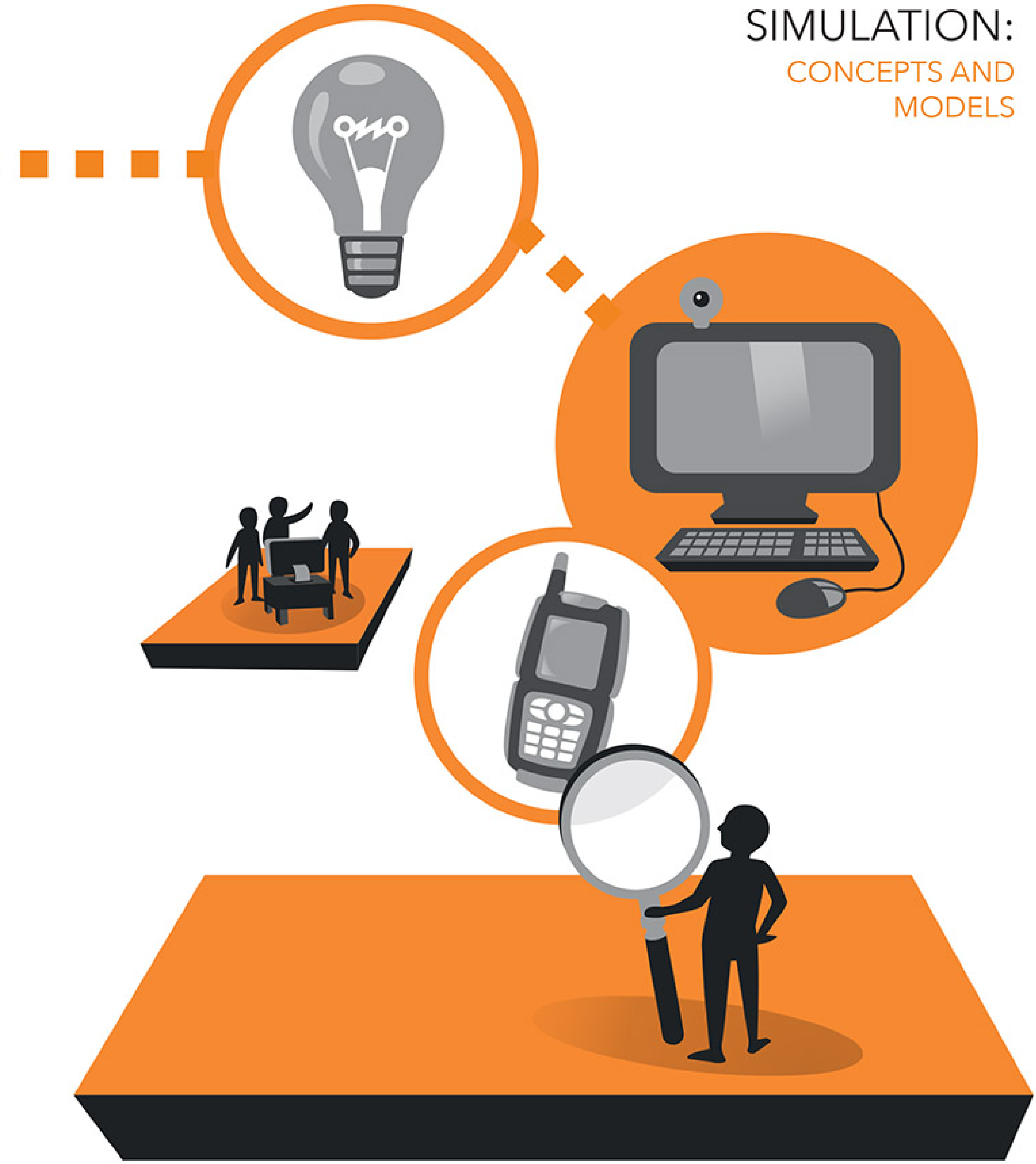
Paula Poikela

RETHINKING

COMPUTER-BASED SIMULATION:

CONCEPTS AND MODELS



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Paula Poikela

Rethinking Computer-Based Simulation: Concepts and Models

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Abstract

Paula Poikela
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The present study investigates the potential of the author's Introduction, Simulation, Scenario, Debriefing (ISSD) model in developing computer-based simulation environments conducive to knowledge creation. The model is elaborated and tested in the context of TETRAsim®, a simulation designed to teach nursing students how to use the TETRA phone, a hand-held device facilitating communication among medical professionals in emergencies. The research draws on qualitative as well as quantitative methodologies to address the principal research question: What kind of theoretical and conceptual frameworks and models form a computer-based simulation environment?

The thesis comprises five sub-studies and an introductory synthesis. Data were collected on 124 participants, most of whom were undergraduate nursing students, some of whom qualified social workers. The first sub-study, a scoping review, provided an overview of the research on the use of simulation in nursing. The second analyzed the simulation environment as well as the extent to which it exhibits the characteristics of meaningful learning from nursing students' perspective. The third compared the use of two teaching methods in simulated practice. The fourth grouped 14 characteristics of meaningful learning identified in the simulation environment into six themes that were considered meaningful from the participants' point of view. The fifth sub-study went on to survey the trainees and ascertain quantitatively the extent to which the six themes manifested themselves in the learning environment.

The principal results of this thesis are the insights into how the ISSD model accords with the trialogical approach to learning and how simulation environments such as that studied support knowledge creation from tacit to explicit in terms of the socialization, externalization, combination and internalization (SECI) learning process. I argue that if a computer-based simulation environment has been developed in collaboration with end-users, it will be meaningful and will constitute a knowledge-creation environment that provides collective benefits. The study offers new knowledge to developers, educators and trainers on how computer-based simulation might best be developed if it is to meet the requirements of learning and knowledge distribution. The insights gained in the research are a resource which facilitators may tap when trainees need more support to achieve learning aims and outcomes.

Keywords: computer-based simulation environment, knowledge creation, meaningful learning

Abstrakti

Tietokonepohjaisen simulaatioympäristön uudelleen pohdintaa käsitteiden ja mallien näkökulmasta
Rovaniemi: Lapin Yliopisto 2016, 146 p.
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Tutkimukseni tarkoituksena on tarkastella teoreettisesti tietokonepohjaisen simulaatioympäristön (TPSy) KSSO-mallia (Käyttöönotto, Simulaatioon tutustuminen, Skenaario ja Oppimisen reflektointi (ISSD=Introduction, Simulation briefing, Scenario, Debriefing). Tutkimuksen tavoitteena on tarkastella ympäristöä mielekkäänä tiedon rakentamisen ympäristönä hoitotyön opiskelijoiden näkökulmasta. Tutkimuksessa hyödynnetään sekä määrällistä että laadullisia metodologisia lähestymistapoja, jotka mahdollistavat tutkimuskysymyksiin vastaamisen ja tietokonepohjaisen simulaatioympäristön kehittämisen mielekkääksi uuden tiedon rakentamisen ympäristöksi.

Tutkimuksessa tarkastelin tietokonepohjaista simulaatioympäristöä, TETRAsim® -opetusohjelmaa. Tutkimuksen eri osatutkimuksiin osallistui yhteensä 124 hoitotyön opiskelijaa ja sosiaalityöntekijöiden ammattilaisia. Ensimmäinen osatutkimus antoi yleiskuvan siitä, mitä hoitotyön simulaatiotutkimuksen alalla on meneillään. Toinen osa-tutkimus oli kaksiosainen. Ensin analysoitiin tietokonepohjaista simulaatioympäristöä ja sitten tutkittiin hoitotyön opiskelijoiden näkökulmasta, miten ympäristössä toteutui mielekkään oppimisen piirteet. Kolmannessa osatutkimuksessa verrattiin kahden opetusmenetelmän vaikutusta simuloidussa harjoituksessa. Neljännessä osatutkimuksessa sijoitettiin 14 mielekkään oppimisen piirrettä kuuteen mielekkään oppimiseen teemaan opiskelijoiden näkökulmasta. Viides osatutkimus toi esille kuuden mielekkään teeman näkyvyyden oppimisprosessissa.

Tutkimuksen keskeisenä tuloksena saatiin selville, miten KSSO-mallia voidaan soveltaa trialogiseen lähestymistapaan, sekä miten tietokonepohjainen simulaatioympäristö tukee tiedon luomista ja näkymättömän tiedon saamista näkyväksi neljässä erilaisessa oppimisen tilassa. Nämä tilat ovat sosialisaatio, ulkoistamis-, yhdistämis- ja sisäistämisprosessit. Tietokonepohjainen simulaatioympäristö on kehitetty yhteistyössä loppukäyttäjien kanssa, ja siitä johtuen siitä tulee uuden tiedon rakentamista tukeva oppimisympäristö.

Tämän tutkimuksen tulokset tuottavat uutta tietoa kehittäjille, kouluttajille sekä loppukäyttäjille siitä, miten tietokonepohjaisia simulaatioympäristöjä pitäisi kehittää, jotta ne täyttäisivät tiedon luomisen ja oppimisen mielekkyyden kriteerit, ja miten paljon ja missä vaiheessa opiskelijat tarvitsevat ohjaajan apua saavuttaakseen oppimisen tavoitteet käytettäessä tietokonepohjaista simulaatioympäristöä.

Avainsanat: tietokonepohjainen simulaatioympäristö, tiedon luominen, mielekäs oppiminen

Acknowledgements

I would like to dedicate this doctoral thesis to my mother. She waited eagerly for the public defence but, sadly, passed away before she could see it. She died a few months ago at the age of 89. I believe that she is following the long-awaited event on the edge of a cloud.

I started thinking about new ways of teaching and learning in nursing education in the beginning of the 2000s. Even then, I thought that we were seeing a new generation coming to us to be taught and that the old ways of teaching would not be enough for them. At that time, I dreamt that nursing students would wear 3D glasses and power gloves and jump right into working life –to virtual reality. Not many believed me! The time was not ripe for such thoughts. But some of my colleagues noticed that my idea was something new and joined me in the crazy idea of developing simulation education. I owe my deepest gratitude to all of them, and regret I cannot thank them all in this short space. But to those of who were in that pioneering band, I would like to say, "Thank you ever so much!"

First, I own my deepest gratitude to Professor Heli Ruokamo, Director of the Centre for Media Pedagogy at the University of Lapland. She found out about me and my teaching at the practically oriented University of Applied Sciences, and open-mindedly guided me towards an academic career. She also gave me the opportunity to work as a researcher in the MediPro project, which gave me a chance to work for a year and study with Dr David Gaba at the Centre for Immersive and Simulation-based Learning at the Stanford School of Medicine in California. Dr Gaba is a pioneer in developing simulation-based learning in the field of healthcare. Having that year was like winning the lottery. Thank you, Heli, for that jackpot.

Heli also introduced me to academic writing and was always willing help me in my research. We worked very intensively together at Stanford, and it was then the sobriquet "my professor" was born. Heli – "my professor" – thank you for all the fruitful cooperation.

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Working in the MediPro project opened doors to a research career and gave me an opportunity to focus on research. I am very thankful to Elina Avela, CEO of Beaconsim Oy, a real developer, who gave me the TETRAsim program so I could study it more closely. I feel that the research results this has enabled will contribute greatly to future development of computer-based simulation environments and thus to teaching that is more relevant to learners.

The reviewers of this thesis were Associate Professor Elisabeth Berragan from the University of the West of England and Docent Sami Paavola from the Faculty of Educational Sciences at the University of Helsinki. I was fortunate to have experts in two different fields: Professor Berragan's expertise is in simulation and nursing education, and Dr Paavola's in educational theory. Their professional comments greatly improved the manuscript, and I deeply appreciate their feedback. Thank you.

There are two other persons I would like to mention in particular. The first, Kerttu Oikarainen, used be my "boss". I am at a loss for the words needed to thank her. She understood and encouraged me in my innovative and sometimes crazy development work. I wish that everyone could have a director like Kerttu. I miss you, Kerttu. The other is Heikki Erola. Heikki, you also believed in me and hopped onto the development bandwagon. I know that I gave you many grey hairs, but together we created something that is still alive and making progress.

I am very thankful to Richard Foley of the University of Lapland, who proofread my manuscript. Without his work, my manuscript would not be as readable as it is now. I would also like to express my thanks to Lasse Virtanen, who designed the figures and tables, and to Miia Anttila, who worked on the cover design.

I must also thank Tuulikki Keskitalo and Hanna Vuojärvi, two young doctors and researchers from the Centre for Media Pedagogy. Without you, I perhaps would have burned out and never made it this far. You supported me by saying that all doctoral students have had similar feelings – that they are failures.

Many other dear colleagues and friends have helped me get where I am now. Outi Tieranta, you, clever young teacher, I know that we respect each other and we both have our own areas of expertise. That is what makes working together on simulation in nursing education so marvelous. Paula Yliniemi, your capacity for innovation sometimes leaves me breathless. I need you! Hanne Selberg, from Denmark, how fortunate I was that you appeared in my life in Shanghai. We are friends and colleagues in simulation. Maria Kiistala, Hellevi Leppiaho and Eiri Sohlman – you are good friends and colleagues to boot. Thank you for supporting me in what has been a long effort and for giving me time to cry with you and with a glass of wine. Riitta Törmänen, my oldest friend, we have known each other since we were twelve. You have always been with me when I had to let off steam. We shared joys and sorrows while we were running and walking 800 km on the Santiago de Compostela route. You keep me in touch with reality.

Kristiina Poikajärvi – happily, our friendship also started in a nursing course. Through you, we – my husband Esko and I – got to know two other couples, Mailis and Esko Tulikoura and Ritva and Kari Väistö, and your husband, Pekka Hyvönen. During this research journey you all kept my eyes open to the world. We became globetrotters together.

I would like to thank all my relatives, my lovely aunt Maikki and uncles Kauko, Simo and Seppo. They have followed my journey to the goal. My brother Jukka and his energetic wife Leena have supported me at every turn. Whatever happened I could trust you. My younger sister, Teija, has followed me on the same career path. I see in her myself earlier; she is so enthusiastic and innovative that I feel dizzy. Thank you also for all the encouragement and admiration you have given me. It has made this all worthwhile.

My lovely family – you are mentioned last here, but are uppermost in my mind. Pekka, you are still my little boy, who left a note on the table saying, "I went to sleep between you and Dad!" Sini, my daughter, you are a great mother, and you and your husband, Arttu, have given us such lovely grandchildren. We are happy about Emma, Elli and Paavo. I see a new generation growing in them – a technology-oriented one.

Esko, my dear husband! I thank you, Esko, for your patience all these years. All this is your achievement – the credit belongs to you. Without you I would not be here. Fortunately you came into my life, and I have lovingly watched you stand by me – uphill and down!

Rovaniemi, January 2017

Paula Poikela

List of articles

Sub-study I

Poikela, P. & Teräs, M. (2015). A scoping review: Conceptualizations and pedagogical models of learning in nursing simulation. *Educational Researchers and Reviews 10(8), 1023–1033.*

Sub-study II

Poikela, P., Ruokamo, H., & Keskitalo, T. (2013). A computer-based simulation to enhance official communication in the health care process— How does it promote the facilitating and learning processes? In T. Bastiaens & G. Marks (Eds.), *Proceedings of E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2013 (pp.* 2051–2060). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

Sub-study III

Poikela, P., Ruokamo, H., & Keskitalo, T. (2014). Does teaching method affect learning and how meaningful is learning from students' perspectives? In J. Viteli & M. Leikomaa (Eds.), *Proceedings of EdMedia: World Conference on Educational Media and Technology 2014 (pp. 1760–1768). Association for the Advancement of Computing in Education (AACE).*

Sub-study IV

Poikela, P., Ruokamo, H., & Teräs, M. (2014). Comparison of meaningful learning characteristics in simulated nursing practice after traditional versus computer-based simulation method: A qualitative videography study. *Nurse Education Today, 35(2), 373–382.*

Sub-study V

Poikela, P. & Vuojärvi, H. (2016). Learning ICT-mediated Communication through Computer-based Simulation. In M. Cruz-Cunha, U. Miranda, R. Martinho, & R. Rijo (Eds.) *Encyclopedia of E-health and Telemedicine. (pp.* 674-687). Hershey, PA: Medical Information Science Reference.

List of figures, pictures and tables

List of abbreviations

CBSe	=	Computer-Based Simulation environment
FTL	=	Facilitating, Training and Learning model
ISSD	=	Introduction, Simulation, Scenario, Debriefing model
KC-CBSe	=	Knowledge Creation-Computer-Based Simulation environment
KPE	=	Knowledge, Practice, Environment
SECI	=	Socialization, Externalization, Combination and Internalization
SELE	=	Simulation-Eased Learning Environment
TELEs	=	Technology-enhanced learning environments

Table of Contents

1 Introduction

1.1 Simulation in Nursing Education

Nursing education has undergone significant changes in the last two decades for many reasons. Nurses today have an entirely different workplace on all levels, particularly as regards the use of social media and information technology, which they encounter every day in their working and private lives and in education (Bauman & Wolfenstein, 2013). Nursing students are not empty vessels: they do not come to the classroom to be filled with knowledge but to create it. From the perspective of the next generation, educators who use PowerPoint presentations are out of touch (McNeely, 2005; Sawyer, 2009). Changes in society necessitate changes in educational methods to respond to the needs of nursing students and enhance formation of knowledge at the individual and team levels (Devane & Bauman, 2013).

Simulation is not a new teaching method; it has been used in aviation, space, and military education for many decades to deliver know-how, allowing employees to learn new skills while honing old ones in order to facilitate seamless co-operation. Teaching in healthcare education has also tapped the potential of simulation to create some of the recent advances, such as virtual- and computer-based simulation and 3D learning platforms (Helle & Säljö, 2012; Keskitalo, 2015). Previous researchers have focused on the usefulness of computer-based simulation programs for teaching practical skills (Salakari, 2007; Silvennoinen, 2014). The author's research on computer-based simulation programs has examined training in the use of the TETRA phone[1], a device specially designed for the communication needs of rescue agencies and police departments in disasters, emergencies and minor accidents (Carver & Turoff, 2007; Meissner, Lukenbach, Risse, Kirste, & Kirche, 2002; Poikela, Ruokamo, & Keskitalo, 2013; 2014). Current plans call for extending the deployment of the TETRA for everyday use in hospitals and social services. The TETRA phone is very effective, as

1 TETRA (Terrestrial Trunked Radio) is a set of standards developed by the European Telecommunications Standardisation Institute that describes a common mobile radio communications infrastructure throughout Europe. This infrastructure is targeted primarily at the mobile radio

it utilizes different networks[2] maintained by Security Networks Ltd., than private mobile services do. One reason why the TETRA phone, as well as other communication systems, has been developed alongside the normal mobile networks (Poikela et al., 2013; 2014) is that communication among colleagues is challenging during busy working days (Pronovost et al., 2003).

Simulation as a tool in teaching and learning is now part of all healthcare education, in both basic nursing and other medical education, and to a growing extent in social education as well; it also continues to ensure knowledge in the workplace (Gaba, 2004; Tynjälä, 2008). Simulation has also been a springboard for transforming the learning process. Teachers are no longer sources of knowledge; knowledge and know-how are in students' minds and hands and created in their collaborative reflection. Students have to find ways of constructing knowledge, for teachers are no longer omnipotent disseminators of it. Learning consists of four basic educational elements: the learner, teacher, subject matter and context (Schwab, 1973). In his *Theory of Education,* Novak adds one more element, evaluation, and goes on to describe the teacher as follows: "teachers have to negotiate the contextual meaning with students and support them so that they significantly improve students' learning" (Novak, 2011). Today, a teacher's role is to support students in developing their own learning processes. This is the reason why educators are searching for new, economically and pedagogically appropriate ways to offer learning opportunities to nursing and medical students as well as to qualified healthcare and social workers (Claeys et al., 2015; Keskitalo, 2011). Simulation in various forms is one opportunity to respond to this challenge.

In this study, I focus mainly on undergraduate nursing students' perceptions of and perspectives on a computer-based simulation environment. This was the population from whom most of the data for the study were collected. A small proportion of those studied were qualified social workers, but the results in their case did not differ from those for the nursing students. Nursing education has always included some sort of simulation, an example being laboratory teaching (Bradley, 2006; Nickerson & Pollard, 2010; Rosen, 2008). The practice dates back a hundred years, when a nursing laboratory called the "Demonstration Room" was common; currently, we call our physical training space "the nursing simulation environment" (Bloomfield, 1916).

Simulation is one solution for addressing the demands for changes in teaching and learning in healthcare education. Different levels of simulation can be used depending on the goal of the learning. One categorization of simulations is that put forward by

2 The task of the State Security Networks Group is to secure the critical leadership of society and information society services in all circumstances. Together with its subsidiaries, the State Security Networks is an expert organization that enables customers to exchange information in a high-quality, reliable and secure manner. The parent company, State Security Networks Ltd, is a non-profit limited company wholly owned by the State. (http://www.erillisverkot.fi/en/erillisverkot/company/)

Alinier (2007) comprising seven types ranging from written simulation on paper (level 0) to high-fidelity simulation in an interactive patient simulator (level 6). Between the lowest and highest levels are written simulations, three-dimensional models, screen-based simulators, computer-based, standardized patients, intermediate fidelity patient simulators, and interactive patient simulators. This classification is the basis for many other classifications of healthcare simulations (Bartlett, 2015). In the present study, I focus on a computer-based simulation environment.

The main aim of the present research is to gain a deeper understanding of the challenges posed and opportunities offered by a computer-based simulation environment where the educational purpose is to enhance knowledge creation and collaborative learning. The broader aim of the thesis is to produce new theoretical knowledge on the challenges and opportunities associated with computer-based simulation environments with a view to furthering their use in practice.

In pursuing the above aims, I have drawn extensively on different theories and approaches, with these including the trialogical approach to learning, meaningful learning, as well as a model describing knowledge creation and the transfer of tacit to explicit knowledge. I have tapped the trialogical approach to learning presented by Paavola, Engeström and Hakkarainen (2012) to define the concepts and models of computer-based simulation in healthcare education. In addition, I draw on the characteristics of meaningful learning (Ausubel, 1968). Complementing these is the widely used knowledge creation model of Nonaka, Toyma, and Konno (2000), referred to hereinafter using the acronym SECI, which incorporates the transfer of tacit to tacit (socialization), tacit to explicit (externalization), tacit to explicit (combination), explicit to explicit (internalization) and explicit to tacit knowledge. The model shows how tacit and explicit knowledge are involved in the knowledge-creation process (Gourlay, 2003). Furthermore, I apply the concept of *ba,* which is an abstract time-space nexus representing trainees' or group's shared context, and consider what kind of role it plays in knowledge creation (Nonaka, 1994; Nonaka & Konno, 1998, 2001; Von Krogh, Ichijo, & Nonaka, 1999). I rely to some extent on the concept of *ba,* because I view learning as taking place in some measure apart from a concrete time and place, in the learners' minds, or *ba.*

My focus during this research is to understand what kinds of functions computer-based simulations should include to meet students' and teachers' needs in learning and in teaching and in healthcare and social environments. To this end, I have synthesized various theories and perspectives. The present study relates to one form of simulation, computer-based, as experienced by nursing students and social workers. Learning occurs in a simulation by presenting information and transforming it from tacit to explicit knowledge to be shared with colleagues and entire healthcare organizations.

1.2 The Computer-based Simulation Environment

Computer-based simulation can be used to supplement other learning methods or to substitute for them, creating an independent learning environment (Desrochers, House, & Seth, 2001; Son & Goldstone, 2011). I examine how computer-based simulation should be developed such that the learning becomes meaningful for students and the shared environment enables knowledge creation. Current research shows that the process of developing computer-based simulation has to be inclusive; that is, those participating in the work should represent different fields. Technical and substance experts provide the basic foundation. Researchers and end-users, working together, undertake to make the simulation environment a meaningful learning environment for users. An appropriate computer-based simulation environment is one which promotes the sharing and cultivation of tacit knowledge and makes this knowledge explicit (Perron, et al., 2009; Rogers, 2011; Weatherspoon & Wyatt, 2012; Yew & Karney, 2010; Zary, Johnson, Boberg, & Fors, 2006).

1.3 Outline and Aims of the Research

The overall aim of the present study is to produce new theoretical knowledge on how computer-based simulation environments can best be developed and on the challenges they pose and opportunities they provide in trying to support the learning process and practical use. This study comprises five sub-studies, which investigate in depth what kinds of theoretical and conceptual frameworks and models best inform learning in computer-based simulations.

The more specific aims of the study are to address the following questions informing the sub-studies:

1) What is the state of research internationally with regard to use of simulations in healthcare, in particular pedagogical models, conceptualizations using simulation, and the use of concepts and theories? (Sub-study I)
2) How meaningful is a computer-based simulation program for learning from nursing students' point of view, and how does such a program relate to healthcare simulations based on other models? (Sub-study II)
3) How does simulation practice appear when carried out using two different teaching methods? (Sub-study III)
4) How did the themes meaningful of learning manifest themselves from the nursing participants' perspective? (Sub-study IV, V)

Previous research has been reviewed (Satava, 2011) to explore what kinds of cooperation and multidisciplinary teams′ aid in developing a computer-based simulation that will create an appropriate learning environment. I studied an existing computer-based simulation environment and determined the characteristics of the program that would be relevant to undergraduate nursing students, from their point of view. As educators, teachers of nursing should use more technology in teaching; they have to offer the current "Net Generation" the best available learning methods and environment (Oblinger and Oblinger, 2005). Dunn, Wilson, and Freeman (2011) state that using computer-based tools and technology enhance the following: students' communication skills, knowledge acquisition, data-sharing skills, critical thinking, problem-solving skills, independence, self-direction, goal orientation, team and group work, new social skills, creativity skills and knowledge delivery. These general skills are comparable to the characteristics of meaningful learning (Ausubel, 1968).

1.4 The Research Process and the Researcher's Position

I began to write the current research in the fall of 2012, and data were collected during 2013 and 2014. Before that intensive period, I dedicated a considerable amount of time and effort to developing simulation in nursing education. Specifically, I have been working on the environment and pedagogy for simulations since 2005 as a project manager at Rovaniemi University of Applied Sciences. In national and international networks, we (nursing teachers at Rovaniemi University of Applied Sciences) have explored simulation environments and collaborated with researchers from the Centre for Media Pedagogy in the Faculty of Education at the University of Lapland to develop simulations and the related pedagogy, integrating these into the nursing curriculum (Poikela, P. & Poikela, E., 2012).

Four of the sub-studies comprising this thesis originated from the research project "Simulation-based pedagogy in education and services for first aid (MediPro)[3]. Figure 1 illustrates the order of the sub-studies, indicating the title of the article associated with each. The data collection lasted 1.5 years and focused on experiences using a computer-based simulation environment, the particular case being the TETRAsim® environment. The results can be applied to any process geared to developing a computer-based

3 The MediPro project (Simulation-based pedagogy in education and services for first aid, 2012-2014) was established to continue the development of simulation pedagogy as we gathered information for the development of the official TETRA phones and the TETRAsim program (www.ulapland.fi/medipro). The MediPro project was funded by the Finnish Funding Agency for Innovations (TEKES), Learning Solution Program, the hospital district of Lapland, and the city of Rovaniemi. The Medipro project was part of the Cicero Learning Network.

environment. The first sub-study, which lasted throughout the entire process writing of the articles, was a scoping review of concepts, models and theories relating to simulation.

Study I	A scoping review: Conceptualizations and pedagogical models of learning in nursing.
Study II	A computer-based simulation to enhance official communication in healthcare processes. How does it promote the facilitating and learning processes?
Study III	Does teaching method affect learning and how meaningful is the learning from the student's perspective?
Study IV	Comparison of the meaningful learning characteristics in simulated nursing practice in traditional versus computer-based simulated methods: A qualitative videography.
Study V	Learning ICT-mediated communication through computer-based simulation.

Figure 1. Sub-studies comprising the thesis

Following is a description of the author's contribution to each sub-study. In the first sub-study, I wrote up and finalized the article. Both authors conducted the review analysis, checked all article reviews together and, in the last phase, shared the reading of the article and cross-checked the analysis. In the second sub-study, the first author was responsible for the theoretical background and, with the second author, co-analysed the computer-based simulation program. The second author also monitored the analysis of the interviews of the nursing students. The third author adapted the Facilitation, Training and Learning (FTL) model for use in the teaching process (Keskitalo, 2015). In the third sub-study, the author was responsible for a major portion of the work. The second author contributed to the analysis section, and the third author was one of the researchers on the experimental research team. In the fourth sub-study, the author was responsible for the entire article, with the second and third authors revising the results of the analysis and the description of the theoretical background. In the fifth sub-study, the first and second authors were both responsible for the article, but the first for the writing process and finalization.

The present study gives a preliminary overview of ideas for developing a meaningful computer-based simulation into a collaborative environment in which knowledge is created. It seeks to prompt interest among nursing researchers, educators, clinical experts and students in examining one aspect of simulation pedagogy for nursing and to find a foundation for nursing and healthcare simulations from t h e distinct perspective which that pedagogy provides (Vierula, Stolt, Salminen, Leino-Kilpi, & Tuomi, 2016).

In the section to follow, I describe the theoretical framework of this research. The third section goes to present the research questions, and the fourth takes up methodological solutions and the research design. Section five then summarizes and evaluates the publications making up the thesis and section six details how the knowledge-creation model for the computer-based simulation environment was formed. In the concluding section, I go on to discuss the results of this research and its limitations, describe practical implementations and provide suggestions for future research.

2 Theoretical and conceptual framework and models for computer-based simulation

This section presents the theoretical foundation of the thesis. I examine the computer-based simulation environment from three different angles: the characteristics of meaningful learning, a trialogical approach to learning and the SECI model, including approaches using the concept of *ba*. The three perspectives draw on different theoretical backgrounds and thus complement each other in shedding light on the complex phenomenon represented by a computer-based simulation environment.

The empirical sub-studies make use of the theory of meaningful learning. In the course of the research, the characteristics of meaningful learning put forward by the theory proved insufficient for addressing the needs that emerge in teaching a vocational subject such as nursing through computer-based simulation. Accordingly, I expanded my research theory from individual, meaningful learning to theories describing collaborative processes and the creation of new knowledge.

2.1 Pressures for Changing Education in Healthcare

The classroom is no longer the only space for information sharing; instead, information and knowledge are disseminated widely throughout society. Teachers have been considered "information bearers" (Lerret & Frenn, 2011), but current working conditions, particularly in the healthcare field, have caused a change in this tradition; for example, teachers must be agile, ready to change their work plans and make rapid decisions on any given working day. To achieve nursing competence, keep knowledge up to date and navigate reduced budgets, nursing students need continuing education to find new ways to teach and learn. One significant change in practice has been evidence-based working. To use evidence-based performance, one does not need information, but working knowledge (Burke et al., 2005; Ciliska, 2015; Profetto-McGrath, 2005). Demanding, technology-oriented workplaces in healthcare today, as well as the related pressures, mark a change in every employee's work routines. Healthcare students' learning aims have also changed: students are not working for points; they are trying to obtain competencies for future jobs (Voorhees, 2001). This development has compelled educators to search for new tools for implementing concrete and comprehensive learning in healthcare practice and education (Rall, 2013). Complex working environments require the sharing of knowledge for everyone to use—including making individuals' tacit knowledge explicit—which can enhance patients' safety (Hämäläinen & Oksanen, 2012).

2.2 Towards Meaningful Learning via Computer-Based Simulation

The characteristics of meaningful learning were first presented by Ausubel (1968). These represent sensible or/and understandable ways for students to build cognitive and meaningful orientations related to real working situations. Where learning is meaningful, it gives students more confidence in the learning content and process (Valadares, 2013). Ausubel and Robinson (1969) contrast meaningful learning with "rote learning", which is learning based on information that is not meaningful for those students who want a deeper understanding of the subject matter. Work done based on rote learning is not an instance of evidence-based work (Fineout-Overholt, Melnyk, & Schultz, 2005).

Fourteen characteristics of meaningful learning in computer-based simulation have been identified based on the FTL model: experimental, experiential, emotional, socio-constructive, self-directed, collaborative, competence-based, goal-oriented, individual, reflective, contextual, critical, active, and responsible. These characteristics have been presented in the simulation-based learning environment (SBLe) model by Keskitalo (2015), which is based on socio-cognitive and socio-cultural theory. A meaningful simulation model makes healthcare simulation learning beneficial. (Säljö, 2009; Vygotsky, 1978.) These characteristics offer a meaningful foundation for other theories and learning processes. In the present study, the fourteen characteristics listed above are used as a foundation for describing the computer-based simulation environment from the perspective of undergraduate nursing students and qualified social workers. The process of meaningful learning gives the learner an opportunity to assimilate new knowledge to old, contextualized knowledge. This facilitates conceptualization, which is a cognitive process (Ausubel, Novak, & Hanesian, 1978.) However, as this theory failed to provide answers where the learning involves collaboration or the transfer of tacit to explicit knowledge, the knowledge spiral was expanded to cover these considerations.

2.3 How Knowledge Evolves and is Disseminated

Nonaka, Toyama, and Konno (2000) describe the SECI process, which consists of socialization in everyday experience, that is, tacit to tacit knowledge transfer. Tacit knowledge is bound to routine procedures and values. It is difficult to find words to articulate the knowledge and make it visible. To achieve externalization, whereby tacit knowledge becomes explicit, knowledge can be shared with others. If research has been combined with explicit knowledge, it can aid in processing and disseminating knowledge in the workplace and learning environment. The process culminates in internalization, the stage in which an individual converts explicit knowledge to tacit knowledge and his or her tacit knowledge may be based on new routines (Nonaka et al., 2000). SECI describes the interaction process among trainees. It is based on an intensive learning process and a learning process in every trainee's *ba*, which is detached from space and time. Learning can sometimes occur after the active learning time (Chatti, Klamma, Jarke, & Naeve, 2007).

Students and experts in the healthcare and social fields create new knowledge through a process in which information "chaos" develops into cognition, using knowledge. In knowledge formation, two processes work in tandem as a "knowledge spiral", proceeding from information chaos to orderly knowledge (Nonaka et al., 2000; see Figure 2).

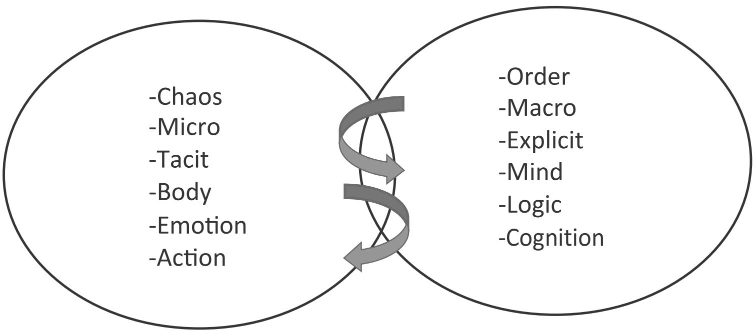


Figure 2. Knowledge spiral (adapted from Nonaka et al., 2000, p. 6)

Simulation as a learning and teaching method is the trigger for the learning process depicted by the spiral. Students need an environment in which they turn information into knowledge and tacit knowledge into explicit knowledge. The environment could be one of abstract space and time; this is the basis of *ba*, a place located in the student's or team's mind, a non-concrete environment. The concept of ba originated in Japan and describes a new relationship with knowledge. According to Nonaka and Konno (1998), information and knowledge differ from one another. If knowledge is separated from *ba* (internal time and place), then that knowledge becomes information or routine only. This can be likened to the point made by Ausubel (1969) that if knowledge is not meaningful, it is rote information.

The transfer of information only is still the teaching method used among nursing teachers. Instead, nursing students should create knowledge using information management. Nonaka et al. (2000) argue that in the business world knowledge continues to be tacitly created after formal education has ended, and thereby becomes visible. The creation of knowledge in healthcare does not mean only obtaining information about healthcare; it is easy to make information "visible" by speaking or writing, but the key question is how knowledge can be made visible. Students can be trained in motor skills repeatedly such that these skills transfer to action (Salakari, 2007) in the work environment, but the skill may be separate from the meaning. This kind of fragmentation in information and skills should be turned into explicit knowledge. If the training skills do not become knowledge in learning, as they do in *ba*, then constructive knowledge is not created, and when that knowledge is transferred to nursing students or staff, it will be only information (Nonaka, Kodoma, Hirose, & Kohlbacher, 2014).

Simulation as a learning and teaching method is one tool for making received information explicit, conscious and shared knowledge. A simulation environment is the key to supporting nursing students' individual information and know-how to enable them to collectively merge these in order to create explicit knowledge. This is accomplished through simulation methods. Kostiainen (2009) has studied knowledge creation among workers in the social services. She identified four features in the development of learning spaces: retiring, antipathetic, personalized, and shared space. She argues that a learning experience should be considered as an entirety, in keeping with the concept of *ba*, and should turn personal information into shared, constructive knowledge.

It has become apparent that further development of the simulation environment requires a wider theoretical perspective than that provided by the characteristics of meaningful learning. Accordingly, I go on to augment the approaches applied thus far with the trialogical model.

2.4 The Trialogical Approach to Learning Enhanced to Understand the Role of Simulations in the Learning Process

Many changes in modern society, including rapid technological development, increased complexity and newly acquired knowledge, must quickly be translated into practice, and require that knowledge creation be considered in a new way. Among the approaches that may enable this is the innovative trialogical learning model, developed by international research[4] team for creating new knowledge among students. Underlying the model is a mediated process using signs and tools (e.g., patients' needs or nursing devices) as tools (Diener & Hobbs, 2012; Vygotsky, 1978), which is related to many other approaches to knowledge, such as problem-based learning, inquiry-based learning and the situated-interaction approach. The trialogical approach to learning incorporates the features of

4 Knowledge Practices laboratory (KB-Lab), http://www.kp-lab.org/project-overview/objectives-of-the-project

Nonaka's SECI model and *ba*. In addition, the approach provides an opportunity to determine what new knowledge working life will require and what knowledge learners must acquire in order to create new knowledge together. The SECI process provides a framework for tacit and explicit knowledge; the trialogical approach goes even further, enabling development that supports the process of knowledge creation. (Chatti et al., 2007; Gourlay, 2003; Nonaka et al., 2000; Paavola et. al, 2011.) The trialogical model represents more concretely the dimensions that are part of the formation of knowledge. Figure 3 depicts the model, showing the interrelationship of individuals, social interaction and collaborative work in a view of learning in which all participants carry previous information and know-how with them throughout the component processes (Paavola et al., 2012). The knowledge-practice environment (KPE) is a technology environment, and it is a virtual working place in *ba* for collaboration after working individually or cooperatively (Moen, Mørch, & Paavola, 2012; Nonaka, 1998).

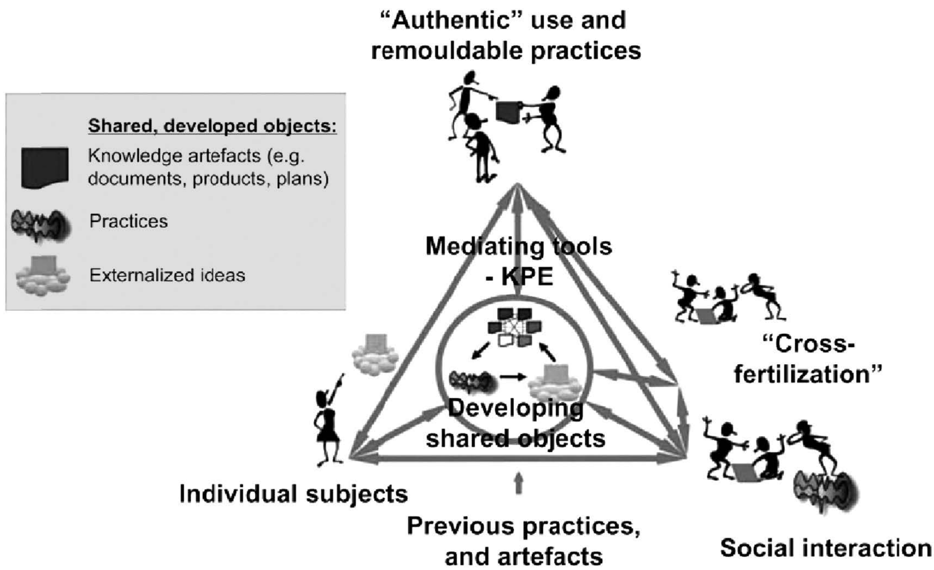


Figure 3. Trialogical approach to learning (adapted from Paavola et al., 2012, p. 235)

A simulation environment exists between theory and concrete practice and mediates information to make knowledge explicit in the simulated practice. Simulation is also a shared space to support collaborative work and to mediate learning in internal time and place, that is, *ba* (Nonaka et al., 2011; Paavola et al., 2012). Tacit knowledge has gained attention in both educational settings and the workplace in healthcare. Tacit knowledge should become visible, as Polanyi (1966) explains: "One person acts and the other comprehends, but this process does not involve words." (p. 60). Tacit knowledge, which is more important in creating a new way to work, includes personal beliefs, value systems, and practical perspectives. Tacit knowledge is always strong individual knowledge (Polanyi, 1966). Trialogical learning supports the externalization of tacit knowledge, and the knowledge-practice laboratories offer tools to implement it (Batatia, Hakkarainen, & Mørch, 2012).

The trialogical approach to learning has been studied and used in, among other locations, the Karolinska Institute's[5] anaesthesia unit in children's resuscitation simulations. Researchers there emphasize the novelty of knowledge and information being added to explicit knowledge; it is no longer "hidden" in the heads of certain experts. During a trialogical simulation process, knowledge creation extends to all of the team members. In this process, simulation acts as a tool, with tacit information being conceptualized through a collaborative platform as explicit knowledge (Karlgren, 2012).

This study draws on the three different theoretical orientations above—Ausubel's characteristics of meaningful learning, Nonaka's SECI model (including *ba*), and Paavola et al.'s trialogical model—to create a new understanding of computer-based simulation environments. All five sub-studies, four of which are based on meaningful learning, combine to conceptualize simulation as the basis of how to construct knowledge from information or routine and to distribute that knowledge to healthcare organizations and others. In the present case, the environment for the simulation is computer-based.

The empirical part of this study is based primarily on the characteristics of meaningful learning, but invoking a more comprehensive theoretical framework yields promising opportunities for learners to create new knowledge. Contemporary society must develop the competences that people need to work productively with explicit knowledge. The trialogical approach to learning makes possible the advanced skills and knowledge that learners will need to thrive in modern society (Paavola, Lipponen, & Hakkarainen, 2004).

2.5 Enabling Effective Teaching and Learning with Case-Based and Problem-Based Learning

To achieve knowledge-based learning, the value of which has been verified by research, as well as education, instead of the dissemination of fragmented information, teaching must be learning-oriented. Healthcare students obtain large amounts of information from, among other sources, teachers, other students and experts from hospitals, and they collect information from different open sources. Information can be fragmented if it has no foundation in real working life (Dahl & Eriksen, 2015). Case-based learning (CBL)

5 http://ki.se/en/startpage

can be described as an adaptation of problem-based learning (Young, 2008; Williams, 2005). Theory is much more easily transferable to practice when CBL is used to translate knowledge into practice and problem-based learning (PBL) is employed to orchestrate the learning (Berkel, 2010; Chan, 2013; Clark, Ahten, & Macy, 2013; Kolodner et al., 2003). CBL and PBL combine two useful teaching and learning methods; indeed, no single educational solution, or cognitive or socio-cognitive approach, can provide all the meaningful teaching and learning tools. Cases from working life are effective and support clinical decision-making; teaching healthcare effectively in the twenty-first century requires the use of cases, as well as the development of teaching methodologies and transformation of learning methods that will respond to the demands of the field (Oermann & Gaberson, 2009; Tompkins, 2001). Healthcare teachers should be able to determine which types of learning methods are suitable for their particular groups of students and expert learners. Teachers should have a "toolkit" of learning methods that match students' needs and instructors should use appropriate methods for guiding students in their learning process. A nursing teacher or facilitator who aids nursing students in learning must be conscious of the group's and individuals' learning styles.

Healthcare research has yielded different models for simulating knowledge and skills. The models are tools for researchers and healthcare teachers that support their work in determining how to design the research process or carry out a learning simulation. These models can elucidate the framework of the entire simulation for healthcare students or experts from working life as well as what happens in the simulation scenarios and how and where the conversion of information to knowledge occurs.

The models provide a strong theoretical foundation for learning nursing through simulations and are an opportunity to see nursing simulation in a different way (Berragan, 2013; Buykx et al., 2011; Griffin-Sobel, 2009; Jeffries, 2005; Keskitalo, Ruokamo, & Väisänen, 2010; Masters, O'Toole, Baker, & Jodon, 2013). The main question is: Where does information transform to knowledge, and where does tacit knowledge become explicit? Can a concrete environment be the place where learning occurs, or is learning mediated by an invisible tool? Many models are based on the simulation process briefly described by Joyce, Calhoun, and Hopkin (2009), with researchers developing the process further based on their own results. I will proceed to compare the models put forward in Dieckmann (2009), Keskitalo et al. (2010) and Poikela et al. (2013) with that presented by Joyce et al. (2009), Figure 4 presents the focal simulation models and a comparison of them.

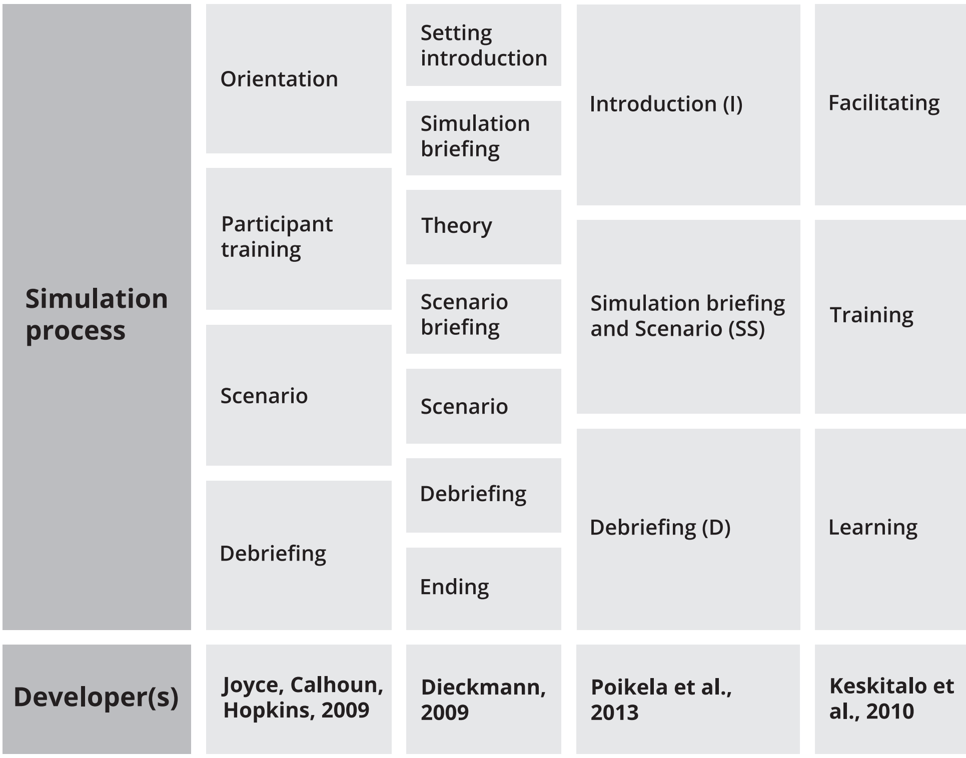


Figure 4. Comparison of simulation processes

Joyce et al. (2009) describe simulation learning as including orientation (briefing) for the learning and participant training, the learning event (scenario), and reflection on the learning (debriefing). Dieckmann (2009) regards simulation as more highly involved. He divides the briefing stage into four different parts: the introduction to the setting, in which an overview of the learning objectives is provided; the simulation briefing, in which individuals become familiar with the learning environment and tools; practical simulated learning, debriefing; and, lastly, the ending. The Facilitating, Training and Learning (FTL) model for simulation-based healthcare education (Keskitalo, 2015) is based on characteristics of meaningful learning as well as on how these characteristics appear from students' and facilitators' perspectives. The FTL model's underpinning is a sociocultural approach to learning and the concept of mediation. The theory claims that learning is a higher psychological action, and teaching contributes to this process (Vygotsky, 1978). Keskitalo et al. (2010) went on to develop the model for high-fidelity simulation settings, which is level seven in Alinier's typology (Alinier, 2007; Rao and Stupans, 2012), that is, an advanced human simulator (simulator imitating the human body as truthfully as possible) (Beyer, 2012). Keskitalo studied how characteristics of meaningful learning emerged in the simulation settings using the FTL model and presented, in her thesis, an advanced pedagogical model for simulation-based healthcare education (simulation-based learning environments, SBLEs). Keskitalo has developed the FTL model based on the stages of simulation e.g. Dieckmann's, which are described above.

The computer serves simulation teaching and learning in many ways. It offers individuals opportunities to learn and practice discrete skills, and an advanced simulation environment also supports team learning. The model derived from the analysis of the first version of TETRAsim is the Introduction, Simulation, Scenario, and Debriefing (ISSD) model; it is shown in Figure 5 below.

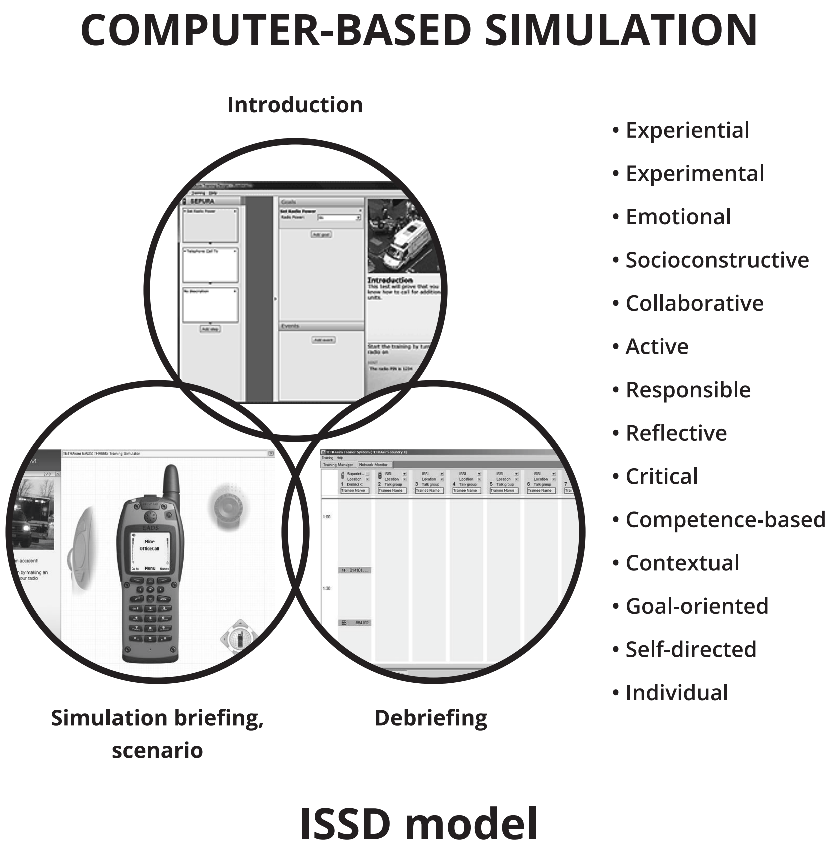


Figure 5. The ISSD model (adapted from Poikela et al., 2013, p. 2056)

The ISSD model has been reflected on and analysed in light of existing models (see Table 2), the FTL model in particular due to its basis in the characteristics of meaningful learning. Computer-based simulation has many roles; one role could be merely to distribute information and act as a single-skill training platform for the mastery of a routine or certain information. Another could be to serve as a platform created to turn information into knowledge and this further from tacit to explicit knowledge. Every designer tries to create a comprehensive platform that it responds somehow to everyone's needs. The roots of the fourteen characteristics of meaningful learning lie in the research of Ausubel and Robinson (1969) and Ausubel and Novak (1978); many researchers after them have continued to refine these characteristics, as appropriate, for their particular purposes (Dreifuerst, 2009; Dreifuerst, 2015; Hakkarainen, 2007; Hakkarainen, 2011; Keskitalo, Ruokamo, & Gaba, 2014). It is essential to study computer-based simulation environments in detail in the light of meaningful learning theory. When implemented and developed further accordingly, they increase opportunities for independent learning and access to teaching (Vuojärvi, 2014). When apply these models, one has to use pedagogical methods such as case- or problem-based learning, with the cases or problems drawn from real life. Authenticity links the learning to practice, makes it contextual and meaningful, and allows it to be further developed and modified.

3 Research questions

The overarching question which this thesis addresses is the following:

1) *What kind of theoretical and conceptual frameworks and models form a computer-based simulation environment?*

The impetus for this question was to understand the current state of and trends in the research being done on simulation in nursing education. After investigating this topic in detail and reviewing the research on what I found to be the salient issues, I undertook the first sub-study, which addressed the following questions:

1. How has simulation-based learning been conceptualized in nursing research?
2. What types of pedagogical models are used in nursing simulations?
3. Which educational concepts and theories are used in nursing simulations?

The second sub-study of the thesis pursued two aims: we were interested in determining first how well the computer-based simulation performs in light of existing healthcare simulation models and second how meaningful the learning involved is as seen from nursing students' points of view. Accordingly, Sub-study II addressed the following research questions:

1. How does a computer-based program promote the facilitating, training, and learning processes?
2. How meaningful is computer-based simulation learning from students' perspective?

In the third sub-study we then took an interest in exploring how two different teaching methods, computer-based simulation and a traditional lecture, affected simulations conducted later. To this end we put forward the following questions:

1. How do different teaching methods affect students' simulation practice when they learn in two different ways how to use the TETRA phone?

2. How meaningful is computer-based simulation learning from students' perspective?

The fourth sub-study pursued a new perspective on the characteristics of meaningful learning through six learning themes that became manifest during scenarios. I proposed the following research question:

1. To what extent do meaningful learning characteristics appear in a simulated nursing practice presented after traditional teaching or computer-based simulation?

Sub-studies II, III, and IV provided the basis for Sub-study V, the aim of which was to provide a deeper understanding of the themes of meaningful learning in the ISSD model. The research question addressed in the sub-study was the following:

1. How do the themes of meaningful learning manifest themselves in the learning processes associated with computer-based simulation from students' perspective?

As noted, each of the five sub-studies contributes to answering the study's main research question. See Table 1, which lists the research questions.

4 Methods and research design

This thesis comprises five sub-studies (see Table 1). Two of the studies have been reported in peer-reviewed international scientific journals, two have been reported in international peer-review conference proceedings, and one is a chapter in a peer-reviewed book. In this chapter, I present a more detailed description of the research design, methods used—both qualitative and quantitative—data collection, analysis and research context. Overviews and evaluations of the methodological solutions adopted in the sub-studies are presented in Chapter 5.

The methodological choices in the sub-studies diversify the treatment of the main research question. Four methodologies have been utilized: (a) scoping review (Arksey & O'Malley, 2005; Armstrong, Hall, Doyle, & Waters, 2011); (b) qualitative content analysis (Merriam, 2009; Morse & Field, 1996); (c) qualitative videography (Knoblauch, Schnettler, & Raab, 2006; Goldman, 2009; and (d) quantitative descriptive analysis (Creswell, 2009; Järvinen, 2004; Chi, 1997). The research design follows the principles of design-based research (DBR), of which the first cycle has been used in the development of the computer-based simulation environment (Barad & Squire, 2004). Also underpinning DBR is a participatory methodology (Winters & Mor, 2008).

Pondering the research questions from many perspectives and answering it required that I view the focal phenomenon from many angles. The methodological choices have been made with due consideration of the aims of the component studies, and have served the overall aim of this study. The overarching ambition was that the methodological choices as a whole would reflect the holistic perspective of the research (Patton, 2002). The methodological journey included many stages, ranging from easy methodological decisions to difficult solutions. Qualitative methods were the most familiar to me, with the exception of videography. I had to familiarize myself with the method; it had to be added to our repertoire, as it offers a richer source of data. We also collected quantitative data and analysing this data was particularly challenging. As a PhD student, I have obtained a wide range of experience with different methodologies.

Table 1. Aims, Research questions, Data, Methods and Publications containing the Sub-studies

Aims	Research Questions	Data	Methods	Publications
Sub-study I To examine the literature regarding the concepts of learning and pedagogical models in nursing simulation.	1) How is learning using simulation conceptualized? 2) What types of pedagogical models are used in nursing simulations? 3) Which educational concepts and theories are used in nursing simulations?	Journal articles: The first phase: 826 articles analysed; second phase, 326; third phase, 66; fourth phase, 32).	Scoping review; a process of mapping the existing literature or evidence base.	**Refereed international scientific journal** Poikela, P. & Teräs, M. (2015). A Scoping Review: Conceptualizations and Pedagogical Models of Learning in Nursing Simulation. *Educational Research and Review*, 10(8), 1023-1033.
Sub-study II To develop a pedagogical model to promote the use of the TETRAsim a computer-based simulation program and study the meaningfulness of computer-based simulation.	1) How does a computer-based program promote the facilitating, training, and learning processes? 2) How meaningful is computer-based simulation learning from the students' perspective?	Study of a computer-based simulation program (n = 1) and pair-interviews (n = 6). Observations by three researchers.	Qualitative content analysis method using *Atlas.ti*	**Refereed international conference proceedings** Poikela, P., Ruokamo, H. & Keskitalo, T. (2013). A computer-based simulation to enhance official communication in the healthcare process—How does it promote the facilitating and learning processes? In T. Bastiaens & G. Marks (Eds.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2013* (pp. 2051–2060). Chesapeake, VA: AACE.
Sub-study III To provides a meaningful space to constitute knowledge by a simulation-based learning method.	1) How do different teaching methods affect students when they learn how to use the TETRA phone? 2) How meaningful is learning from the students' perspective?	Pair interviews (n = 12), field notes (n = 3). Observations by three research.	Qualitative content analysis method	**Refereed international conference proceedings** Poikela, P., Ruokamo, H. & Keskitalo, T. (2014). Does teaching method affect learning and how meaningful is learning from students' perspectives? In *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications* (pp. 1684–1692). Chesapeake, VA: AACE.
Sub-study III To examine the impact of two different teaching methods in a simulated practice.	1) To what extent do the characteristics of meaningful learning appear in a simulated nursing practice presented after a lecture or a computer-based simulation?	Video recordings; (n = 4h, 2min, 1s). Observations by three researchers.	Qualitative videography	**Refereed international scientific journal** Poikela, P., Ruokamo, H., & Teräs, M. (2014). Comparison of meaningful learning characteristics in simulated nursing practice after traditional versus computer-simulation methods: A qualitative videography study. *Nurse Education Today, 35*(2), 373-382.
Sub-study V To determine students' perceptions of the themes of meaningful learning.	1) How do the themes of meaningful learning appear in t h e learning processes in computer-based simulation from the students' perspective?	Questionnaire data (n = 124).	Quantitative analysis, carried out using *SPSS statistical software*	**Refereed international book chapter** Poikela, P. & Vuojärvi, H. (2016). Learning ICT-mediated Communication through Computer-based Simulation. Encyclopedia of E-health and telemedicine. In M. Cruz-Cunha, U. Miranda, R. Martinho, & R. Rijo (eds) *Encyclopedia of E-health and Telemedicine.* (pp. 674–687) Hershey, PA: Medical Information Science reference.

4.1 Research Design Based on Design-Based and Participatory Research

Sub-studies II, III, IV and V applied the principles of design-based research (DBR). Wang and Hannafin (2005) described how DBR has potential in both the research and design of technology-enhanced learning environments (TELEs). In the case at hand, we (the authors of sub-studies I, II, III) have developed and envisage elaborating a computer-based simulation environment by using technology enhancing knowledge on how to use the TETRA phone. Amiel and Reeves (2008) introduced the model of design-based research, which sets out four phases (see Figure 6). In the present research process, we reached the second phase.

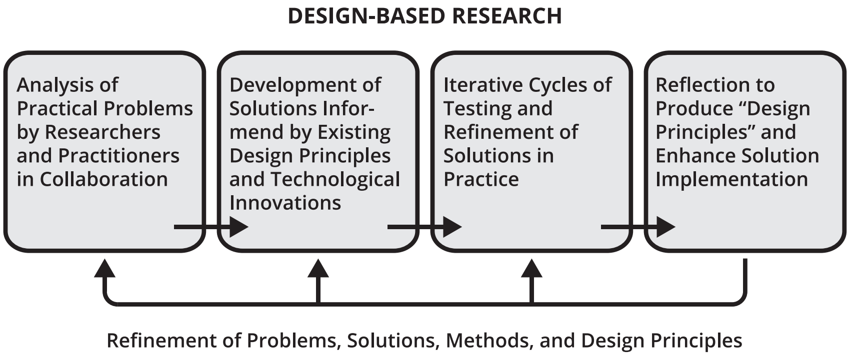


Figure 6. Model of design-based research (adapted from Amiel & Reeves 2008, p. 34)

Sub-study II was conducted using qualitative content analysis. The process started with an analysis of the computer-based simulation program (TETRAsim), with due consideration of the principles of design-based research (Amiel & Reeves, 2008; Barab & Squire, 2004). The analysis was carried out with researchers and to an extent with participants in the research using participatory *methodology* (Collins, 2009; Winters & Mor, 2008). In keeping with the aims of content analysis it brought to light conceptual structures in the computer-based simulation. These components of the simulation learning process were then considered in terms of the current beliefs about simulation of structural elements (e.g. briefing, simulation scenario, debriefing, learning, and introduction) in healthcare (cf. Berragan, 2013; Dieckmann, 2009, Keskitalo, 2015). The ISSD model (see Figure 5) was then designed on the basis of the definitions used in healthcare simulation. The first step was to select components from the computer-based simulation as a whole based on trainees' learning experiences and researchers' teaching experience in healthcare simulation. Hevner (2007) presents three design cycles based on his research: a relevance cycle, rigour cycle, and design cycle. (Adapted from Hevner's design Science Research Cycles, see Figure 5: Computer-based simulation environment design).

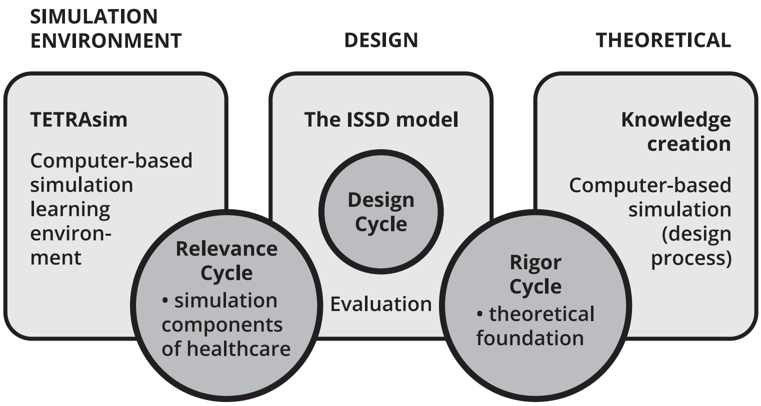


Figure 7. Computer-based simulation design (cf. Hevner et al., 2004)

In the relevance cycle, the TETRAsim program was described in light of other simulation processes in healthcare. The model that emerged was named ISSD, standing for Introduction, Simulation Briefing, Scenario and Debriefing. In comparing the ISSD model to the procedure used in previous simulations, all phases can be identified. In the first design cycle, the model was evaluated by the nursing students. They considered how meaningful the model was in the learning process and how the ISSD model's components accounted for routine working, information transfer and knowledge creation (Paavola et al., 2011). The rigor cycle provided the theoretical foundation for the ISSD model. This thesis provides one cycle and in the future the model must be tested as a knowledge-creation learning environment. In this cyclical process it will perhaps be necessary to go back to the relevance cycle and through the design cycle deepen or even modify the theoretical foundation (Brown, 1992; Design-based Research Collective, 2003).

When developing the ISSD model for the present computer-based simulation environment, a participatory approach was used alongside DBR to make the work meaningful from the trainer's point of view; this choice enhanced the general and deeper understanding of the computer-based simulation environment (Bergold & Thomas, 2012). Participatory methodology manifests itself as the use of qualitative methods; that is, it is a natural companion to research. The very early study of participatory design was used in design research to strengthen the everyday use of computers in the workplace (Kensing & Blomberg, 1998). Clementson, Larsen, and Kyng (2007) used participatory design methods to evolve computer-support applications for diabetes patients. Cooperative work occurred between researchers and practitioners: a solution for practical problems, a change in practice, and the development of a theory (Holter & Schwartz-Barcott, 1993). Kemmis and McTaggart (1982) portray the participatory design research in cycles. One cycle includes (a) a plan; (b) an action; (c) an external observation; and (d) a reflection on function; all these cycles involve end-users working with researchers, technology developers and other needed experts (e.g., physicians and nurses).

After the initial analysis of the TETRAsim program to develop the ISSD model, the first cycle involved testing the model's phases: introduction, simulation briefing, scenario, and debriefing. In the first cycle, characteristics of meaningful learning were found in each of the phases. In the second cycle, using the revised plan, the computer-based simulation program and learning outcomes (how trainers/nursing students use the TETRA phone) in simulated practice were tested for the themes of meaningful learning. Three researchers acted as observers in the research process, and conclusions were drawn after the scenario and simulated practice were arranged.

4.2 Quantitative Methodology

A quantitative methodology was used in Sub-study V. Table 2 presents the study and its contributions to elucidating the themes of meaningful learning.

Table 2. Quantitative study

Quantitative study	Participants	Theoretical contributions
Study V Learning ICT-mediated Communication through Computer-based simulation	Nursing students and social workers (N=124)	The themes of meaningful learning appear in the ISSD model's learning process

In this fifth sub-study, quantitative methods were used to analyse the trainees' performance through a series of 11 simulation training days during which they practiced using the TETRA phone in the computer-based simulation environment. The data were collected using a questionnaire was administered after the training sessions by means of Webropol® software. We opted to use this online method, because it is an effective tool in reaching a large number of participants and facilitates the processing of the data. As the questionnaire was presented immediately after the training sessions, some students felt that they were required to answer it, although doing so was voluntary.

The questionnaire was based on a Likert scale from 1 to 5 (1=disagree, 2=moderately disagree, 3=neither agree nor disagree, 4=moderately agree, 5=agree). It contained four items on demographic variables, 29 questions focused on the ISSD model, and 29 on trainees' emotions during the computer-based learning session (Jaques & Viccari, 2006).

All data were analysed quantitatively using SPSS Version 21.0. Twenty-five preselected items were subjected to factor analysis (principal component analysis, varimax rotation) to identify the items that best corresponded to the themes of meaningful learning. Seven themes with eigenvalues above 1 emerged; the Kaiser-Meyer-Olkin measure of sampling adequacy had a value of .809.

Individual questionnaire items, grouped by factor analysis, were used to create seven scales. The internal consistency of the scales was tested by calculating Cronbach's alpha (Cronbach, 1951). Cronbach's alpha assumes values from 0 (indicating no correlation) to 1 (indicating identical results), and an alpha value of 0.7 or above is considered evidence of acceptable internal consistency (Nunnally, 1978). The alpha value was above 0.7 for four scales and these were included in further analysis.

To identify the items that describe students' emotions when learning with TETRA-sim, 20 pre-selected items were subjected to factor analysis (principal component analysis, varimax rotation). Four themes with eigenvalues over 1 emerged from the data, with a Kaiser-Meyer-Olkin measure of sampling adequacy value of .841. Individual questionnaire items, grouped by factor analysis, were used to create four scales. All but one scale had an alpha value above 0.7.

In further analysis, the frequencies of the created sum variables were calculated. We looked for the presence of a correlation between the emotions experienced and the manifestation of the themes of meaningful learning.

4.3 Qualitative Methodologies

Review Methodology

To have an overall picture of the field of healthcare simulation research, the first substudy carried out a scoping review of the relevant research. The aim was to outline what is already known and to find out from the nursing literature how the concepts of learning and pedagogical models have been used in nursing education studies. Dijkers (2015) defines a scoping review as one aiming to map rapidly the key concepts underpinning a research area and the main sources and types of evidence available. We followed the scoping path described by Arksey and Malley (2005) and the data were analysed using scoping methods (Arksey, 2005; Armstrong, Doyle, & Waters, 2011; Nygren & Blom, 2002).The procedure they set out is the following:

1. Identify the research questions: what domain needs to be explored?
2. Find the relevant studies, through the usual means: electronic databases, reference lists (ancestor searching), websites of organizations, conference proceedings, etc.
3. Select the studies that are relevant to the question(s)
4. Chart the data, that is, the information on and from the relevant studies
5. Collate, summarize and report the results
6. (Optional) consult stakeholders (clinicians, patients and families, policy makers, or whatever is the appropriate group) to get more references, provide insights on what the literature fails to highlight, etc.

In this review article, we summarized 826 and analysed 32 articles (Colquhoun et al., 2014; Davis, Nick, & Gould, 2009; Poikela & Teräs, 2015). We used stakeholders to ensure reliability. Table 3 presents the scoping review.

Table 3. Scoping review of nursing studies

Scoping Review	Data of analysis	Theoretical contributions
Study I Literature review	Articles on nursing studies (N=32)	Nursing simulation conceptualizations, pedagogical models for nursing simulation and concepts and theories used in nursing simulation

As was mentioned above, a scoping review is a method for rapidly gathering knowledge from the literature, consulting stakeholders and thus giving authenticity to research.

Qualitative Content and Videography analysis

Three of the sub-studies applied qualitative content analysis and qualitative videography approaches. Qualitative content analysis was used in Sub-studies II and III, and video analysis in Sub-study IV. In Sub-study II, the analysis used Atlas.ti software. Nursing students' statements regarding the ISSD model's introduction stage revealed eight, the briefing and scenario stages nine, and debriefing three characteristics of meaningful learning. Sub-study III included experiments testing two teaching methods for their effectiveness in simulated practice. Researchers' field observations were included (Creswell, 2009; Marshall & Rossman, 2006.) The data for Sub-study III consisted of video recordings (total length of the recording: 4h 2 min 1s). Videography is still a new method in the field of education research. To date it has been used mainly in anthropological research; yet, today camcorders offer a new perspective on educational research and data collection (Knoblauch, et al., 2006). Data were collected using video recordings during the computer-based simulation learning and simulation practice. Table 4 below summarizes the three different qualitative methods.

Table 4. Studies based on qualitative content and videography methodology

Qualitative studies	Focus of analysis	Theoretical contributions
Study II Nursing students' opinions of the ISSD model's meaningfulness	Nursing students' interviews (N=6)	Characteristics of meaningful learning appear in each of the ISSD model's four stages
Study III Comparing the effectiveness of two teaching methods in the simulated practice	Interviews of nursing students (N=12) Observation notes by two researchers	Computer-based simulation practice before in simulated healthcare practice or in healthcare practice
Study IV 14 characteristics of meaningful learning falling within the six themes of meaningful learning	Videography analysis before, during and after simulation scenarios (N= before 40 students, during and after N=12 students), duration of video 4h 2 min and 1 s	ISSD model for the knowledge creation environment

Using the video data collected, the 14 characteristics of meaningful learning identified earlier were matched to six themes of meaningful learning: concrete, personal, social, liable, content-based, and metacognitive. These six characteristics made by qualitative analysis. Video recordings are a better source of data than written or verbal responses in many cases (Goldman, 2009). Researchers cannot observe the students' behaviour in detail in a simulated practice, but even the smallest detail can be captured in a video recording.

4.4 Data Collection and Participants

Learning scientists who conduct design-based research usually collect multiple types of theoretically relevant data (Barab & Roth, 2006). The first sub-study was based on a full range of the relevant research literature and scoping methodology was used in the data collection. In the other four sub-studies (the second, third, fourth and fifth), the data were collected using video recordings, observations, field notes, an online questionnaire created with Webropol, and paired interviews conducted by three researchers. After the simulation scenario, opinion surveys were administered to the research participants in the computer-based simulation environment, with these followed by paired interviews. The experiment was video recorded and observed for its entire duration. There were 143 participants who attended the computer-based training sessions and of that number 124 agreed to participate in the study. Email addresses were collected from those students, and they were sent messages containing a personal link to the questionnaire. The research took place in the spring and fall of 2013 and in the spring of 2014; it was conducted at Rovaniemi University of Applied Sciences and Kemi-Tornio University of Applied Sciences in northern Finland. Figure 8 describes the course of the research day. First, all participants were given an introduction to the day's program, the theoretical background of the TETRA network and all research details, and the TETRAsim simulation environment. The second stage was using the TETRAsim simulation program (Sub-studies II, III) and face-to-face teaching (Sub-study II). The day continued with the use of the TETRA phone in realistic simulated practice and debriefing after the learning session.

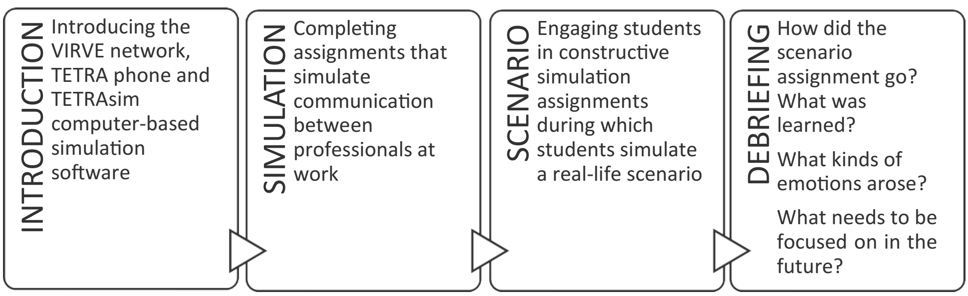


Figure 8. Description of the experiment day (adapted Poikela & Vuojärvi, 2016, p. 68)

All of the participating students experienced a similar simulation scenario in the afternoon based on their prevailing knowledge and skills. The sixth experimental day, held in the fall of 2013, was designed for qualified social workers. Students were informed that they had the right to obtain information about the study and that they were free to withdraw from the study at any point.

In the second sub-study, 17 nursing students studied the use of the TETRA phone using the CBS program (Curtin et al., 2011). They had four phones that they could hold in their hands and use during the program. The teaching experiment was conducted by two facilitators, one of whom is the author of this thesis, and the other of whom was a nursing teacher.

The experiment lasted six hours with a one-hour lunch break and was organized as follows: There was a general introduction about simulation learning and the TETRA phone, and then training took place through a computer-based simulation on how to use the TETRA phone. The experiment involved a comparison of the two different teaching methods followed, as described above, except in the case of the nursing student group who received a traditional lecture about the TETRA phone. The afternoon consisted of case-based simulation exercises using the TETRA phone. See Table 5 for a description of the afternoon training session.

Table 5. The flow of the scenario

Description of the simulated practice	
The roles of participants	**Learning environment**
• Two student nurses • Two student nurses • Two student nurses • Two facilitators	• internal unit • medical emergency team (MET) • intensive-care unit • both units
The aims of simulated practice • The nursing students can use the basic functions of the TETRA phone and transmit information about patients between the units using the TETRA phone. • The nursing students understand the operational logic of the VIRVE network. • The nursing students recognize the patients' symptoms and initiate first aid and defibrillation.	

The simulated practice occurred in an internal hospital unit. The patient was undergoing a physical examination, and the nurses noticed that the patient was becoming lifeless. Basic resuscitation was begun and additional help was solicited using the TETRA phone. The Medical Emergency Team (MET team) arrived to assist in the patient's resuscitation. The resuscitation was successful and the patient's spontaneous circulation returned after the first defibrillation. The MET team transferred the patient after resuscitation to the intensive-care unit to receive advanced intensive care. Before the patient was transferred, the nursing students had to convey the initial information about the patient from the intensive-care unit. The unit received the patient, and the MET team provided information on the patient's health.

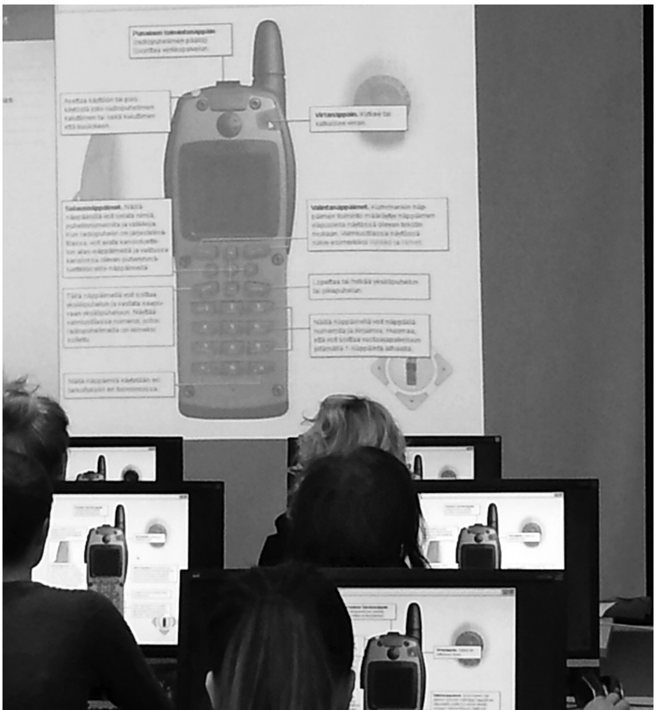
4.5 Research Context

This research was conducted largely as part of the MediPro project (2012–2014). Accordingly, the research environments were the same ones that were involved in this project. The environments are described in more detail below.

Computer-based simulation environment — TETRAsim® training system

TETRAsim simulators using computer-based technology enhance the system and enable efficient and effective TETRA phone training. The parameters used in the TETRAsim virtual TETRA network are set to match those of the authentic operational environment. TETRAsim training is reality-based, measurable, and easily controlled by the trainer. TETRAsim interactive exercises help create scenarios and tasks for a single trainee (individual exercise) or for a group of trainees (group exercise). TETRAsim interactive exercises are the best way to teach and enforce an organization's communication protocol. With the TETRAsim Educational Platform, it is easy to measure and compare the trainees' skills. The pictures below illustrate the training system with the computer-based simulation program, the TETRAsim. Picture 1 shows collaborative learning in the computer-based simulation environment, Picture 2 a personal drill.

Picture 1. Collaborative training sessions using the internal network



Picture 2. Training in the use of single components of the TETRA phone

Picture 2 shows the computer-based training platform. This TETRAsim computer-based simulation environment was the main research context. This environment was used in the four sub-studies of this thesis.

Simulation Environments of the Research

The research for the four sub-studies took place at Rovaniemi and Kemi-Tornio Universities of Applied Sciences[6]. At the beginning of 2014, these universities joined to form Lapland University of Applied Sciences. Both universities had nursing departments of the same size and the curriculum followed the European Credit Transfer and Accumulation System (ECTS) and provided education leading to a bachelor's level qualification. Both universities were developing simulation pedagogy and concrete simulation environments, Rovaniemi starting in 2005, Kemi-Tornio in 2012.

The Envi® Simulation and Virtual Learning Centre (see Figure 9) was built as part of Rovaniemi University of Applied Sciences and Rovaniemi Vocational College (Rovaniemi, Finland) during the years 2005–2008. It was one the first simulation centres established and the first virtual centre in applied sciences in Finland. The unique atmosphere makes the physical environment conducive to the processes pertaining to patients or clients in official health and social care. The Centre has also begun to engage in pedagogical development, activities and curriculum renewal (Oikarinen, Tieranta, & Poikela, 2013).

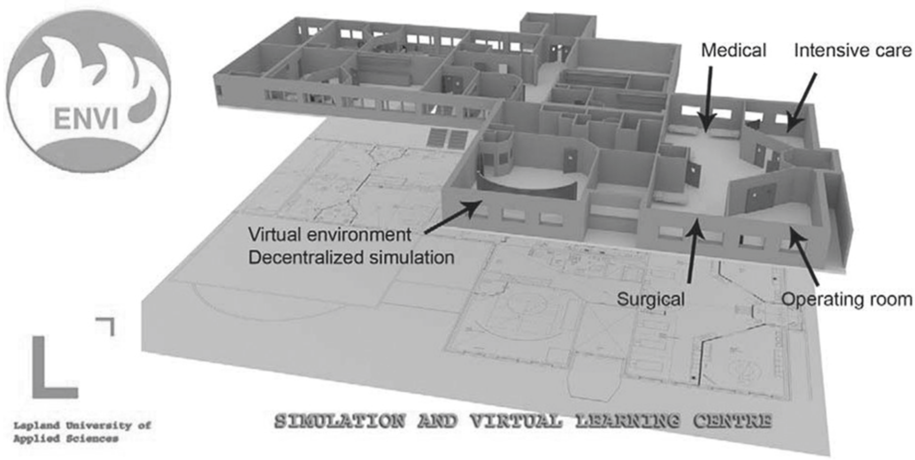


Figure 9. ENVI® Simulation and Virtual Learning Centre

6 https://fi.wikipedia.org/wiki/Rovaniemen_ammattikorkeakoulu, https://fi.wikipedia.org/wiki/Kemi-Tornion_ammattikorkeakoulu

The Centre has been updated to meet the demands of today and continually develops simulation pedagogy. In any event, the new environment maintains its unique idea for patient and client processes. At the same time, demands for decentralized, computer-based simulation are increasing. The ENVI environment was used in Sub-studies II, II, III and IV. It provides a realistic environment for studying use of the TETRA phone.

The SKY Simulation and Developing Simulation Environment was developed in the year 2013 and is located on the Kemi campus. SKY is used in teaching and advanced education to simulate adaptation to different situations and purposes. The environment includes two spaces: one is the patient care environment consisting of emergency, intensive care and bed units; the other houses teaching and home-like environments. Picture 3 presents how the latter space has been converted into a home-like environment.

Picture 3. Simulation and Developing Environment at the Kemi Campus

This simulation and developing environment was the other simulation environment in which the computer-based simulation learning and afterwards simulated use of the TETRA phone occurred. The SKY environment was used in the third sub-study.

5 Summaries and evaluations of the sub-studies

This chapter provides summaries and evaluations of the sub-studies comprising this thesis, as well as an account of my learning process. I introduce the sub-studies respective to their roles in and contributions to the research.

5.1 Sub-study I: Conceptualized Models Theories, and Educational Concepts Manifested in Nursing Simulation

Related publication
Poikela, P. & Teräs, M. (2015). A scoping review: Conceptualizations and Pedagogical Models of Learning in Nursing Simulation. Educational Research and Reviews, 10(8), 1023–1033.

This sub-study opened my eyes to the realm of research on nursing simulation. Through the writing of this review article, I became familiar with the research field of healthcare simulation. This sub-study encompassed a thorough review of the literature and described the theories, simulation models, and useful concepts that nursing simulations are based on at this time in the research field. We defined the following research questions, which capture the aim of the sub-study: a) How is learning using nursing simulations conceptualized? b) What types of pedagogical models are used in nursing simulations? c) Which educational concepts and theories are used in nursing simulations? Learning theories (e.g., cognitive theory and experiential learning) (Bandura, 1997, 2001; Kolb, 1984) have often been tied to nursing simulation without any reflection on what they mean in that context (Rutherford-Hemming, 2012). Our sub-study showed that in the nursing discipline, many researchers are interested in developing nursing simulations and have discussed diverse concepts of simulation. Many models to structure and assist in understanding nursing simulation have been developed, but these are not concrete enough for educators, teachers and trainers to employ them in planning simulated practice and for end-users' utilization. The review concluded that in nursing simulations has been conceptualized in many ways, and many models exist without understanding what their application in concrete learning might be. We also noted that the literature mentions many theories (e.g., Nestel & Bearman, 2015).

This sub-study opened up a new perspective within the area of nursing simulation research. Currently, nursing simulation relies on conceptualizations of other disciplines and does not include reflection on where learning occurs. Kaakinen and Arwood (2009) reviewed 120 articles, and 16 of those published between 2007 to 2009 were further analysed; the researchers concluded that the articles discussed teaching models rather than learning models and that more investigation was needed to improve conceptual learning from the students' point of view. Our first questions focused squarely on the question of how simulations had been conceptualized in previous studies. Most of the research from both the medical and nursing fields did not question the concepts behind simulation-based learning (Dieckmann, 2009, Sekiguchi, Bhagra, Gajic, & Kashani, 2013; Fadale, Tucker, Dungan, & Sabol, 2014; Poore, Cullen, & Schaar, 2014; Yeun Bang, & Ryoo, 2014.) For instance, The National League for Nursing has accepted the "The Nursing Education Simulation Framework" as one approach for conceptualizing simulation (Jeffries & Rogers, 2007).

Nursing simulation has links to research on other education methods, such as problem-based, case-based and narrative learning, to name just a few (Murphy, Hartigan, Walshe, Flynn, & O´Brien, 2011). Different models have been developed or structured around learning through simulation. This article showed us that the research field is being examined to explain nursing simulation from the discipline's own perspective. The researchers strove to cite well-known authorities in the field of pedagogy to justify the theoretical basis they put forward. Furthermore, the concepts used are quite variable and inconsistent. This becomes confusing because the same concept means different things to different users depending on the context. Researchers are also eager to develop models for simulation mainly on how teaching should be arranged, but not from students' perspective on learning. In the studies on nursing simulation in which students are the focus, the main themes are how satisfied and confident students are in the case of simulation learning. This review article gave us every confidence to continue pedagogical research from the learning point of view in healthcare education. Computer-based simulation learning is one example of how one can arrange simulation learning for nursing students to make the best possible use of students' learning process.

Our scoping review afforded a good insight into what is currently going on in simulation teaching and learning in healthcare and particularly in the field of nursing research. The methodology was appropriate for exploring this topic. The scoping review method includes consulting stakeholders from different sectors of society and different lines of work. Our six stakeholders spanned administration, research, teaching and practice. Their evaluation of the results enhanced reliability because they judged how the research results helped their work. The limitation was that this was the first time I had conducted this kind of research and was unable to objectively determine the best methodology. I could have obtained more in-depth results with another review method, for example, a narrative systematic review, evidence mapping or meta-analysis (Dijkers, 2015).

5.2 Sub-study II: Computer-Based Simulation Evaluated in Light of a Meaningful Learning Environment

Related publication
Poikela, P., Ruokamo, H., & Keskitalo, T. (2013). A computer-based simulation to enhance official communication in the healthcare process— How does it promote the facilitating and learning processes? In T. Bastiaens & G. Marks (Eds.), Proceedings of E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2013 (pp. 2051–2060). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

This was the starting point of a series of studies for understanding a computer-based simulation environment from nursing students' point of view. This sub-study has its roots in the MediPro research project. We wanted to know how one computer-based simulation program (TETRAsim™) typified the existing simulation models used in nursing education and how appropriate the program was from nursing students' point of view. We first analysed the computer-based simulation program (TETRAsim™), comparing it to an existing simulation model in terms of the phases of the FTL model (Keskitalo, 2015) and how those phases manifest themselves in the program. As noted previously, the ISSD model provides a tool for analysing the program.

In this sub-study, we also examined which characteristics of learning can be seen that are meaningful from nursing students' point of view (Keskitalo et al., 2010). This sub-study is based squarely on the analysis of nursing students' interviews. The introductory phases of the experiment include the active characteristics of learning and experimentation, but the emotional, socio-constructive, reflective, critical and individual characteristics of learning were lacking. In the briefing and scenario phases, socio-constructive, reflective, competence-based, and individual characteristics of learning were found to be lacking. The debriefing phase lacked the experiential, experimental, emotional, socio-constructive, collaborative, reflective, competence-based, contextual, goal-oriented, and self-directed characteristics of learning (Dreifuerst, 2015; Mariani, Cantrell, Meakim, Pierti, & Dreifuerst, 2013). All of these characteristics of meaningful learning that were found to be lacking can be introduced in the ISSD model if the facilitator tutors and supports the nursing students for the entire learning time (Poikela et al., 2013; Robinson & Dearmon, 2013). The nursing students were satisfied with the concrete aspect of practicing use of the TETRA phones (Romero-Hall, 2015). The most common characteristic of meaningful learning present was the experimental. This was the first step towards understanding the computer-based simulation program in the most appropriate way for the students.

The main findings were that the computer-based simulation (TETRAsim™) program includes stages of stimulation models that already exist and can involve characteristics of meaningful learning. The focus of our study was a single computer-based simulation environment, TETRAsim™.

Table 6 displays the characteristics of meaningful learning that emerged in the student interviews as well as the stage in which specific meaningful characteristics appeared in the environment. It also indicates the characteristics that were lacking and the stage of the computer-based simulation environment from which they were (Fanning & Gaba, 2007).

Table 6. Characteristics of meaningful learning identified by nursing students in the computer-based simulation environment

<table>
<tr><th colspan="4">Occurrence of characteristics of meaningful learning in the ISSD model</th></tr>
<tr><th>Introduction</th><th>Simulation briefing</th><th>Scenario</th><th>Debriefing</th></tr>
<tr><td>• experiential
• experimental
• active
• self-directed
• competence -based
• contextual
• collaboration
• goal-oriented</td><td colspan="2">• experiential
• experimental
• active
• self-directed
• competence-based
• contextual
• collaboration
• goal-oriented
• emotional</td><td>• active
• critical
• individual</td></tr>
<tr><th colspan="4">Missing characteristics</th></tr>
<tr><td>• emotional
• socio-constructive
• reflective
• critical
• individual</td><td colspan="2">• socio-constructive
• reflective
• individual
• critical
• individual</td><td>• experiential
• experimental
• self-directed
• competence -based
• contextual
• collaboration
• goal-oriented
• emotional
• socio-constructive
• reflective</td></tr>
<tr><td colspan="4">• responsible</td></tr>
</table>

This sub-study showed that when one starts to develop a new simulation environment (either computer-based or involving changes to a physical environment), the development process should not be one-sided; that is, it should be based on a multi-professional team consisting of researchers, educators, an IT developer and end-users. In developing computer-based simulation programs for the health care sector, particularly in nursing education, the process should have four components: researchers, developers, end-users (also healthcare students) and medical or nursing experts should be included (Banks, 2011). This could be a means of creating a platform in which information transforms into knowledge, and tacit knowledge transfer becomes visible. The developmental work must be performed by a multi-disciplinary team, and the design of the research should remain less visible. One limitation of this research is that we have not carried out the next development stage and thus need to test it.

Curtin, Finn, Czosnowski, Whitman, and Cawley (2011) researched the effects of computer-based simulation training and found that diverse skills can be acquired before a simulated nursing practice through a computer-based simulation environment before simulation practice. Additionally, the developmental work has to establish the foundation for the multidisciplinary practices involved; where this is done, all needed perspectives are included in the learning process. The present study revealed that students were satisfied with their training in mechanical skills. These undergraduate nursing students were in the very beginning stages of their studies, so they needed to learn discrete skills mechanically.

This study offered a novice researcher an initial impression of how fruitful it is to work as part of a research team including scientific professionals in different stages of their careers. The study also showed very clearly what types of correlations exist between nursing students' expectations and their backgrounds, these depending on what stage of education they were at. In this sub-study, the results were recorded by means of the TETRAsim program itself and by interviews of nursing students (cf. Cant & Cooper, 2014; Johnson, Hickey, Scopa-Goldman, Andrews, Boerem, Covec, & Larson, 2014; Persson, Dalholm, & Wallergård, 2014). The positive points were that there are very few studies on the extent to which computer-based simulation programs fulfil the pedagogical demands of a simulation and how different types of simulation supplements promote learning processes. This was the first step in designing a path to developing a simulation program for nursing students. Now, however, testing for the first version of the ISSD model is needed. It is the next step and a future research task. We received helpful results regarding nursing students' expectations, and how to meet them, but more student interviews are needed.

The methodology chosen was reasonable. The nursing students had practiced using the TETRA phone first with a computer-based simulation, after which they had to use it in simulated practice. Reliability increased since three researchers interviewed the pairs. The computer-based simulation environment should be tested with a large number of nursing students.

5.3 Sub-study III: Two Different Teaching Methods and Their Impact on Simulated Practicing

Related publication
Poikela, P., Ruokamo, H., & Keskitalo, T. (2014). Does teaching method affect learning and how meaningful learning is from student perspectives? In J. Viteli & M. Leikomaa (Eds.), Proceedings of EdMedia: World Conference on Educational Media and Technology 2014 (pp. 1760–1768). Association for the Advancement of Computing in Education (AACE).

In this sub-study, we compared two learning methods: face-to-face teaching and computer-based simulation. This kind of research has been conducted from a wide range of perspectives throughout the history of nursing simulation. Arnold, Johnson, Tucker, Chesak, and Dierkhising (2013) compared three different levels of nursing simulation in emergency education and found that high-fidelity simulation in emergency learning made nursing students more self-confident and provided greater satisfaction. A large number of researchers have made comparisons between different forms of simulation and "traditional teaching." Here, I present just a few in which contradictory results were found (Arnold, Johnson, Tucker, Chesak, & Dierkhising, 2013; Beyer, 2012; Golchai, Nazari, Hassani, & Bahadori, 2012; Schwerdt & Wuppermann, 2011). The last two researchers asked a relevant research question in their study, "Is traditional teaching really all that bad?" (p. 361). This means that one also needs some instances of "traditional" or "classroom" teaching (Swanson et al., 2011). Researchers, Schwerdt and Wuppermann, (2011), compared three active learning methodologies: case-based learning, simulation, and simulation combined with narrative pedagogy. They tested these three methodologies in the same group and found that nursing education should make use of high-fidelity simulation as a teaching strategy as much as possible. Our research supports this, for the main results were that students who learned to use the TETRA phone with the computer-based simulation program were much more confident and satisfied during the simulated practice (Hyland & Hawkins, 2009).

In this study, we found that training in the computer-based simulation environment supported students' use of the TETRA phone in simulated practice in that it was much easier for them to employ these skills in such practice. Computer-based simulation is a necessary tool that plays a key role in learning and provides explicit information on the use of the TETRA phone. The learning community (Paavola et al., 2011) is the forum in which this knowledge can be distributed. This sub-study also shows that (a) computer-based simulation, if it is formulated from the perspective of nursing students, is valuable when used before other training and (b) simulation mediates the information presented such that the knowledge becomes visible in the learning community (Nonaka et al., 2005; Paavola et al., 2012). In the research, we tried to comprehend more deeply how important it is to practice discrete skills before going on to practice in simulation scenarios. We found ourselves asking: Is this computer-based simulation program one solution for giving undergraduate nursing students and professional nurses, doctors and other healthcare experts the chance to practice discrete skills? And how meaningful should the program be such that information is transferred and becomes knowledge? The three sub-studies discussed thus far used data gathered by multiple means; in this third study we also used researchers' observation. Overall, this sub-study demonstrated that we have to emphasize how important this computer-based simulation environment is if we are to achieve meaningful learning. The fourth and fifth studies, to be described below, went on to examine the characteristics of meaningful learning that the computer-based simulation entailed.

In this sub-study, researchers' observations on introspective analysis support the understanding that teaching methods play a significant role in students' learning process. The main limitation was that we only conducted one experimental teaching test.

5.4 Sub-study IV: Six Meaningful Learning Themes

Related publication
Poikela, P., Ruokamo, H., & Teräs, M. (2014). Comparison of meaningful learning characteristics in simulated nursing practice after traditional versus computer-based simulated methods: A qualitative videography study. Nurse Education Today, 35 (2), 373–382.

The purpose of Sub-study IV was to analyse recorded videos using videography to ascertain how well two groups of nursing students (N=40) learned to use the TETRA phone. The first group were taught using a traditional lecture; the second used the computer-based simulation environment. This sub-study continued the line of inquiry pursued in the second and third sub-studies, in which the following question was addressed: To what extent do characteristics of meaningful learning emerge in a nursing simulation presented via traditional lecture as compared to a computer-based simulation? The characteristics of meaningful learning that we observed were categorized in terms of six themes brought to light in the analysis: concrete, personal, social, liable, content-based and metacognitive.

The six themes, also detected in Kolb's experiential learning cycle, include watching, feeling, doing, and thinking; these happen before (for), during (in), and after (in) simulated practice (Poore et al., 2014). Poikela (2012) has further studied the experiential learning (Kolb, 1984) integrated into simulation learning. Watching, doing, feeling, and thinking are all manifested in the simulation process. Reflecting on the scenarios of doing, watching, and thinking, we can see three themes of meaningful learning in this stage: concrete, personal, and social. The content-based theme of meaningful learning appeared before, during, and after the scenario. Metacognitive capabilities increased noticeably after the scenario, in the debriefing phase (Dufrene & Young, 2014.)

Kolb and D. Kolb (2008) constructed the themes based on Nonaka and Konno's (1998) ideas of zones and spaces of learning. The themes of meaningful learning offer an opportunity to consider learning from nursing students' points of view. The themes of meaningful learning show how relevant the learning is and do not focus so much on the teaching arrangements. Video analysis of the simulated practicing revealed clearly that the themes of meaningful learning were very much in evidence in the practicing. Learning is not only a gathering of information, but is also mediated by knowledge gained through simulation. Drawing on the themes of meaningful learning, one can readily make visible nursing students' requirements where the computer-based simulation program is concerned. Sub-study V went deeper into these themes, investigating them using quantitative methods.

The main limitation of the present sub-study was analysis of the video recording. We used a software program called Live Movie Maker (Microsoft) as the analysis tool. As the program is not intended for research purposes, it is possible that we did not extract all the information from the available data that would have been necessary for our research purpose.

5.5 Sub-study V: A Computer-Based Simulation Environment as a Mediated Tool in the Learning Process

Related publication
Poikela, P. & Vuojärvi, H. (2016). Learning ICT-mediated Communication through Computer-based Simulation. In M. Cruz-Cunha, U. Miranda, R. Martinho, & R. Rijo (Eds.) *Encyclopedia of E-health and Telemedicine*. (pp. 674-687). Hershey, PA: Medical Information Science Reference.

This sub-study was conducted with reference to the themes of meaningful learning. We sought to determine how the themes emerged in the learning processes at work in the computer-based simulation environment from students' perspectives. The data used in the study were those we had collected via Webropol throughout the entire project. These data included all participants (N=124), including qualified social workers. Our analysis showed that students' perceptions of how the themes of the ISSD model emerged were quite neutral. This might be because the students perceived TETRAsim software as rather mechanical. The theme that figured most prominently was social, which may indicate that students appreciated the collaborative tasks of TETRAsim. It seems that students found the experience of using TETRAsim to be quite positive, even though they did not express noticeable feelings of confidence or enjoyment. The positive attitude towards using TETRAsim could perhaps be attributed to the fact that the students experienced little or no frustration or uncertainty.

This sub-study directly addressed the following questions about the use of the computer-based simulation program: 1) How should the nursing simulation be designed to correspond to the learning process? and 2) What should the nursing simulation learning be based on? The quantitative research provided statistical support for answering these questions with confidence. The results indicated, in light of the themes of meaningful learning, that the nursing students were quite satisfied with the program. The limitations were that most of the participants were nursing students in the very initial stages of their education and that they did not want a complicated program requiring them to make decisions. At their level of learning, they needed to practice concrete skills. Only the participants from the social sector who had been in the workplace, most with long job histories, were considered experts, but they had no previous familiarity at all with the TETRA system and needed practical guidance. All of the themes of meaningful learning were in evidence in this sub-study but to a rather modest degree, and this kept use of the program at a mechanical level. This showed very clearly nursing students' and social workers' experiences of using TETRAsim to achieve the prescribed skills. The weakness of this sub-study was that we should have tested the themes of meaningful learning more with users at various levels of education or career stages (Table 2). The low occurrence of frustration or uncertainty might indicate that students were aware of their need for training in how to use the basic functions of the TETRA phone to find it useful.

The alphas of the sum variables describing the characteristics "concrete" and "personal" did not fulfil the requirements of reliability, as Cronbach's alpha remained under the acceptable rate of .60 (Cronbach, 1951). Therefore, these were left out of the analysis. This shortcoming might result from the formulation of the questions being unsatisfactory or some fundamental limitations in the content of these two experiments as designed here that render the conclusions uncertain and must thus be investigated. A large number of variables affect the success of the design, many of which cannot be controlled. Effective pedagogical practices develop through subsequent refining and testing, and it needs to be noted that this was only the second implementation of the ISSD model; moreover, the analysis is based on quantitative data alone. The analysis could also be made more robust by comparing results across designs or across contexts to include more variables regarding the content as well as the design of the training (Collins, Joseph, & Bielaczyc, 2004).

The methodological limitations of the data were their low reliability. We should obtain more results that are valid at higher confidence levels to evidence the themes of meaningful learning. In early studies, we found that "concrete" was a particularly important feature in this computer-based simulation environment.

5.6 Contributions of the Sub-studies to Answering the Main Research Question

Each of the sub-studies enriched and furthered my investigation of the main research question: What kind of theoretical and conceptual frameworks and models form a computer-based simulation environment? Figure 10 shows the contribution of each of the sub-studies to answering the question.

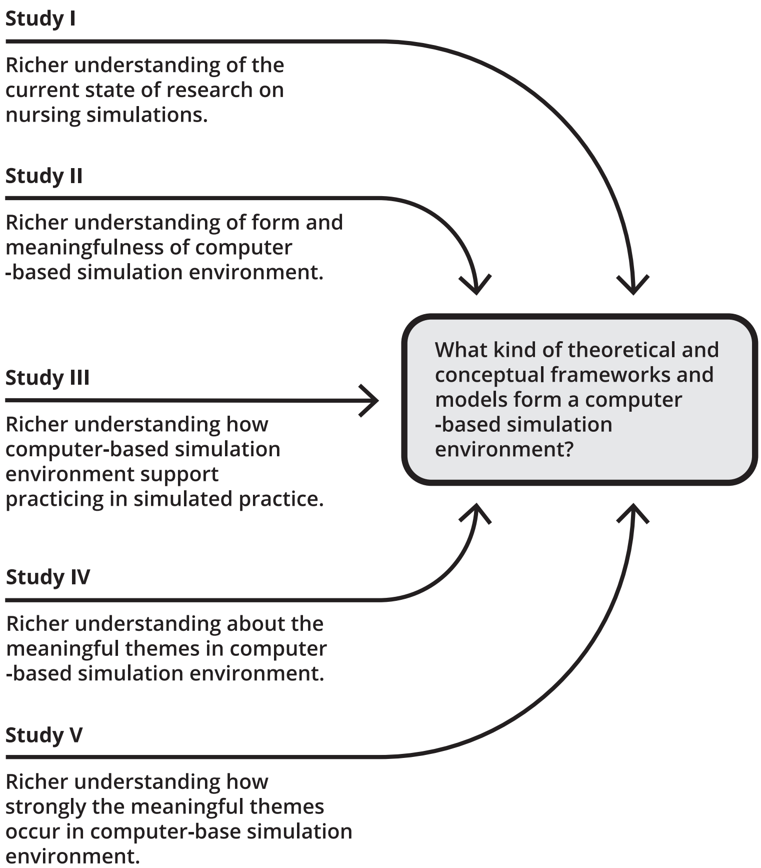


Figure 10. Main research question and central conclusions emerging from the sub-studies

In this context, a richer understanding means that all the sub-studies advanced the overarching aim of developing the ISSD model. The ISSD model review covered the characteristics of meaningful learning and extended, through the trialogical approach, to developing social interaction and practice.

6 Results: defining the computer-based simulation environment through theories

The aim of this chapter is to examine theoretical insights into the ISSD model to be gained from the computer-based simulation environment. Here, I track the ISSD model's journey through the explicit trialogical knowledge-creation environment, information chaos and knowledge spiral in the private and shared *ba* processes. Although I have not used trialogical knowledge creation in my empirical sub-studies, I recognize the potential of the trialogical model of knowledge creation in developing computer-based simulation environments in the future. In all of the five sub-studies I have examined different theories and models of learning which could inform development of the simulation environment. My four empirical sub-studies are based on Ausuble's characteristics of meaningful learning; these characteristics are meaningful for the individual. According to current conceptions of learning, knowledge must be made self-regulatory and shared, becoming first tacit and thereafter explicit knowledge, for use by everyone in a given environment. (Muukkonen & Lakkala, 2009.)

6.1 Analysing the Purpose of Trialogical Knowledge Creation from Tacit to Explicit Shared Usable Knowledge

According to Hakkarainen et al. (2006), technologies need a human participant in any co-operation because no one can be alone in developing processes; theorists cannot work alone in their researcher's chambers without technologies and end-users. Computer-based simulation environments are the focus in this study, with TETRAsim the particular case of interest, and we, researchers, thus need to take into account social practice in the practice and educational setting. Hakkarainen and his team at the Knowledge-Practice Laboratory (KP-Lab) have developed social practice as an addition to the trialogical model of learning. The trialogical model has been searching for inspiration from the following theories; Nonaka and Takeuchi's (1995) knowledge-creation and Engeström's expansive learning (Engeström, 2001; Engeström & Sainio, 2010). I do not consider expansive learning in any detail here, for its features come into view through trialogical knowledge creation. Sfard's (1998) study utilized two metaphors, acquisition and participation, and argued that it is dangerous to choose only one of these metaphors; they must be connected in the learning process. She claimed that either metaphor singly serves certain groups and is disadvantageous to others. Paavola & Hakkarainen (2005) added a third metaphor, one regarding the creation of new knowledge. The developers of the trialogical model consider, on the basis of research, that two dimensions are not sufficient and some tools (e.g., nursing devices, such as blood pressure monitors) are needed to mediate the shared objects of the model; these crucial components may be artefacts, the processing of external information, ideas or representations (Paavola et al., 2011). In the present case the shared object is the TETRA phone, as well as the process of learning to use the phone and develop skills in using it through the computer-based simulation. Even though the process of developing the simulation environment was not always made explicit in the empirical studies, development was an element of the activities throughout. The students share the learning situation through the phone, using a particular phone.

Today's students are comfortable working with computers and advanced communication technology. Increasingly, they face demanding technology-oriented care and multifaceted technology care devices (Diener et al., 2012). The nursing students individually practiced using a computer-based simulation, that is, the TETRAsim learning program, and in this case the learning process was paused before they used the object, the TETRA phone. The success of the process depends on the level of facilitation provided by the instructor (Hämäläinen, Vähäsantanen, 2011).

This thesis attempts to explain a computer-based simulation environment from a different perspective, one distinct from the history of healthcare simulation.

First, I consider the results of all the sub-studies, as well as how these have been designed appropriate, to examine the focal computer-based simulation learning environment, which allows the construction of knowledge from students' point of view. Three generations have already used theory-enhanced learning (Hakkarainen, 2009a). The first generation sought knowledge; the second had a research focus and a participatory focus; and the third was concerned with knowledge creation (Hakkarainen, 2009b). The fourth generation, the "Z-generation" or technology-generation, needs more knowledge creation in a collaborative space of their own and/or according to Nonaka's a common *ba. In trialogical learning, interaction occurs by developing shared* objects of activity and expanded knowledge, which has been created in *ba and has evolved from tacit to explicit (Hakkarainen, 2006; Paavola, 2006; 2011; 2012). All learning should be based on meaningful learning and relevant knowledge. That* is why the characteristics of meaningful learning should include not just visible learning but also invisible learning. Decision making is easier in different nursing and healthcare simulation situations when students can experience meaningful learning and find the themes of meaningful learning in a computer-based simulation environment (Poikela et al., 2013).

In the ISSD model, the first, or introduction phase, offers information about necessary practical functions. In the TETRAsim program, this phase was introduced in the "information distributor" phase. Because self-directed characteristics figure very prominently in this phase, the knowledge gained could disappear at the routine level. Nevertheless, the students succeeded in operating the TETRA phone with the skills and information that they gained during the computer-based simulation process. In this phase, the trainees were using the acquisition metaphor to acquire information sufficient to reach the level where they could use simple functions of the TETRA phone. (Paavola et al, 2004.)

The second and third phases, the simulation briefing and scenario, give students the opportunity to emerge from information chaos and turn routine skills into knowledge. A simulation briefing gives guidelines to the students for the scenario. It is also the acquisition phase, in which trainees absorb as much information as possible. (Paavola et al., 2004.) The second phase flows into the third, the scenario, in which students can proceed from routine information to the construction from information of shared knowledge with others; this phase of learning in a computer-based simulation environment adheres to both the acquisition and participation metaphors (Schwab, 1973). The fourth and last phase, debriefing, is the most important, the one in which students can reflect on the knowledge they have acquired. The final debriefing phase is when the knowledge creation, shared knowledge of the TETRA phone used, should take place individually and jointly (Fanning & Gaba, 2007; Paavola et al., 2004; Rudolph, Simon, Raemer, & Eppich, 2008).

Training and learning in computer-based simulation environments benefit individual students by allowing them to learn without obstacles related to place and time, the aim in this case being to learn to use the TETRA phone. Obstacles to learning in the environment are that it has not been developed to the point where it would afford the opportunity to turn information and routine working skills into knowledge; the information and skills can remain superficial and easy to convey to colleagues. Tacit knowledge is still inner knowledge, and it should be available to all those who need it during a work shift, for example, experts, emergency staff, doctors and nurses. Attention must also be paid to development needs that become apparent during use.

6.2 Research and Development Toward Theoretically Justified Computer-Based Simulation

The main research question that I sought to answer with the empirical sub-studies is this:

1) What kind of theoretical and conceptual frameworks and models form a computer-based simulation environment?

The first sub-study is a review article. It gives an overview of the research on nursing simulations and shows how different researchers have tried to (a) conceptualize learning in simulations; (b) develop simulation models of nursing; and (c) create educational concepts and theories in nursing simulations. Most studies approach learning as simulation-based, and simulations merge problem-based learning and case-based learning. These studies reproduce existing theory, pedagogy, and models. The models developed have been used at many levels, and two typical examples have been put forward of research outcomes in which the design of a simulation scenario and the provision of a research framework were introduced: learning through simulations (Joyce et al. 2009) and simulation settings (Dieckmann, 2009). The articles were divided into three categories: those that focused on and used basic education theories, such as narrative pedagogy or situated learning theory (Lave &Wenger, 1991); those that employed simulation learning concepts and frameworks, such as The Nursing Education Simulation Framework (NESF) (Reese et al. 2010), also known as the simulation learning pyramid; and those that employed theories from other disciplines, such as socialization theory or critical feminist sociology. The articles were further divided into two categories: those in which learning was mentioned but not discussed further; and those in which educational concepts and theories were also addressed in the discussion section. The articles in the latter category gave reassurance that most researchers focus on simulations taking place in authentic environments (operating rooms, intensive care units, bed units, and so on).

The second sub-study offered two insights. The computer-based simulation environment was configured by following previous simulation models (Dieckmann, 2009; Joyce, 2009; Keskitalo, 2015). It can be seen that knowledge practice creation adheres to the phases of the ISSD model (introduction, simulation briefing, scenario, and debriefing). It mediated information and knowledge to nursing students on the forthcoming simulation exercise. The study established that the CBSe includes 14 characteristics of meaningful learning from the students' perspective and shows where they occur in the phases of the ISSD model. Only three (see Table 7) characteristics were present in the debriefing phase. The ISSD model seems to be meaningful to nursing students from their perspective; they did not analyse where they were getting knowledge from (information or learning) but they valued the model nonetheless.

The phases of the ISSD model include the use of mediating epistemic artefacts, in the present case the TETRA phone, which are components of knowledge creation. In the first phase, these tools were connected to each other and we were able to have an initial look at the meaningfulness of the model as an enhanced learning process. When I consider the second sub-study in terms of the trialogical model and the data collected in connection with the sub-study, information on the TETRA phone and skills could be considered artefacts (e.g. device for measuring blood pressure) or shared objects (e.g. knowledge, what was happing at the moment).

The third sub-study revealed that computer-based simulation training before simulated practice is valuable in enabling nursing students to apply the skills in practice (in this case, using the TETRA phone). This quasi-experimental study clearly showed that a traditional face-to-face lecture left most of the students outside of the learning process, although four phones circulated during the lecture and in the computer-based simulation training. It was significant that the nursing students who trained with the computer-based simulation used the phone more readily in a collaborative manner and did not leave their fellow students on their own to solve emerging operational problems. This sub-study revealed very clearly how the computer-based simulation environment provided an opportunity for social interaction. (Nonaka et al., 2004.) Even trainers who were acting individually in the phase of simulation briefing joined the simulation scenario in the computer-based simulation environment and cross-fertilization occurred, with participants reflecting on learning and either turning back to the previous knowledge step or moving on to the next one (Hakkarainen et al., 2006).

The fourth sub-study identified 14 characteristics of meaningful learning and related them to the six themes of such learning: concrete, personal, social, liable, content-based, and metacognitive. The computer-based simulation environment was superimposed on the KPE (Knowledge-Practice Environment) to reveal the mediated learning process that takes place in the computer-based simulation environment (Bauters, Lakkala, Paavola, Kosonen, Markkanen, 2012). Ultimately, this environment can be defined as a knowledge-creation computer-based simulation environment (KC-CBSe). It involves practicing use of TETRA phone in the computer-based simulation environment either interactively with others or individually. This environment was augmented by using knowledge in simulated situations (in this case, in simulated practice). Part of the tacit information can contribute to the all colleagues' explicit knowledge. The learning stages of the ISSD model can be identified in the KP-CBSe. The shared object in the interaction phase is the TETRAsim simulation program, where students familiarize themselves with the functions of the device. In the simulation briefing, the rehearsing phase ensues and the training can easily start technically. Simulated practicing takes place in the scenario phase, and social interaction with other trainers can augment this phase, if necessary. KC-CBSe allows everyone to remould practices. In these three phases, the greatest difference was that, in the simulated practice, a metacognitive theme was identified but was not in the group that listened to a traditional lecture dealing with the TETRA phone.

The fifth sub-study showed that it is valuable for the facilitator to be involved in the learning process if it is to realize the themes of meaningful learning; otherwise, the CBS environment is quite neutral and it is not as demanding of nursing students. As Vygotsky (1978) has pointed out, more experienced peer providers can assist a novice or novice group to reach independence. This is the state (Poikela & Vuojärvi, 2016) in which knowledge creation can occur, and tacit information can turn into explicit knowledge. In the learning process, the facilitator has to enable the trainers to create cognitive links from new material to their own previous knowledge or information. They also need an authentic place to demonstrate their knowledge to the learning community (Brown, Collins, & Duquid, 1989; Greeno, Collins, & Resnick, 1992).

6.3 Excaming the Computer-Based Simulation Environment through the Trialogical Approach

To design the computer-based simulation environment in accordance with the ISSD model, which includes theoretically justified simulation phases, one needs to ensure a pedagogically reasonable path. It has to be relevant to future teaching and learning demands (created knowledge, tacit to explicit knowledge and social interaction). The computer-based simulation environment has to resonate with the end-users' point of view regarding learner-centered design (LCD) (Soloway, Guzdial, & Hay, 1994). I want to create a model of learning for computer-based simulation that uses the theoretical idea of knowledge creation in a trialogical manner to produce a knowledge-creating environment and make this meaningful from learners' point of view (Paavola et al., 2012; Quintana, Namsoo, Norris, & Soloway, 2006). In healthcare education and practice, there needs to be an everyday, open-ended problem-solving method, and the trialogical approach with computer-based simulation is mediated knowledge building in this field. In this process, many collaborative teaching or learning methods can be tapped (e.g., situated-interaction inquiry learning, project-based or problem-based teaching and learning (Paavola, Engeström, & Hakkarainen, 2012). This is exemplified in Figure 11 below. It shows the SECI learning process, in which the ISSD model acts as an initial knowledge-creation mediator.

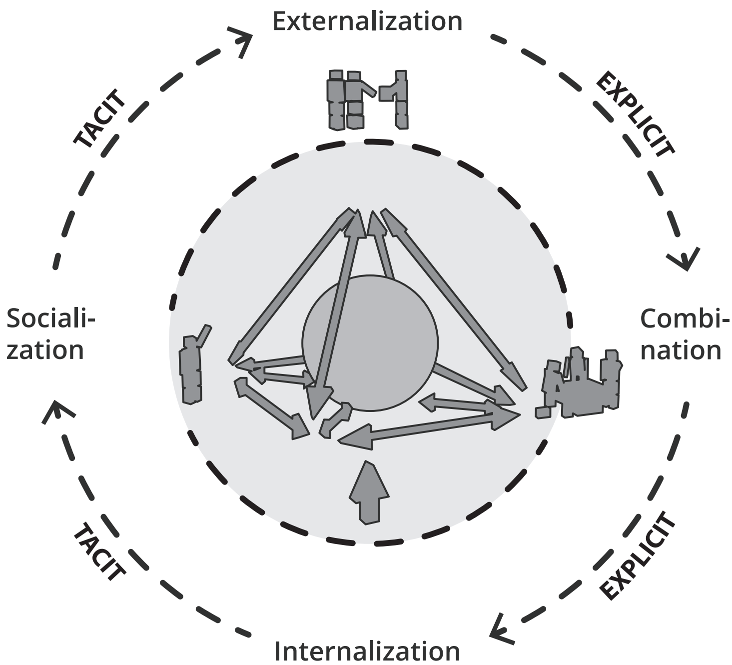


Figure 11. Learning process based on the SECI model as a part of the knowledge-creation environment (cf. Chatti et al., 2007; Nonaka et al., 1998; 2000)

The outer cycle in this model shows the learning process, which varies from tacit to explicit depending on the phase in which learners are in their learning process. It means that the learning process is an open system. Tacit and explicit learning span socialization, externalization, combination and internalization. Information flows in from different sources, for example, social media, newspapers, or acquired knowledge. The inner cycle (see Figure 12) depicts how the computer-based simulation environment, described by the ISSD model, is the concrete mediator in the learning process. The environment causes learning to progress towards knowledge creation. The KC-CBSe can be used both individually and in social interaction. When it is used alone, without social interaction, the learner cannot get input from social interaction but from the outside, and this might be only information, in which case the process turns into routine. Received information should become visible through spoken language, turning into knowledge.

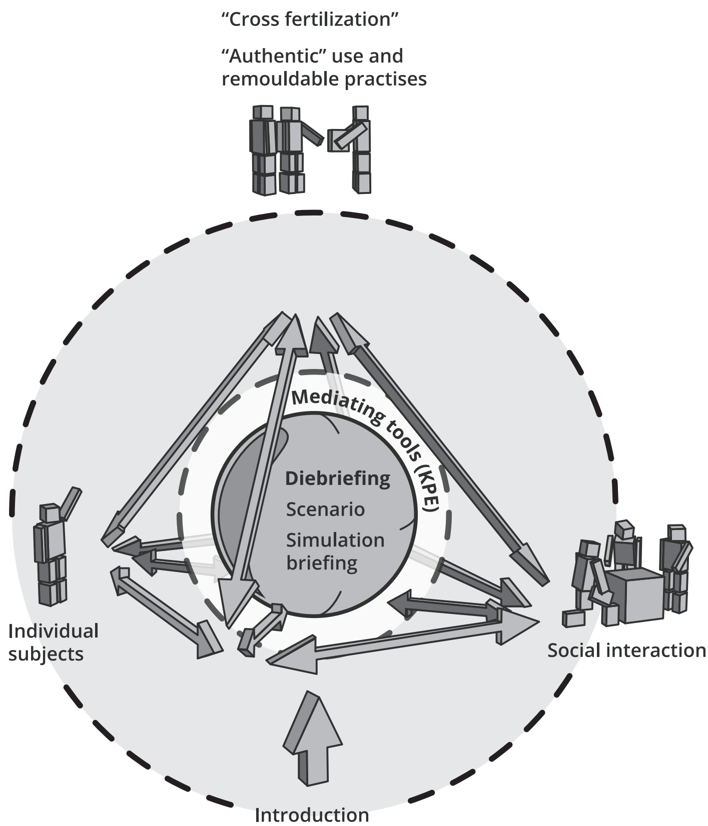


Figure 12. KC-CBSe as a learning process (cf. Paavola et al., 2012; Nonaka, 1994)

The introduction phase has been located outside the core, as the practical function of the TETRA phone can be practiced alone as just a drill. Individual subjects practice with this current information and knowledge to use the TETRA phone. Individuals do not necessarily need others in this phase. The purpose of the phase is to become familiar with buttons, functions, and the regulator. It is an acquisition metaphor that serves some trainees, but not all, more experienced users. Others could require participation to achieve higher levels in training (Sfard, 1998; Tuomi-Gröhn, 2007).

Simulation briefing and scenarios allow for social interaction (cf. Figure 11). Using social collaboration depends more on the trainees' experience, level of education, and healthcare practice. Nursing students who have a one-year educational background need a great deal of support from the scenario's facilitator to achieve social interaction. Advanced trainees can use social interaction to find out how to use the environment to solve problems presented in the environment in a reasonable way in collaboration. A facilitator functions like scaffolding[7] in the learning process to help trainees achieve a deeper understanding and flexibility in practicing with the computer-based simulation environment. This scaffolding is tailored to the trainees' needs to transform information into shared knowledge and to the creation of new, explicit knowledge as the process proceeds towards de-briefing (Sawyer, 2009). Facilitators are given coaching tools enabling them to familiarize themselves with trainees' background, education level and experience. The main approach is asking questions. The questions depend on which phase trainees are in in their scaffolding (Collins, 2009). The introduction, simulation briefing and scenario are tools to facilitate knowledge creation. Debriefing is the highest level, where knowledge creation should proceed from tacit to explicit in keeping with the SECI process (cf. Figures 11 and 12). In this phase, the facilitator's support is minimal. In this KC-CBSe, evaluation can be carried out for the purpose of accountability. The rate at which learning occurs can be evaluated, in a process focusing on trainees' learning of skills, not their knowledge comprehension. In addition, the computer-based simulation program should enable cognitive assessment (Means, 2009).

The next step in the development process is to take the TETRA phone into use after this training with the KC-CBSe. It is here where one can address the question of how valuable learning with the computer-based simulation environment has been. This is the most important stage for practicing social interactions and improving operations and authentic/simulated use. The results of the present study have shown that nursing students were able to use the technical functions of the phone fairly smoothly. The question is whether they only learned these skills and superficially memorized information. The next step is to use this phone in real situations. Following this comes a phase of cross-fertilization in which all those who took part in the simulated practice commit themselves to further development of the computer-based simulation program.

7 Scaffolding is the support given during the learning process which is tailored to the needs of the student with the intention of helping the student achieve his/her learning goals.

7 General discussion

7.1 Evaluation of the Study

The present study enhanced my understanding of a computer-based simulation environment as support for the effectiveness of teaching and learning and for nursing students' ability to process information and knowledge individually and as part of a team. The present study gives an overview of the computer-based simulation environment's usefulness, as well as a more in-depth understanding of such environments and how they might be developed to afford trainees opportunities for meaningful learning and knowledge creation. The three main limitations of this study merit mentioning. The first two were that the sub-studies involved a rather small number of participants and the data collection phase was brief. Nevertheless, we received assistance in developing the computer-based simulation environment to aid teaching in a university setting, in which contact teaching hours are being continually reduced. These limitations were addressed by using three researchers on data collection days. The third limitation was that the participants on whom data were collected were mainly nursing students. There was one group of social workers, but they were comparable to nursing students in terms of their skills in using and understanding the TETRA phone.

In our computer-based simulation environment, the participatory design was the following: the nursing students will be end-users after graduation and developers in the future; during this research process, the participants (nursing students) gave indications as to how the computer-based simulation environment should be developed to promote knowledge creation. In their development work, Sjöberg and Timpka (1998) used primary care as an arena from which they received very compelling feedback from the voice of practice. This element is missing from our research process. Being in an early stage of their education, students were not able to anchor information to practice, and thus the information conceptualized was incomplete. Situated learning requires that action is tied to a concrete situation. Even if a trainee learns a skill, the knowledge does not transfer between skills. (Anderson, Reder, & Simon, 1996).

The ISSD model is a process model with features from other simulation models. The purpose of this thesis was to show how all computer-based programs could be conceptualized for closer examination, as well as for further development. This development would focus on benefits for the end users in their learning process, in this case qualified social workers and nursing students. In the ISSD model, all features are equal and a trainee could start from the bottom (introduction phase) or in the phase which she or he considers to be appropriate to her or his own learning or learning level.

7.2 Evaluation of Ethical Issues

The study was conducted according to the ethical guidelines for educational research (Cohen et al., 2011; National Advisory Board on Research Ethics, 2000). In this study, research ethics were considered in every case, since for every sub-study (I–V), research permission was sought and, in all cases, granted by the local institutional review board. Data collection was conducted in keeping with the ethical principles of autonomy and self-determination.

We also guaranteed that participation was voluntary and that participants could refuse to participate in the study or withdraw from it at any time. We properly informed the participants about the topics and tasks related to the study. The study was integrated into their curriculum at the appropriate stage of the nursing education.

All participants' privacy and confidentiality issues were taken into account in the following way: All the research data were stored on a secure server and only the authors of the current study had access to the data. Additionally, all data files were named using a code making it impossible to trace them to individual students.

The ethical principle of beneficence was considered; that is the aim was to produce some benefit rather than simply carry out a study for its own sake (Murphy & Dingwell, 2001). The learning that the nursing students acquired during the teaching experiment was in line with the learning objectives of the curriculum. Teaching experiments were integrated as part of the course as a whole. In addition, the nursing students benefitted from taking part in the study, as they were given access to the TETRAsim simulation program, which is usually a commercial product and has not yet been made available for students' use at the Universities of Applied Sciences in Rovaniemi and Kemi. The students also received productive feedback on their performance in the simulation and experience in being involved in developing the computer-based simulation program.

7.3 Implications and Future Studies

This thesis has a number of implications for developing computer-based environments for healthcare experts and students. The most important contribution is that I point out the value of taking into consideration how a computer-based simulation environment can be turned into a knowledge-creation environment. This is currently the main challenge due to reduced financial resources and workers hurrying during their shifts to acquire new knowledge as quickly as possible while ensuring customers' and patients' safety. The question is: Can the same program serve both students and experts? Both have different expectations as regards learning with the program. My thesis also broadens the theoretical background of computer-based simulation environments. I have considered computer-based simulation environments in theoretical perspective. In the future a wide range of participants, such as developers, engineers, researchers and end-users, can apply it for on-the-job professional development. From the beginning, the ISSD model was analysed against existing simulation models. I first gained insight into the theory of computer-based simulation environment. The second insight was that regarding how this kind of model can enhance knowledge creation and how we can develop a computer-based simulation environment towards becoming a meaningful and theoretical learning environment. The next step is to test the ISSD model in a knowledge-creation environment with experts who have already mastered versatile use of the TETRA phone.

As Nonaka has said, the private business world cannot afford to educate only one person; rather, knowledge needs to spread to create new know-how that everyone can use. Corporations have taken this seriously, which is why information is the fastest-growing and most important type of capital in the business world. This has not happened yet in public organizations or educational organizations. A great deal of knowledge has been wasted, a fact which has not been noted in healthcare education.

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Original publications

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