkimus (Yin, 2003) osana laajempaa design-tutkimuskokonaisuutta.

Tutkimuksen empiirinen osio koostuu kolmesta osatutkimuksesta (artikkelit II–IV), jotka toteutettiin vuosina 2011–2013. Kaikissa osatutkimuksissa käytettiin yhteisöllistä oppimispeliä ″Game Bridge″, joka on suunniteltu ja toteutettu osana Jyväskylän ammattiopiston koordinoimaa kehittämishanketta (artikkeli I). Game Bridgen tavoitteena on korostaa eri alojen ammattilaisten välisen yhteistyön tärkeyttä ja merkitystä työelämässä, synnyttää pelaajien välistä yhteisöllistä tiedonrakentamista sekä laajentaa pelaajien tietoisuutta inhimillisestä kestävyydestä. Peli suunniteltiin ja toteutettiin yhteistyössä eri alojen ammattilaisten kanssa (esim. tutkijat, opettajat, pelisuunnittelijat ja ohjelmoijat).

Game Bridge koostuu kolmesta tehtävästä, joiden ratkaiseminen yksin ei ole mahdollista vaan vaatii usean pelaajan työpanosta, tiedon jakamista, toiminnan koordinointia ja yhteisen ymmärryksen muodostamista. Pelitehtävät perustuvat aiemmissa tutkimuksissa esiin tulleisiin yhteisöllistä oppimista edistäviin toimintoihin, jotka ovat 1) tiedon koordinointi (Barron, 2000), 2) hajautettu asiantuntemus, tiedollinen riippuvuus sekä yksilöllisten ja yhteisöllisten tehtävien integrointi (Price ym., 2003) ja 3) kognitiivinen konflikti (Chan & Chan, 2001). Pelin suunnittelussa pyrittiin löytämään keinoja hyödyntää pelimekaniikkoja yhteisölliselle oppimiselle suotuisten olosuhteiden luomiseksi, ja pelaajien välisen vuorovaikutuksen sekä yhteisöllisen toiminnan edistämiseksi. Pelin toteutuksessa käytetyt pelimekaniikat ovat tilallinen eristäminen (spatial isolation), jaettu tila (shared space), jaettu objekti (shared object), salattu tieto (encrypted information), täydentävä toiminto (complementary action), epäsuora toiminto (indirect action) sekä joustava strategia (flexible strategy) (artikkeli I).

Käytännössä Game Bridgen pelaajat toimivat talkoolaisina inhimillistä kestävyyttä tukevilla hyväntekeväisyysfestivaaleilla. Eri tehtävissä toimien heidän tulee vastata festivaalien kokonaisjärjestelyistä ja varmistaa näin asiakkaiden tyytyväisyys. Pelin ensimmäisessä tehtävässä (Gate) pelaajat ovat saapuneet festivaalialueen läheisyyteen, ja heidän tehtävänään on avata portti festivaalialueelle. Toisessa tehtävässä (Restaurant) pelaajien tehtävänä on palvella festivaalien asiakkaita ja bändin jäseniä ravintolateltassa ja pitää heidät tyytyväisinä. Kolmannessa tehtävässä (Stage) pelaajien tulee järjestää esiintymislavalla olevat bändin jäsenten varusteet oikeille paikoille. Pelitehtävät etenevät lineaarisesti, joten ne tulee suorittaa tietyssä järjestyksessä. Pelaajilla on kuitenkin vapauksia päättää omista toimintatavoistaan tehtävien ratkaisemiseksi.

Kaikki osatutkimukset toteutettiin autenttisissa luokkahuoneympäristöissä. Kolmannessa osatutkimuksessa luokkahuone oli varustettu tarvittavalla tutkimusvälineistöllä (äänentallennuslaitteisto). Ensimmäiseen ja kolmanteen osatutkimukseen osallistui vain ammatillisen koulutuksen opiskelijoita ja opettajia (artikkelit II ja IV). Kolmanteen osatutkimukseen osallistui myös korkeakouluopiskelijoita (artikkeli III). Kaikki osatutkimukset noudattelivat samaa kaavaa. Tutkimustilanteessa osallistujat pelasivat noin kahdesta kolmeen tuntiin kestävän pelin. Ensimmäisessä (artikkeli II) ja toisessa (artikkeli III) osatutkimuksessa osallistujat täyttivät pelin jälkeen sähköisen kyselylomakkeen. Tutkimustilanteessa pelaajat oli järjestetty niin, että heidän oli mahdollista kommunikoida vain peliin integroidulla puheyhteydellä (VoIP) tai chatilla. Kenelläkään tutkimukseen osallistuneista ei ollut aiempaa kokemusta Game Bridgestä, eikä osallistujille annettu erityisiä ohjeita pelin pelaamiseksi.

Ensimmäiseen osatutkimukseen (artikkeli II) osallistui 69 opiskelijaa ja opettajaa. Osallistujat oli jaettu satunnaisesti neljästä viiteen hengen peliryhmiin. Toiseen osatutkimukseen (artikkeli III) osallistui 86 opiskelijaa ja opettajaa. Heidät oli jaettu satunnaisesti 18 peliryhmään, kuitenkin siten, että opettajat ja opiskelijat oli tietoisesti sijoitettu eri peliryhmiin. Kolmanteen osatutkimukseen (artikkeli IV) osallistuvat opiskelijat ja opettajat (N = 20) oli jaettu neljään ryhmään siten, että opettajat oli tietoisesti sijoitettu eri peliryhmiin erilaisten työskentelyolosuhteiden aikaansaamiseksi. Työskentelyolosuhteet vaihtelivat siten, että kahdessa peliryhmässä opettaja osallistui peliin peliryhmän jäsenenä ohjaten samalla oppijoiden tiedonrakentamista ja kaksi peliryhmää pelasi ilman opettajan ohjausta.

Tutkimusaineisto kerättiin käyttämällä sähköistä kyselylomaketta (artikkelit II ja III) sekä tallentamalla peliryhmissä käydyt keskustelut (artikkeli IV) pelin aikana. Sähköiseen kyselylomakkeeseen sisältyi kaksi alun perin erillistä kyselyä; game experience questionnaire (GEQ) (Poels ym., 2008) ja sociability scale (SS) (Kreijns ym., 2007). GEQ on kehitetty kattamaan laajasti pelikokemuksen eri osa-alueet, ja siihen sisältyy omat osionsa ydinpelikokemukselle (engl. core game experience) ja sosiaalisen läsnäolon tunteelle (engl social presence). Ydinpelikokemukseen kuuluivat seuraavat osa-alueet: flow (flow), immersio (immersion), kompetenssi (competence), haaste (challenge), positiivinen vaikutus (positive affect), negatiivinen vaikutus (negative affect) ja jännitteisyys (tension). Sosiaalisen läsnäolon tunnetta käsittelevä osio puolestaan jakautui empatiaan (empathy), negatiiviseen tunteeseen (negative feelings) ja toiminnalliseen suhteeseen (behavioral involvement). Kyselyn osa-alueiden luotettavuudet (Cronbachin alfa) olivat seuraavat: flow (0.895), immersio (0.865), kompetenssi (0.864), haaste (0.636), positiivinen vaikutus (0.901), negatiivinen vaikutus (0.823), jännitteisyys (0.812), empatia (0.867), negatiivinen tunne (0.546) ja toiminnallinen suhde (0.896). SS on kehitetty mittaamaan tietokoneavusteisten yhteisöllisen oppimisen ympäristöjen synnyttämää sosiaalisuuden tunnetta (engl. perceived sociability). SS:n luotettavuus (Cronbachin alfa) oli 0.926. Varsinaisten kyselyiden lisäksi lomake sisälsi kysymyksiä osallistujien taustaan liittyen, kuten osallistujan status (opiskelija/opettaja), ikä, sukupuoli ja peliaktiivisuus. Kolmannessa osatutkimuksessa käytettiin äänentallennusjärjestelmää kaiken tarvittavan tutkimusaineiston tallentamiseksi. Pelaajien keskustelut tallennettiin käyttämällä ″Audacity″-ohjelmistoa.

Kyselyaineisto analysoitiin tilastollisin menetelmin ja keskusteluaineisto käyttäen laadullista ja määrällistä sisällönanalyysia. Artikkelissa II tarkasteltiin oppijoiden kokemuksia Game Bridgestä tietokoneavusteisen yhteisöllisen oppimisen ympäristönä. Tutkimuksessa selvitettiin millaiseksi oppijat arvioivat pelin sosiaalisuuden ja millaisia sosiaalisen läsnäolontunteita pelin pelaaminen synnytti, sekä kuinka nämä osa-alueet ovat yhteydessä toisiinsa. Näihin kysymyksiin vastaamiseksi aineiston analysoinnissa käytettiin tunnuslukuja (keskiarvo ja keskihajonta) sekä korrelaatioanalyysiä. Artikkeli III keskittyi Game Bridgen synnyttämiin subjektiivisiin pelikokemuksiin sekä pelaamisen sosiaalisen ulottuvuuden merkitykseen ydinpelikokemukselle. Suhteessa tähän tavoitteeseen tutkimusaineiston analyysissä hyödynnettiin tunnuslukuja (keskiarvo ja keskihajonta), T-testiä, varianssianalyysiä (ANOVA) sekä korrelaatioanalyysiä. Viimeinen osatutkimus (artikkeli IV) keskittyi opettajan ohjauksen rooliin yhteisöllisen tiedonrakentamisen prosesseille. Tarkoituksena oli selvittää keskeisimmät erot tiedonrakentamisen prosesseissa pelattaessa peliä opettajan reaaliaikaisen ohjauksen tukemana tai ilman ohjausta. Erojen selvittämiseksi keskusteluaineisto analysoitiin käyttäen määrällistä ja laadullista sisällönanalyysiä. Määrällisen sisällön analyysin tavoitteena oli selvittää poikkeavatko tiedonrakentamisen prosessit toisistaan ja laadullisen sisällönanalyysin tavoitteena puolestaan oli selvittää näiden erojen luonnetta.

Tulokset ja johtopäätökset

Tutkimuksen tulokset osoittivat Game Bridgen toteutuksessa käytettyjen pelimekaniikkojen olevan käyttökelpoisia yhteisöllisten oppimispelien suunnittelussa. Tätä tukevat empiiristen osatutkimusten tulokset, joiden mukaan pelin sosiaalisuus arvioitiin varsin korkeaksi, ja suurelta osin korkeammaksi kuin perinteisemmän asynkronisen virtuaalisen oppimisympäristön (artikkeli II). Lisäksi pelin pelaaminen herätti pelaajissa vahvoja sosiaalisen läsnäolon tunteita (artikkelit II ja III) yhdessä pääosin positiivisten ja vetovoimaisten pelikokemusten kanssa (artikkeli III). Peli myös synnytti pelaajien sosiaalista vuorovaikutusta sekä yhteisöllistä tiedonrakentamista (artikkeli IV).

Tutkimus vahvistaa käsitystä yhteisöllisten oppimispelien potentiaalista tietokoneavusteisen yhteisöllisen oppimisen ympäristönä. Osatutkimusten mukaan peli tuki yhteisöllistä oppimista ohjaamalla ja jäsentämällä oppijoiden tiedonrakentamista (artikkeli IV), sekä tukemalla heidän sosio-emotionaalisia prosessejaan (kuten ryhmäytymistä ja luottamuksen rakentamista) (artikkelit II ja III). Pelin sisäisen tuen lisäksi opettajan ohjauksella on merkittävä rooli yhteisöllisen tiedonrakentamisen tukemisessa (artikkeli IV). Opettajan reaaliaikainen ohjaaminen mahdollisti oppijoiden paremman keskittymisen tehtävien ratkaisemiseen, auttoi kehittämään yhteistä ymmärrystä tehtävien monialaisuudesta, sekä kannusti oppijoita selittämään tilannettaan ja toimintaansa osana yhteistä ongelman ratkaisua. Tutkimus siis osoitti opettajan reaaliaikaisen ohjauksen kehittävän yhteistä tiedonrakentamista ja parantavan yhteisöllisen toiminnan tuottavuutta oppimispelissä. Samalla opettajan toiminta myös vahvistaa pelin sisäistä ohjausta. Tutkimuksen avulla ei voitu selvittää opettajan ohjauksen merkitystä oppijoiden sosio-emotionaalisille prosesseille. Se kuitenkin osoitti, että opettajan osallistuminen peliin vähensi muun kuin ongelmanratkaisemiseen liittyvän keskustelun määrää (artikkeli IV). Tämä saattaa osoittaa, että pelattaessa peliä opettajan reaali-aikaisen ohjauksen tukemana, oppijoiden sosio-emotionaalisille prosesseille (kuten ryhmäytyminen ja luottamuksen rakentaminen) ei jää niin paljon tilaa.

Tutkimus myös osoitti, että peli koettiin turvallisena ja vakaana ympäristönä vuorovaikutukselle ja yhteisölliselle toiminnalle. On kuitenkin huomionarvoista, että vaikka peli itsessään ei välttämättä ole sen viihdyttävämpi kuin perinteiset virtuaaliset oppimisympäristöt (artikkeli II), niin se silti rohkaisi oppijoita vuorovaikutukseen ja yhteisölliseen tiedonrakentamiseen. Tätä selittää se, että turvallisessa ja vakaassa ympäristössä oppijat ovat luottavaisempia ilmaisemaan omia mielipiteitään (myös kriittisiä), sekä perusteluita, joiden on todettu olevan edellytys tuottavalle yhteisölliselle toiminnalle (Rourke, 2000). Pelaajien välille muodostunut positiivinen psykologinen suhde (artikkeli II) osoittaa yhdessä toimimisen olleen mielekäs tapa toimia ja ratkaista ongelmia pelissä. Tämä on tärkeää, koska jos oppijat kokevat olevansa pakotettuja toimimaan yhdessä, niin he voivat pikemminkin vaikeuttaa yhteisöllistä toimintaa kuin edistää sitä (Hämäläinen, 2008b).

Tutkimuksen tulokset korostavat pelin sosiaalisuuden ja sosiaalisen läsnäolon tunteen merkitystä yhteisöllisissä oppimispeleissä kahdesta syystä. Ensiksi, pelin sosiaalisuus näyttäisi vahvistavan oppijoiden sosio-emotionaalisia prosesseja (artikkeli II), joilla on merkittävä rooli sosiaalisen vuorovaikutuksen ja yhteisöllisen toiminnan syntymiselle (Kreijns ym., 2013; Guzzo & Dickson, 1996). Tämä vahvistaa aiempaa käsitystä siitä, että tietokoneavusteisten yhteisöllisen oppimisen ympäristöjen sosiaalisuus ja oppijoiden kokema sosiaalisen läsnäolon tunne ovat keskeisiä tekijöitä vuorovaikutuksen syntymiselle (Kreijns ym., 2013). Toiseksi, pelin sosiaalisuus ja sosiaalisen läsnäolon tunne vaikuttavat olevan merkittävä osa positiivista ja vetovoimaista pelikokemusta (artikkeli III). Tämä haastaa aiemman näkemyksen siitä, että pelien sosiaalinen luonne voi jopa häiritä ydinpelikokemusta, erityisesti flow:n kokemista (Sweetser & Wyeth, 2005). Tutkimuksen perusteella vahva sosiaalisen läsnäolon tunne pelin aikana voi edistää miellyttävien ja vetovoimaisten pelikokemusten syntymistä (artikkeli III), joilla on edelleen esitetty olevan positiivinen vaikutus oppimiseen (Kiili & Lainema, 2008; Whitton, 2010; De Grove ym., 2010).

Yhteenvetona tämän tutkimuksen tulosten perusteella voidaan sanoa, että yhdistämällä yhteisöllisen oppimisen teoreettista tietämystä sekä pelisuunnittelun mahdollisuudet voidaan löytää uusia keinoja tukea yhteisöllistä oppimista oppimispeleissä. Erityisesti pelimekaniikkoja (Aleven ym., 2010; Mariais ym., 2011) hyödyntämällä voidaan luoda tilanteita, jotka edistävät vuorovaikutuksen ja yhteisöllisen tiedonrakentamisen muodostumista. Lisäksi opettajan reaaliaikaisella ohjauksella on merkittävä vaikutus oppijoiden tiedonrakentamisen tukemisessa. Tulevaisuuden oppimispelien tutkimukselle ja suunnittelulle on tärkeää luoda yhteistä sanastoa ja ymmärrystä oppimisen ja pelisuunnittelun ammattilaisten välisen vuorovaikutuksen edistämiseksi. Suuri haaste on löytää, toteuttaa ja kuvata käytettyjä pelisuunnittelumenetelmiä riittävällä tarkkuudella yleistettävyyden parantamiseksi. Tämän lisäksi on olennaista kiinnittää huomiota siihen kuinka pelisuunnittelussa tehdyt ratkaisut vaikuttavat pelaajien toimintaan pelin aikana. Tätä varten on tarpeen kehittää uusia tutkimusmenetelmiä pelaajien kokemuksien arvioimiseksi reaaliaikaisesti sekä keinoja hyödyntää pelianalytiikkoja aiempaa tehokkaammin pelisuunnittelun apuna.

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COLLABORATIVE SERIOUS GAMES can be considered as one promising way to use technology to support collaborative learning. However, they are not a self-evident solution leading to successful productive social interaction, collaborative knowledge construction, or learning. Thus, to take advantage of the full potential of collaborative serious games, there is a need for the better use of the theoretical knowledge about collaborative learning and game design as a foundation for game development.

This study provides insights into designing serious games and supporting collaborative learning. Findings of the study indicate that by combining the theoretical knowledge on collaborative learning and game design, it is possible to find new ways to support collaborative knowledge construction in serious games. Especially game mechanics appear to be a potential way in which to generate and support social interaction and collaboration among the learners in the game context. In addition to the game's internal guidance, the teachers' real-time orchestration during the collaboration situation plays a crucial role in achieving productive, collaborative knowledge construction. For the future research and development of collaborative serious games, there is a need to develop a shared vocabulary and understanding among professionals in the fields of education and game design further.

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