From the DEPARTMENT OF LEARNING, INFORMATICS, MANAGEMENT AND ETHICS

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DESIGN OF BLENDED LEARNING FOR CIVILIAN AND MILITARY TRAUMA CARE

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DESIGN OF BLENDED LEARNING FOR CIVILIAN AND MILITARY TRAUMA CARE

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"…Water is fluid, soft and yielding. But water will wear away rock, which is rigid and cannot yield. As a rule; whatever is fluid, soft and yielding will overcome whatever is rigid and hard. This is another paradox: What is soft is strong…"

(Lao Tzu, 500 CE)

With an endless love to:

Valentin, Samuel and Christoffer and my parents Nils-Arne & Susanne

PROLOGUE

In developing e-learning within military medicine for the Swedish Armed Forces, my responsibility was the landscape of e-learning as support for flexible and effective education. It was not much of a landscape, but rather small footprints to follow. This question has been often asked in both civilian and military medical educational systems, where e-learning is compared to face-to-face learning: *Which is the best?* This kind of question will be of secondary importance or even impossible to answer. The landscape needs to be drawn, knowledge gaps identified, for the design of blended learning, in civilian and military trauma. Educational design needs to integrate face-to-face, and online learning/teaching, into blended learning, and to make use of available innovative interactive technology in education.

International collaboration is highly prioritized due to the lack of experience and volumes of cases in countries. The educational challenges in Swedish military medicine are complex. The military medical system is based on more than two hundred years of peace, and is related to disarmament and the reduction of resources in both civilian and military medical systems.

This journey started by following the small footprints in Sweden, and sketching a landscape in Canada, Denmark, Finland, Norway, New Zealand, South Africa, United Kingdom and USA followed. An amazing international network was developed. Through close interaction, it has been possible to investigate educational challenges in civilian and military trauma care, described by international experts, armed forces medical services, healthcare professionals, educators and the learners. The design work has been performed through interaction with all the role players, using different methods such as interviews, video recorded resuscitations, and observations. Even if the drawing of the landscape is not fulfilled, the sketch is unique and very beautiful. Why? These perspectives have contributed to a holistic sketch of the landscape, with identified educational challenges, and provided an educational model for blended learning in trauma, including the use of design principles and virtual patients.

Challenges and learning are the drivers in life as well as during this journey. Although I have worked in many fields of emergency medicine, education, and innovation, the journey itself is the goal. It is time to make up plans and to identify new goals, but the journey has already started in my heart and mind. In the chapter “Ongoing and future work” you can read more about this. I intend to continue the drawing of the civilian and military trauma care landscape.

Wishing you a challenging and fun journey!

ABSTRACT

Violence in society is increasing, but action plans to mitigate this problem are insufficient in several countries. New educational strategies, such as blended learning which integrate face-to-face and online education are needed. Knowledge about how to design such strategies and learning environments can contribute to strengthening and coordinating medical resources, sharing competences and more collaboration in the development of civilian and military trauma care. The model in Nordic countries, of necessity share specialized healthcare professionals between the civilian and military medical systems. The overall aim of this thesis was to increase knowledge about the design of blended learning and builds on four studies:

Study I explored the similarities and differences in education and training at military medical services in the Nordic countries and to what degree blended learning was used. Results showed opposing views; some were negative to e-learning, whereas others were much more positive and saw potentials for innovating education. Contextual knowledge of healthcare was identified as the crucial key to success, but in order to blend education and training into blended learning, modern pedagogical competencies were needed.

Study II identified educational challenges in civilian and military trauma care, expressed by health care professionals and was studied through observations, interviews and survey during education. The most difficult aspect of learning in management of complex trauma patients was perceived as the lack of real practice in extreme environments. Blended learning was seen as the potential of supporting learning processes.

Study III, through interviews and video recordings investigated what internationally trauma experts described as challenging in teaching. Eight educational challenges were identified which represented particularly difficult aspects to teach and master in the area, and which were viewed as crucial for decision making. The results contributed as basis for identifying and introducing design principles for the design of virtual patients.

Study IV introduced these design principles, then developed and tested two virtual patients. The virtual patients addressed the specific educational challenges in complex trauma care, provided possibilities for unlimited training, and supported decision making. They were integrated with the existing face-to-face education into one example of a blended learning model.

Conclusions and implications: Key persons in the Nordic military medical systems, senior healthcare professionals and educators identify different and sometimes contradictory educational challenges and solutions, but share the view that there is an urgent need for developing education and training in the area. A particular mindset when managing complex trauma patients was identified as crucial by trauma experts. Two virtual patients were designed to address some of the challenges. Course participants appreciated the virtual patient cases and viewed them as realistic but expressed a need for more feedback. A pilot test confirmed that the decision-making in the cases posed challenging for the target group in the way the educators had predicted. Design principles and an educational model for blended learning for civilian and military trauma care are suggested.

LIST OF SCIENTIFIC PAPERS

I. Sonesson, L., Boffard, K., Lundberg, L., Rydmark, M., Karlgren, K.
The challenges of military medical education and training for physicians and nurses in the Nordic countries – an interview study.
Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine. 2017, Apr 11;25(1):38.
https://doi.org/10.1186/s13049-017-0376-y.

II. Sonesson, L., Boffard, K., Lundberg, L., Rydmark, M., Karlgren, K.
The potential of blended learning in education and training for advanced civilian and military trauma care.
Injury. International Journal of the Care of the Injured. 2018, 49(1):93-96
https://doi.org/10.1016/j.injury.2017.11.003

III. Sonesson, L., Boffard, K., Lundberg, L., Rydmark, M., Karlgren, K.
Decision-Making in Management of the Complex Trauma Patient: Changing the Mindset of the non-trauma Surgeon.
World Journal of Surgery. 2018. Jan 16. (Epub ahead of print)
https://doi.org/10.1007/s00268-018-4460-x

IV. Sonesson, L., Boffard, K., Lundberg, L., Rydmark, M., Karlgren, K.
Blended Learning for Complex Trauma – Design Principles for Creating Virtual Patients.
Submitted: Medical Teacher.

CONTENTS

LIST OF ABBREVIATIONS

ATLS	Advanced Trauma Life Support A trauma course developed by the American College of Surgeons for training doctors how the handle the trauma patient in the first hour after injury
BATLS	Battlefield Advanced Trauma Life Support An ATLS course, designed in the Netherlands and the United Kingdom, to provide ATLS in the military situation
DBR	Design-based research
DSTC	Definitive Surgical Trauma Care A course designed by IATSIC for the specific decision making, anesthetic and surgical skills required for the definitive management of the trauma patient after ATLS. It is provided in both military and civilian formats.
IATSIC	International Association for Trauma Surgery and Intensive Care
ISS	International Society of Surgery
PHTLS	Prehospital Trauma Life Support A course developed for the training of healthcare professionals to manage patients at the scene of injury

Definition of terms

For the purpose of this thesis, the following terms are defined:

Austere environment medicine: An area that regularly experiences significant environmental hazards (e.g. cold, heat, remote situation), or deprivations (e.g. shortage of water or supplies) that would exacerbate existing medical conditions, and when the resources for protection against these hazards is not routinely available.

Blended learning: The combination of face-to-face learning/teaching and knowledge about design integration of online instructional components. In this thesis, the term is linked to sociocultural learning theory which also is one of the roots of the trialogical learning approach.

Civilian medicine: The practice of medicine as is normally implied in the civilian environment, such as cities, and countries not at war, and applying to those injuries commonly seen in that environment (such as road traffic crashes, falls, etc)

Complex trauma: Trauma injuries are considered as "simple" if only one body system is involved, and "complex" when there is injury to more than one body system. Advanced techniques are required to sustain the physiology of the body, and are applied when the complex injury results in potential for loss of life.

Design principles: Design principles are sets of generally applicable laws, rules, and guidelines that guide the detailed design decisions you make as you are working on a project, all of which reflect the accumulated knowledge and experience of practitioners and researchers. They serve as a starting point for the creation of new designs to solve problems. Design principles usually combine developments across all design-related disciplines, including behavioral science, sociology, physics, and ergonomics. Design principles can be general and specific.

Decision making: Decision making is the selection of a course of action amongst several alternative possibilities, during the sequence of decisions needed to be made when treating a patient.

Disaster medicine: Disaster medicine is a systems oriented-specialty, in which the provision of medical services and care, occurs in a situation of sudden and unexpected demand, and which then exceeds the ability of delivery of those services or care within the resources available.

Education: In this thesis education is defined as the process of alteration or improvement of an intellectual reasoning and thinking in a particular field.

Humanitarian medicine: Humanitarianism drives people to save lives, alleviate suffering, and promote human dignity in the middle of man-made or natural disasters, or systems of poverty, providing medical care on a large scale to the world's economically deprived people. Humanitarian medical values transcend the differences between medical care in conflict, and those arising from poverty or natural disasters.

Military medicine: Military medicine is often defined as the practice of medicine as applied to the special circumstances associated with military operations and includes areas such as emergency medicine, traumatology, psychiatry and preventive medicine during extreme conditions. Here the concept refers to the planning and practice of the medical (typically surgical) management of complex trauma cases resulting from the use of military weapons, and from within the military environment. It includes the logistical and administrative considerations of establishing and operating combat support hospitals.

Training: The process of alteration or improvement of a physical skills-set for a particular dexterous task.

Trialogical learning: The characteristic of trialogical learning is that learners are collaboratively creating, developing or transforming a "shared object of activity" in a systematic fashion. The shared object can be something concrete like a document, article, report, model, prototype, product or it may be a practice. It has sociocultural learning as one of its roots and especially emphasizes learning as a process of knowledge creation, highlighting mediated processes in which an object is collaboratively developed.

1 INTRODUCTION

1.1 EXTENDED CIVILIAN AND MILITARY COLLABORATION IN COMPLEX TRAUMA

In times of change, with increased threats, an extended civilian and military collaboration in disaster medicine and trauma are prioritized in several countries. There is ongoing work to develop action plans to meet the new demands and strengthen the effects of medical resources in societies, focusing on sharing competences and coordination resources [1, 2]. The Nordic countries are characterized by having a model sharing specialized healthcare professionals between the civilian and military medical systems. The healthcare professionals constitute the basis that makes the medical system work [2]. Expertise and knowledge in management of complex trauma patients are essential but there is a lack of expertise, and knowledge, due to low volumes of complex trauma cases. One of the strengths of military medicine is the experience and knowledge about complex trauma [3-5]. Development of national education and training programmes has been highlighted as crucial, as well as research and innovation [1, 2]. In Sweden the number of full-time military healthcare providers is limited, and extensive use is made of physicians and nurses whose main area of work is within the civilian sector. Hospitals in Sweden do not always support education and training in the field, by failing to release time for further training of physicians and nurses. This places great constraints on the requirement for such education and training [4, 6]. A core challenge internationally, as well as in Sweden, is to identify educational methods which also cover team training in the areas [2, 6]. Internationally, the development of education and training also focuses on extended civilian and military collaboration; new strategies and innovative methods are needed in order to meet new demands, and as support for learning and teaching [7].

2 BACKGROUND

2.1 MILITARY MEDICINE

Military medicine and complex trauma, are areas which are largely of a practical nature and not to a high degree research based. One reason for this is that access to data may be restricted [4]. Military medicine is often defined as the practice of medicine as applied to special circumstances associated with military operations. Here the concept refers to the planning and practice of the medical (typically surgical) management of complex trauma cases, and the logistical and administrative considerations of establishing and operating combat support hospitals [8]. The International Committee of Military Medicine (ICMM) defines the term as including research, emergency medicine, traumatology, psychiatry and preventive medicine, both in conditions of war, and in times of peace [8]. Military medicine is characterized by its interdisciplinary basis including two different cultures, requiring interaction with various administrative authorities. Military medicine significantly differs from complex trauma or emergency care in the civilian context by the extreme environment and conditions. Specific issues affecting military medical work may be: ongoing arms fire, darkness, extreme cold or heat, shortcomings in available medical equipment and other resources, and tactical constraints in the form of delayed transport to hospital [4]. In addition, a double hierarchy may be present (medical skills vs the military rank structure).

2.2 EDUCATIONAL CHALLENGES

In several countries, both in civilian and military medical settings, there is a need to develop common educational and training methods, to enhance the capability of managing complex trauma cases, including mass casualties [1, 4, 7, 9]. Civilian healthcare has changed significantly in recent decades through ongoing specialization of medical personnel, at the expense of narrowing the range of experience to which health professionals are exposed [4, 5]. While most surgeons are well trained for a certain kind of surgery in advanced settings, they may have little experience and preparation (and with limited resources available), for managing and treating multiple patients with injuries from high-energy projectiles and blast wounds from explosives [10]. Such injuries are different from those seen in civilian trauma centres, yet there is a need for competence in managing such situations in the case of large scale accidents or terrorism. Competence in complex trauma care is crucial in military medicine and the civilian medical system could benefit from collaboration with military medicine where training for such care is prioritized. Previous studies have shown that educational challenges to take into consideration when designing courses, is to support health professionals by providing visualization and training in the extreme environment which they will need to be able to work in [4, 11]. The lack of medical equipment, resources and collaboration with external professionals have been shown to be most important because this differs from what health professionals are used to at their home hospitals. Senior health professionals as the target group for pre-deployment education and training in the Swedish Armed Forces does not need to practice their medical skills [4]. The educational design needs to make use of innovative educational methods which support visualization of the environment and stimulation of their thinking in how to make use of their professional competences, but in a new and extreme environment [12, 13].

International courses like Advanced Trauma Life Support (ATLS) [14], Prehospital Trauma Life Support (PHTLS) [15], Battlefield Advanced Trauma Life Support (BATLS) [16] and Definitive Surgical Trauma Care (DSTC) [17] for medical providers in the management of trauma cases, have been developed during the last years, all with the goal to teach their target audience a simplified and standardized approach. ATLS is available to more junior doctors, especially in the civilian sector. The Swedish Armed Forces provide BATLS and DSTC to physicians and nurses as a part of a program in military medical education and training. These international courses provide medical simulations to support the visualization of the extreme environment and training of standardized decision making but in limited extent. Online learning or teaching is still limited, and the educational tradition is historically characterized by didactic performance [12, 13, 18]. There is a need to use digital technologies to be able to release time and to support healthcare professionals in their acquisition of special skills and preparation for professionalism during extreme conditions. Even if extreme conditions are difficult to visualize in conventional educational environments, digital technologies in combination with different educational methods and media can contribute to such understanding and preparation [12]. There is a lack of knowledge about how to design and integrate face-to-face with online learning/teaching [19, 20].

2.3 BLENDED LEARNING

Blended learning is a term referring to an educational approach which has been much discussed since the late 1990s. There is a broad range of different concepts in the area of blended learning such as: online learning/teaching, information and communication technologies and technology-enhanced learning, which is similar [13, 19, 20]. This range of concepts has been developed in relation to the rapid development of technology. The concept of blended learning, in its simplest form, is defined as the combination of face-to-face (physical) and online (virtual) learning environments and methods [20-24].

Different types of blends

Blended learning is about a mixture of instructional modalities, delivery media, instructional methods, and web-based technologies. Blends of instructional modalities usually include a balanced mixture of onsite, web-based, and self-paced learning [20, 21, 23]. To make blended learning more powerful, educators can blend various media delivery types, for instance, classroom trainings, seminars, web-based course, computer simulations, books and study guides [25]. In most cases, blended learning is designed with the use of synchronous and asynchronous web-based technologies, such as chat rooms, wikis, threaded discussions, virtual classrooms, instant messaging, computer conferencing, and blogs [19, 20, 26]. Incorporation of new pedagogies, learning theories, and instructional methods transform conceptual models of teaching and learning in blended learning environments [23, 24, 26, 27]. The choice of a blend is usually determined by several factors: the nature of the course content and instructional goals, student characteristics and learning preferences, instructor experience and teaching style and online resources [12, 20, 28].

There is extensive research, literature and statements of blended learning, indicating its success and the pitfalls in education and training [11, 19, 28]. The main focus in the research has often been comparisons between online and face-to-face learning with focus on learners' (students') perspectives and learning in blended environments [19, 20]. The extensive research results about the learners' perspectives, in an emerging field such as blended learning, contribute to important knowledge for educators (teachers/instructors) but needs to be complemented also by the educators' perspectives because of their significant influence on learning and development of education and training. There is a lack of research on the educators' perspective and on how to design blended teaching to include online elements [11, 20, 23]. Complexity in blended learning arises when educators choose to implement the blended learning approach and need to address varied discipline and professional learning outcomes, as well as creating an effective pedagogy, by using the strengths of face-to-face and online settings in an integrated fashion [20, 28]. Face-to-face teaching has a long tradition and educators therefore have strong historical and personal experience of face-to-face teaching and learning, which is reflected in their beliefs about teaching and deeply embedded in their practice [20, 24]. The development of blended learning has reached the stage when younger educators already use online elements and technology as an integrated part of their communication and interaction, but there is a lack of research about their perceptions on blended learning [20].

The development of blended learning has not taken place to the same extent in the field of military medicine [11-13]. There are examples of online interactive scenarios such as the "moulages" at trauma.org developed specifically for complex trauma care, and which are useful also for military medicine [29-30]. The NATO Centre of Excellence for Military Medicine has developed e-learning courses to support distance learning in military medicine [31]. The International Committee of the Red Cross is another organization that has developed e-learning to assist healthcare personnel deploying into armed conflicts and other emergencies. These courses are mainly distance courses offering interviews with experts in the field and various learning activities [32]. Studies have shown that blended learning appears to be a suitable tool to complement traditional teaching in disaster surgery [33]. A blended learning approach used in disaster surgery training, effectively improved participants' confidence in competency achievement and reduced perceived needs for further training. A civilian and military case study on the implementation of blended learning in cultural education and training highlight the importance of blended learning [34]. The results showed that key conditions for the effective use of this form of teaching are well-prepared virtual didactic materials, such as teaching modules, and an appropriate combination of resources and tools for synchronous and asynchronous communication [12, 13].

A key issue to the success of blended learning is knowledge of the design itself. Results have identified a knowledge gap in research regarding design, how to integrate face-to-face with online learning/teaching and as support for collaboration [11, 19, 20, 23]. Research and literature on blended learning often compares face-to-face with online learning/teaching, but there is less research going beyond such comparisons, or investigating the key issues in blended learning such as knowledge about integration between the two environments [19, 20, 35]. Previous studies have shown that knowledge of

how to design a blended learning model contributed to a learner-centered and technology-mediated learning, focused on knowledge construction, authentic activities and social interaction [20, 23, 24, 36, 37]. Blended learning incorporating learning theories, as in previous results, also contributed to change the role of the educator to one which is more facilitative as well as emerging the role of course design and the challenges of developing an integrated learning design [20, 23, 38].

New innovative educational strategies and design-based research are needed on the effects of task complexity, and other design features on performance, to be able to contribute to an easy and daily use of digital technologies in education and training [19, 37-39]. Innovative educational strategies design support learning processes, flexibility and mobility to be able to meet new educational challenges in societies [19, 20, 35, 37].

2.4 USING VIRTUAL PATIENTS TO PRACTICE DECISION MAKING

Virtual patients (VPs) are computer- and web-based programs that simulate real-life scenarios or authentic cases. The learner acts as a healthcare provider to obtain a history, conduct a physical exam and make diagnostic and therapeutic decisions [40-43]. Virtual patients have been used for decades in medical education, but often focus on students at a basic level in their medical education. Studies about virtual patients as support for senior health professionals in reasoning and decision making are still rare [45]. There are several different kinds of virtual patients in medical education and different kinds of taxonomies have been suggested to describe them [41, 46]. Linear and branched taxonomies are the most common ones. A virtual patient with a linear structure consists of predetermined steps, as opposed to branched structure which allows the case in a virtual patient to change based on the learner's performance during the case [46]. Virtual patients can be used in different ways and educators are encouraged to explore the multitude of uses to which virtual patients can be applied, and the ways in which activities can be constructed around them. Different kinds of activity can employ different kinds of virtual patients, of varying levels of complexity [43, 44, 46, 48]. Previous studies have shown that virtual patients should be designed and used to promote clinical reasoning skills, but there is still a need for research on how to effectively use virtual patients [42, 43]. The opposing forces of increased training expectations, and reduced training resources were highlighted as having a great impact on health professionals' education [48].

2.5 THEORETICAL FRAMEWORK OF TRIALOGICAL RESEARCH

Research has shown that incorporation of new educational concepts, learning theories and instructional methods contributed to the transformation of conceptual models of teaching and learning in blended environments [23, 49]. The trialogical approach in learning theories, in combination with digital technologies, supports the processes of knowledge creation where some parts could be developed collaboratively [37, 51]. An example of a trialogical approach could be using a web-based wiki during a course, but in collaboration, also developing the content in wiki as one part of an assignment in the course. A typical characteristic of trialogical learning is that learners are collaboratively creating, developing or transforming a "shared object of activity" in a systematic fashion. The shared object can be something concrete like a document, article, report, model, prototype, product or it may

be a practice [36]. The trialogical approach to learning was introduced as a concept around 2004 in a series of articles [39, 51. It has sociocultural learning as one of its roots but especially emphasizes learning as a process of knowledge creation highlighting mediated processes where some object is developed collaboratively [49]. It builds on the work of a number of theorists who have contributed to work on "knowledge-creation", i.e., knowledge advancement and the pursuit of newness and innovation [49, 52, 53] and on students' "knowledge-building" with educational technology [54]. The trialogical approach to learning consequently in particular emphasizes collaborative creation of knowledge with the use of digital tools. Such tools are often incorporated in our communication culture, supporting interaction and activities [23, 39, 49, 54]. This theoretical framework aims at analyzing such learning but it also has a clear aim of developing educational models for supporting and encouraging such collaborative learning. Specific design principles have been created based on the trialogical approach with the aim of supporting educational design fostering collaborative learning and purposeful innovation with digital tools [39]. By anchoring the development of blended learning in a trialogical approach a contribution may be made as support for designing education and training in civilian and military trauma care.

3 AIM OF THE THESIS

The overall aim was to increase knowledge about the design of blended learning for civilian and military trauma care.

The first objective was to study the educational challenges in the appreciation of complex trauma as described by subject matter experts representing the armed forces medical services, educators and health care professionals (Studies I, II, III).

The second objective was to develop design principles and designing virtual patients as support for a blended learning model aimed for education and training in trauma care (Study IV).

The specific aims were:

Study I	The study described how education and training in military medicine for health professionals was organized in the Nordic countries, identified specific challenges and investigated to what degree blended learning was utilized.
Study II	The study took the learners' perspective and focused on their learning experiences. It analyzed the educational challenges as expressed by senior health professionals, and investigated the potential use of blended learning in civilian and military complex trauma care.
Study III	The study took the educators' perspective on teaching. It aimed to study what trauma experts described as challenges in teaching and training, specific to surgical decision-making, and their beliefs about the typical problems that non-trauma surgeons may encounter. Baseline for introducing design principles and virtual patients.
Study IV	The study aimed to contribute knowledge of how to design blended learning for civilian and military trauma care, addressing the specific challenges in complex trauma education and training by the support of virtual patients.

4 DESIGN AND METHODOLOGY

4.1 RESEARCH APPROACH

The research approach was distinguished by the DBR approached in studies I-IV. Figure 1 shows the studies in relation to the DBR steps and iterative processes. The figure is inspired by how Reeves' contrasts design-based research with predictive research Reeves, T.C. (2006) [55] but modified to reflect this thesis and the different studies have been added to relate these to the steps of the overall process.

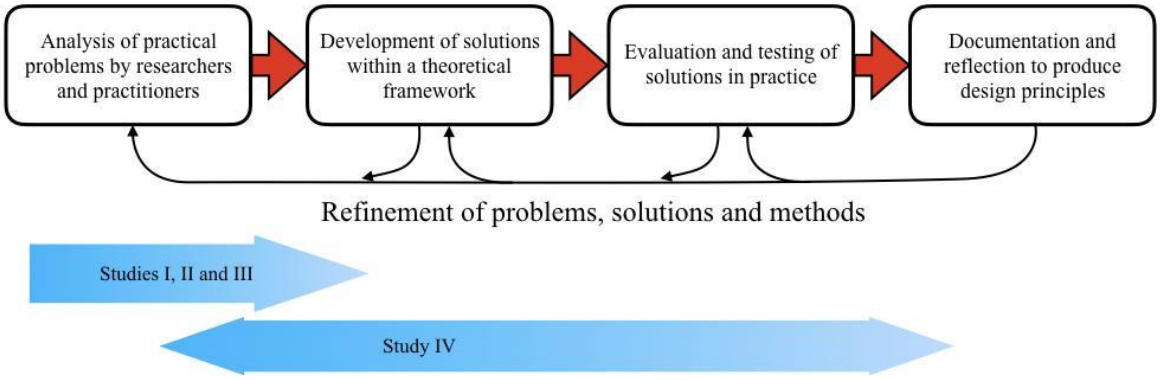

Figure 1. *The studies in relation to the different steps and iterative processes of Design-based research. Source: Reeves, T.C. (2006).*

4.1.1 Design-based research

Design-based research (DBR) is a research approach which focuses on complex problems, aims to understand the world of educational practice, and takes place in the real-life setting, where learning normally takes place. Characteristics for DBR research is the use of research methods in close interaction and collaboration with practitioners [38, 56, 57]. The practitioners' needs are in focus and researchers support this by identifying the needs and together with the practitioners, try out different kind of solutions to the needs in iterative cycles. DBR research as an approach often consists of a design where research, theory and practice are intertwined in the studies. Within the DBR research approach, design principles often are used and can be useful as a shared language in interdisciplinary development and research, as support for identifying, testing, and validating interventions or innovations in education and practice. More design-based research on the effects of task complexity and other design features on performance has been called for, to be able to contribute to the easier and more frequent use of digital technology in blended learning [55, 57].

4.1.2 Design

The research project has largely been a qualitative project. The studies have been descriptive in nature aiming at understanding and explaining the underlying challenges and tensions which may affect learning, and the educational design for the target group. The research has been conducted for the sake of increasing and advancing the knowledge base but also to serve as a basis for the design work that followed. The research has been participatory to a high degree. Whereas studies I-III were descriptive and used interviews,

questionnaires, collaborative walk-through authentic cases, study IV has had more focus on design work and developing prototypes for virtual patients. The last part has, however, also included engaging stakeholders in the design work through letting experts/educators verify the content of the design proposals, and through evaluation within the target group, as well as studying the resulting log files from such tests.

In the present thesis, a research design combining several different methods for data collection was chosen: semi-structured interviews, observations, and video recorded resuscitations at a civilian trauma centre with the video recording serving as documentation and the basis for reflections and participant checking. The semi-structured interviews were an appropriate method when studying complex problems in the military medical educational setting, because the method combines a predetermined set of open questions with the opportunity for the interviewer to explore particular themes or responses further [58, 59]. Observations were chosen as one of the methods used, to assist in understand the setting of the studies II-IV and to be able to study the interaction between learners and educators, and learners to learners more closely and naturally. Observations gave immediate access to the reality [59], which in this case was the setting of the military version of the international DSTC course. By triangulating different methods in a DBR research approach, a deeper understanding about underlying causes was achieved. Each method contributed with different perspectives in relation to the research question and a holistic picture showing the complexity of educational challenges in civilian and military trauma care was conveyed [59]. An overview of the research design for studies I-V is presented in Table 1.

Table 1: Overview of the research design for studies I-IV

Study	Focus	Participants/source	Setting	Data collection	Analysis
I	How education is conducted in military medicine and the use of e-learning	Eleven key persons from military medical units served as officers at the rank of major or above	Military medical units in Denmark, Finland, Norway and Sweden	Interviews were performed in each country	Qualitative content analysis according to Graneheim & Lundman (2004) and Elo & Kyngäs (2008)
II	Learners' experiences of challenges in military medical education	51 physicians and nurses who participated in a DSTC course Eleven participated in interviews: six surgeons, two anesthesiologists and three specialized nurses	Military version of the DSTC course	Course survey Interview study Post-course survey	Qualitative thematic analysis according to Braun and Clarke (2006)
III	Educators' experiences of educational challenges of non-trauma professionals	Eleven international trauma experts	International network, the IATSIC* and the senior instructor faculty of DSTC The DSTC course	Three set of interviews with an applying a think-aloud method Video recordings of resuscitations at an academic trauma centre	Qualitative thematic analysis according to Braun & Clarke (2006) and DBR according to Wang & Hannafin (2005)

IV	Design of virtual patients	Results from S2 and S3	International network, the senior instructor faculty of DSTC. The DSTC Course Web-based VP system	Two sets of interviews Virtual patients Log files from the VP system Survey	DBR, Design principles according to Wang & Hannafin (2005) and Goodyear (2009)

4.2 THE SAMPLE OF PARTICIPANTS AND SETTING OF THE STUDIES

Figure 2 illustrates a conceptual model showing the overlapping perspectives of military medicine, trauma, medical education and military medical education and training.

Figure 2. *Conceptual model showing overlapping perspectives in civilian and military trauma care*.

4.2.1 Study I - Key persons at military medical branches in Nordic countries

In study I, eleven key persons (n=11) in military medical education and training in the Nordic countries were identified as sample of the study. The Surgeon General of each respective nation identified the respondents, provided military clearance and gave permission for interviews. The respondents were all serving as officers at the rank of major or above in the armed forces of Denmark, Finland, Norway and Sweden. Nine were male, two were female. The respondents held key positions as directors of studies and educators in the domain, military medical branches. The eleven respondents had background as

following: four physicians, three registered nurses and four non-medical personnel. All the respondents were involved in development of educational practice and policy.

4.2.2 Study II - Physicians and nurses as learners during education

In study II, the sample consisted of 51 physicians and nurses participating in education. Of the 11 respondents, who volunteered for semi-structured interviews, were six surgeons, two anesthesiologists and three specialized nurses. The respondents were working with trauma but lacked the experience of patient management in complex trauma or military medicine such as injuries from high-energy projectiles and blast wounds from explosives. The setting of the study was an international course, Definitive Surgical Trauma Care (DSTC) – Military Version. The course aimed at teaching techniques particularly applicable to the patient who requires surgery and intensive care for major trauma and was one of the courses in a pre-deployment programme in military medicine. The pre-deployment programme aimed at preparing physicians and nurses for work during extreme conditions in a military medical setting. The chairman of the DSTC international faculty and the international instructor and national course director were supportive when planning and performing the studies.

4.2.3 Study III - Educators represented by international trauma experts

In study III, the sample consisted of eleven international trauma experts (n=11) with profound expertise in trauma care, from Canada, New Zealand, Norway, South Africa, Sweden, United Kingdom, and USA. They were seen as experts because of their expertise and experience in the areas of civilian and military complex trauma care. The experts were active in education and research as well as in clinical practice on an international basis. The participating experts volunteered individually for interviews, and were recruited from the International faculty of the DSTC Course, with the support of the Chairman and National course director. The Course was designed, owned, and managed by the International Association for Trauma Surgery and Intensive Care (IATSIC), which is an integral part of one of the world's largest international surgical organizations, the International Society of Surgery (ISS), based in Zurich, Switzerland.

4.2.4 Study IV - Educators, learners and the project team

In study IV, the design work was performed in close collaboration and interaction with participants from three groups. One group with eleven (n=11) international experts in complex trauma was recruited from within IATSIC by the ISS Secretary-General, who supported the access to the field and reality. The other group consisted of twenty-one (n=21) physicians and nurses who were course participants in the military version of the DSTC course in June 2017. The participants were recruited with support from the national course director and the chairman of the DSTC faculty, who helped in providing access to the course setting and the respondents. Participation was voluntary. An open request to volunteer in the research project was communicated to the whole group of course participants (n=47) and twenty-one of these agreed to participate. The third group consisted of the project team with one PhD student, one medical informatician and four supervisors with complementary competencies such as: education, complex trauma, military medicine, medical informatics and human-machine interaction.

4.3 DATA COLLECTION

In this thesis a research design combining several different methods for data collection was chosen: observations, semi-structured interviews, surveys, video recordings and logfiles during the design work according to World Medical Association Declaration of Helsinki [60, 61].

4.3.1 Study I - Semi-structured interviews within military medical branches

Data in study I was generated from eleven semi-structured interviews during December 2015 to March 2016 with key educators at military medical units. The interviews explored the similarities and differences in education and training in military medicine for health professionals in the Nordic countries and how e-learning was used in education and training. Information about the study was given both verbally and through an information letter by the Surgeon General of each nation and then contact was established by the researcher through mail and phone. The interviews were conducted face-to-face in Denmark, Norway and Sweden while the interviews in Finland were conducted through teleconference. Iceland was excluded as the country does not have military service. The interviews were semi-structured and the questions asked were open-ended. Questions in the interview guide were structured into topics related to the aim and every respondent were asked the same set of questions, but the openness in semi-structured interviews also allowed diverting and new thoughts or ideas to be brought up during the interview. All interviews were recorded, transcribed, and the identities of the respondents were anonymized in the study by using a numbered code for each informant.

4.3.2 Study II - Observations, surveys, semi-structured interviews

Data in study II were collected from observations, survey and semi-structured interviews. The observations supported immediate access to the reality [59, 60]. Observation sessions were performed by the support of an observation protocol. Five observation sessions were performed during September 2015 and three observation sessions during June 2016. Data was also collected from one course survey and semi-structured interviews when respondents were participating in the DSTC Course – military version in September 2015 and one online post-course survey during March 2016. The time period chosen to conduct the online post-course survey was chosen taking into consideration to that several of the respondents were on international military medical duty.

The combined methods aimed to contribute to broad data but with deeper understanding of underlying causes. The observations supported a better understanding of the setting as well as underlying causes of educational challenges. The course survey described outcomes from the course while the interviews identified and described challenges in education and training and what kind of blended learning support was needed. Information about the study was given verbally by the course director and informed consent was collected in writing. The concept of blended learning was introduced during the interviews to initiate a

constructive discussion of its possible use. Blended learning as a concept was defined as using mixed educational methods including digital support in the educational and training context. The interviews were semi-structured and the questions asked were open-ended. Questions in the interview guide were structured into topics related to the aim and every respondent was asked the same set of questions but the openness in semi-structured interviews also allowed diverting and new thoughts or ideas to be brought up during the interview. All interviews were recorded and transcribed, and the identities of the respondents were anonymized in the study by using a numbered code for each informant. The online post-course survey focused on earlier experiences of advanced trauma care, the use of knowledge from education and training and the need for further improvement. The online post-course survey was conducted through email to 42 of the 51 participants and 21 responded. The discrepancy was due to the fact that nine participants could not be reached because of incomplete contact details.

4.3.3 Study III - Semi-structured interviews, video recorded resuscitations

DBR aimed to develop close interaction between researchers and the international trauma experts. The working progress of DBR in the study distinguished by iterative processes in cycles and findings were discussed and verified together with international trauma experts (Figure 3). Different methods were combined to collect data. Three set of interviews and one set of video recorded resuscitations at a major academic trauma centre were conducted between March 2016 until September 2017 [55, 59, 60]. The first set of semi-structured interviews focused on the decision process in complex trauma and was responded individually. A think-aloud method was used to lay bare the international experts' reasoning in decision making when going through authentic cases to focus on how they would like to solve the case, which kind of key decision points were seen as important and according to their experiences as educators, where would non-trauma professionals made the wrong decision and why [62, 63]. The pre-results showing outcomes from identifying educational challenges through authentic cases were presented discussed and verified with the experts and as basis for interviews of resuscitations. A second set of video recordings in combination with interviews in management of resuscitations at a civilian academic trauma centre were conducted with the purpose of identifying the findings also in clinical practice [64, 65]. The video recordings had ethical permission and there was no focus on the patient, the cameras were strategically placed to avoid the patient and focused on the interaction and communication in the team. Trauma team who volunteered in the study also performed the video recordings. Two of the international trauma experts voluntarily participated in video recorded resuscitations when managing complex trauma patients in reality and afterwards participated in follow-up interviews to going through the video sessions and reasoning about how they solved management of the patient and whether were possibilities to identify the educational challenges in clinical practice. The educational challenges and the decision making in complex trauma were verified by a third set of interviews with all the experts, focusing on teaching and training of less experienced surgeons [66, 67].

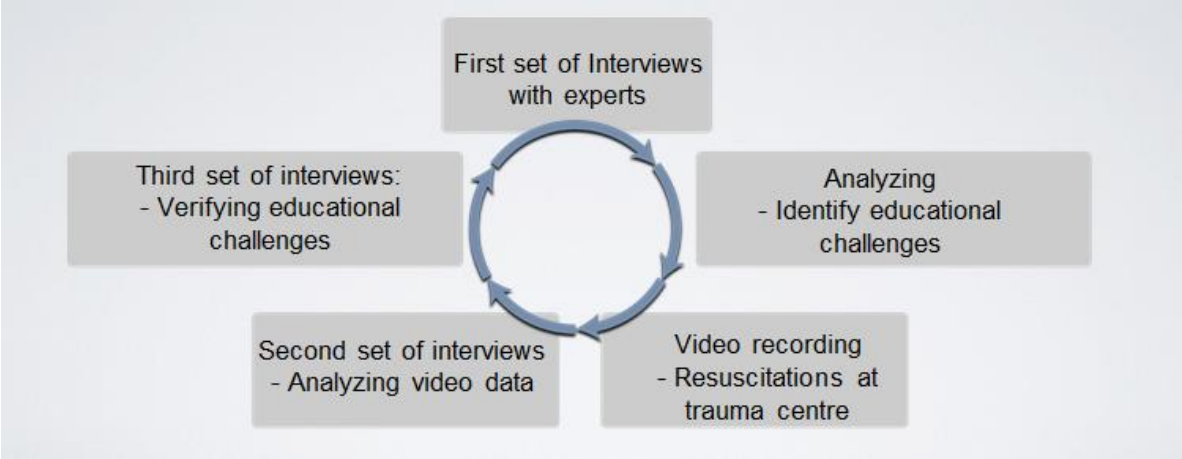

Figure 3. *The design-based research approach consisted of iterative processes and cycles in close collaboration between researchers and practitioners.*

4.3.4 Study IV - Log files, semi-structured interviews

Previous research studies (SII-III) gave input to the design process in study IV by making use of the data collected from observations, semi-structured interviews, surveys, video recordings, case descriptions and log files [59, 60, 65, 66. The data were reviewed and analyzed. The design work itself included numerous design meetings, workshops, interviews with the group of experts, as well as surveys and log files from users trying out the virtual patients. Trauma experts, researchers, PhD student and a medical informatician collaborated on the design work. The work focused on an overall level, the design of one example of how to integrate face-to-face and online learning into blended learning, aimed for the overall educational context. The work also focused in a specific context of complex trauma by designing virtual patients.

4.4 METHODS OF ANALYSIS

4.4.1 Study I - Content analysis

In study I, a content analysis was performed and outcomes from the analysis were six categories describing the similarities and differences in military medical education and training, the educational challenges for education and training and views on e-learning and technology-enhanced learning [68]. The focus in the analytical process was on the systematic procedure aimed to extract the main content of the transcribed interview data [69]. The transcribed data consisted of texts and was read individually and then discussed in the research group. Ideas of interest for the study were marked in the text, and ideas about what was in the data were written down. Meaning units were recognized, condensed, and abstracted into categories [68]. The categories were discussed and reviewed in relation to the coded groups of text and to the entire dataset. To ensure trustworthiness the specifics of each category were refined and discussed until agreement was reached in the research group. The analysis involved moving back and forth between the dataset, the coded text, and the ongoing analysis of the data. During the entire analysis process, discussions among the researchers were continually held to ensure rigor toward data and contribute to

coherence of the findings. The outcome of the analysis was grouped into six categories answering the three research questions about how education and training in military medicine for health professionals was organized in the Nordic countries, and to what degree blended learning was utilized [68, 69].

4.4.2 Study II-III - Thematic analysis

In studies II-III, thematic analysis was chosen because it aimed to identify and analyse patterns across the collected data sets, as well as implicated and explicated ideas within the data, capturing the intricacies of meaning within a data set, comparing to content analysis in previous study which was more detailed [70]. The total amount of collected data from several set of data sources: the DSTC course survey, semi-structured interviews during the course and the online post-course survey were transcribed for analysis. Each set of data was transcribed for analysis and the process was performed through four different phases; the texts were read several times, meaningful sentences were identified and mapped in relation to each other, and linked to the research questions. In study II the questions related to educational challenges as expressed by senior health professionals, and the potential use of blended learning in civilian and military complex trauma care. In study III the questions were related to challenges in teaching and training, specific to surgical decision-making and according to the experts' beliefs about the typical problems that non-trauma surgeons may encountered. To ensure trustworthiness outcomes from each analytical phase was discussed until agreement was reached in the research group. The analysis involved moving back and forth between the datasets and arranged into categories representing educational needs for improvement and the potential of blended learning according to the learners and educators [70].

Design-based research is distinguished by iterative processes in cycles and in Study III during close interaction with the international trauma experts in the analysis of each data set. The data sets were represented by a first set of interviews with international experts, going through cases in complex trauma. Data set from this cycle represented challenges in decision making, the decision making process and the mindset in decision making for complex surgical trauma. The material for analysis consisted of video recorded interviews. The video recorded interviews were transcribed into pictures and texts and linked to the research questions [64, 65]. Outcomes from the analysis identified eight educational challenges for teaching and training needed for decision making. The second and the third set of data consisted of the video recorded resuscitations and interviews with trauma experts at an academic trauma centre, and aimed to capture and verify the outcomes in clinical practice, the data was transcribed [64].

Outcomes from the datasets in study III were verified with the international trauma experts and to ensure trustworthiness outcomes from each analytical phase and the total amount of collected data was discussed within the research group until agreement was reached. The analysis resulted in a description of eight educational challenges related to decision making and specific for education and training in civilian and military complex trauma care.

4.4.3 Study IV - Design work

Gaining an understanding of the design problem is crucial in all design work. To develop an understanding of the design problem in this educational context, the previous research studies included observations, semi-structured interviews, surveys, video recordings and log files [59, 60, 65, 66]. A starting point for the design work was to analyze the perceived gaps in the non-trauma surgeons' competences, in close interaction with the educators in the field, while going through the authentic complex trauma cases which were used as material in the course. Outcomes from the analysis at this stage were identified as "key decisions points" for decision making of complex trauma patients. During face-to-face lectures the choice of a plausible, but incorrect key decision point could result in continued management of the patient, but at some point along the incorrect trail, complications as a result of the decision would result. The educators would then stop the discussion in the class, reinforce the reason why the decision path was incorrect, and return the management back to the correct decision making process. The design work of the virtual patients was developed from the key decision points and by making use of authentic trauma cases in to create cases which could stimulate reasoning in complex trauma. The inclusion criterion was that the authentic cases would be appropriate for both civilian as well as military medical settings. The cases highlighted the management and treatment of gunshot wounds and blast injuries. The case descriptions of authentic cases were converted into web-based virtual patients in which users were able to make decisions about examinations, tests and treatments of the trauma patients. The web based open source platform OpenLabyrinth was used for developing a branched case, and a linear case. The original cases described surveys of the patients, included images of the patient and presented a couple of key decisions, operative procedures and the final outcome. The structure of these cases was seemingly simple in structure, in one case the entire case description consisted in 14 PowerPoint slides including a title and question page (Figure 4). Converting such case descriptions however amounted to considerable work. A key issue here was to shift perspective by creating a virtual environment in which the user would be the main person in charge of the patient rather than just a passive onlooker or reader. This required creating an environment that allowed examining and relating to the patient in a more authentic manner. This put requirements on the presentation, such as using many more images. An important part of this shift of perspective also meant allowing users to choose what to do at a certain point rather than just follow a predefined sequence of slides. The complexity of the case thereby increased very rapidly. A screen dump showing the network of nodes and links between these nodes illustrates the complexity of the same case after conversion into a virtual patient case (Figure 5). In the network, each node represents a situation in which the users were faced with a new decision about how to proceed. As a goal was not to restrict the options of the users and instead enable possibilities to freely explore the consequences of suboptimal decisions, the network quickly grew in size. The design proposals were verified with the educators in iterative processes during the design work when developing the virtual patients. The design proposals were also tested and verified by the learners during participation in the course and the log files from that session was analyzed. Outcomes from the analysis of the log files showed how the learners used the virtual patients and what kind of choices they made and time spent at each key decision point.

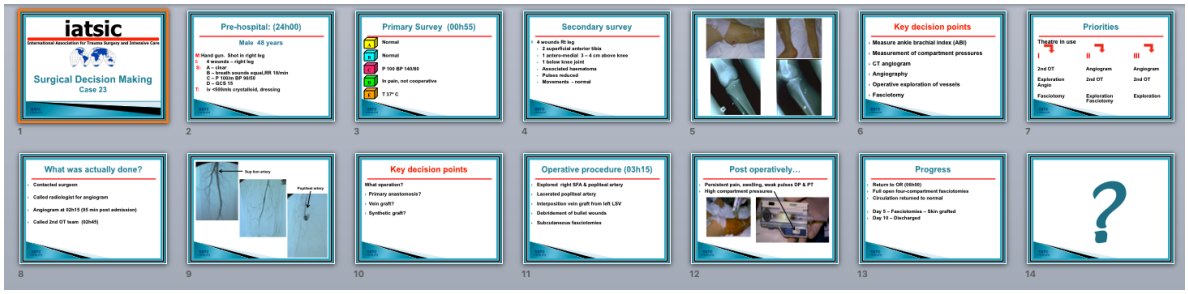

Figure 4. *The original case descriptions presented authentic patient cases in a simple structure; a sequence of PowerPoint slides. In this example, the entire case consisted in 14 slides and the patient was only shown in one.*

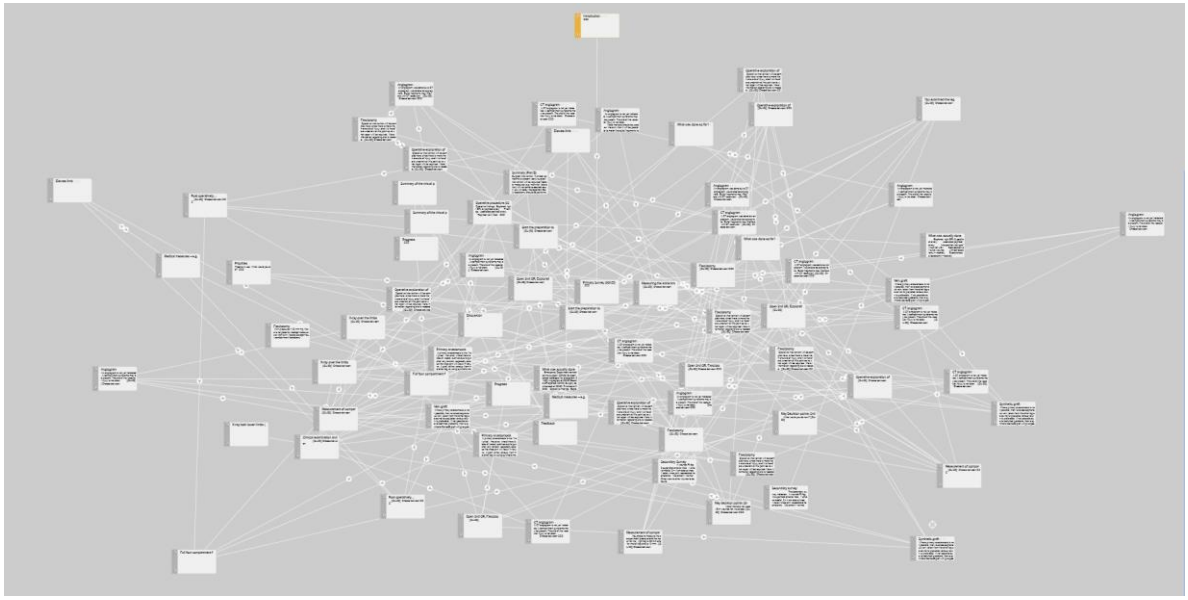

Figure 5. *The case rapidly grew in complexity when converted into a virtual case allowing users to explore different decisions and their consequences. Each node represents a situation in the virtual patient case and each link shows how users can make a decision leading to a new situation.*

4.5 Trustworthiness and credibility

To ensure trustworthiness and credibility of data analysis in the studies different data sources were triangulated and pre-results were member checked [59, 71]. Triangulation of data sources was carried out by using a variety of methods and to thereby illuminate different perspectives on the research problem. Combining different methods, enables a deeper understanding of the research problem. The methods applied for triangulation of the data sources were: observations during courses, semi-structured interviews and video recorded resuscitations at a civilian trauma centre with follow-up interviews [62, 64, 65]. Video recordings were also served as a tool for systematically verification through notes, reflections and basis for member checking. The pre-results were member checked with the trauma experts. Member checking is about presenting the findings to the respondents in order to check the accuracy of the researcher's interpretations and thereby ensuring validity.

4.6 Ethical considerations and approval

Research has followed international guidelines for research ethics [72] and has been performed, based on close dialogue and interaction with respondents in the studies as characterized for design based research. Respondents in the studies were neither patients

nor persons in vulnerable positions. Participation was voluntary, and the respondents were able to withdraw at any time. The research in this thesis does not process sensitive information in the sense of the Swedish Ethical Review Act. Written and verbal information about the research project and informed consent in relation to each one of the sub studies was communicated by papers and emails. The verbal information was given by key persons in each study setting and by the PhD student in relation to the research activities. The data were treated according to the Declaration of Helsinki (2013) and handled confidentially. Data are not attributable to any identifiable individual and a code-system has been applied to protect individual identities. The data have been saved on external hard desks and stored securely according to research guidelines but also in consideration of the military security guidelines. Only the research group and the PhD student have access to full data.

An ethical vetting was waived by the Ethical Regional Review Board in Stockholm, Sweden regarding the Swedish part in the research project (reference no: 2016/1701-31/5). In study I military clearance by the Surgeon General of each respective nation needed to be obtained and collectively identification of 11 respondents. The Surgeon General for each country and the respondents gave the permissions for interviews. The interviews were conducted in each one of the Nordic countries, except Finland which was conducted over phone. In studies II and III, the research permission for surveys and interviews was given by the international faculty of DSTC. In study III data were also collected from video recorded resuscitations at an Academic Trauma Center in Johannesburg, South Africa. An ethical application was waived the Ethical regional Review Board in Sweden, and permitted by the Human Research Ethics Committee (certificate number: M161113) of the University of the Witwatersrand, and the Research Operation Committee at Netcare Milpark Hospital (reference no: UNVI-2017-0005) in Johannesburg, South Africa.

5 FINDINGS

5.1 STUDY I - NORDIC EDUCATIONAL CHALLENGES AND VIEWS ON BLENDED LEARNING

The study explored the similarities and differences in education and training in military medicine in Denmark, Finland, Norway and Sweden. The study identified specific educational challenges described by key persons in the Nordic military medical system and investigated how e-learning was used in education and training.
An overall educational challenge was identified at the political and organizational level in the military medical systems, which influenced the opportunities and qualification of education. Lack of pedagogical competencies, from the organizational level to the personal level of educators and it mirrored the military tradition, oriented towards practical skills training. Results from the study identified gaps in methods of quality improvement and transferring outcomes from education into practice, as well as feedback of the outcomes to military medicine. It put great demands on educators and director of studies to be able to take responsibility for educational improvement without knowing if the education and training matched the need. An educational challenge identified on the political level was the models of recruitment and employment of health professionals. The political support and conditions for military medical education and training differed between the Nordic countries and affected the ability for health professionals to gain actual experience from the military environment. The Danish military medical personnel were more exposed to the extreme military environment through international missions compared to the Swedes, who lacked experiences of complex trauma and working during extreme conditions as a result of political decisions. Results from the study also confirmed the identified gap of lack of expertise and management of complex trauma patients in several countries and the need of international collaboration in education because of the lack of volumes in education and training as well. International collaboration was highlighted as important, especially on Nordic basis and through joint education and training. Extended collaboration in education and training as well as in research would support and accomplish specific courses, exchange experiences and knowledge as well as evaluating outcomes from joint education and international missions.

The views on e-learning or blended learning as potential support for learning and teaching as well as collaboration for joint programmes were seen as challenging, due to earlier pitfalls on the development of e-learning, and results from the study confirmed that blended learning or e-learning was underutilized in military medicine. Results from the study showed opposing views between the different kinds of responses. Some were quite negative to e-learning and viewed it as something taking time from actual practice, only valuable for rehearsing theoretical knowledge, whereas others were much more positive and saw the potential for innovating education. These opposing views were related to a lack of knowledge about e-learning or blended learning, and mirrored existing historical culture in education, characterized by face-to-face teaching. Technological support for training and practice were found in the field of medical simulation with digitized manikins. Technology was described by the few respondents with specific interests in technology and education, as having the potential for developing simulation scenarios and for electronic cases. Technology-enhanced learning through web-based scenarios as in virtual patients was

identified as of importance to provide health professionals visualization and preparation of the extreme military medical environment. The results highlighted contextual understanding and experience of healthcare as crucial factors for successful development of e-learning or blended learning (Figure 6).

Figure 6. *Thematic map showing identified educational challenges and views of blended learning as categories related to the research questions.*

5.2 STUDY II - THE LEARNERS' PERSPECTIVES ON EDUCATIONAL CHALLENGES

Study II identified educational challenges and views of blended learning in civilian and military trauma care according to senior health professionals, i.e., the learners in this context. The learners participated in education with the aim of preparing for work during extreme conditions either in civilian or military trauma care. The educational challenges therefore contributed with knowledge for the civilian and military medical system and the educators when designing education and training. The study also contributed with results describing what kind of online learning support was viewed as supportive for preparation and reflection or for releasing time, according to the learners. This kind of knowledge contributed to identification and ideas of what kind of online learning support would be suitable for the learners in civilian and military trauma care.

Education and training providing multidisciplinary team-training in the military medical environment was highlighted as most important by the learners, confirming previous studies, because the military medical environment is hard to visualize and understand in another way [4]. The need for practical team-training with medical equipment in extreme military medical environments was emphasized because of the lack of experience and limited volumes of complex trauma cases at home hospitals or during military operations.

The learners highlighted the need for extended team-training, focusing on communication and the importance of understanding roles and responsibilities, in relation to the military medical hierarchy as well as collaboration with other external actors or nations as important. The learners highlighted the lack of experience and knowledge of complex trauma care as the most difficult aspect of learning how to manage the complex trauma patient. Even though the learners were considered as knowledgeable in theoretical aspects of complex trauma management, they lacked personal experience of managing complex trauma cases. Cases presented during the course represented significantly greater complexity of injury, compared to those usually seen in hospitals and during military deployment. Limited time available for preparation and reflection during education and training was identified by the learners as one of the greatest challenges. The reasons cited included difficulties for the home hospital in releasing staff, associated with the reduced availability of specialist expertise for long period, which was also a challenge. The learners were mainly well-educated specialists and some of them also practicing researchers, and the limited time for preparation before participating in education was valuable and affected their opportunity of making adequate time available. Time for preparation before participating in education was related to be able to plan for a replacement at work, and to make use of the released time to be introduced to the new knowledge area. According to the learners, the long and intense days in large groups during the course, often made it difficult to follow the discussions. The time allocated for discussions and reflections was perceived as important, but inadequate. The learners had previous experience of e-learning in education and training, mainly as online learning, and highlighted the need for blended learning as support for education and training. Online components such as learning platform which included instructional films, scenario-based films, virtual patients, and multiple-choice tests as pre-tests, were identified by the learners as examples of how to blend education and training and release time for learning, reflection and collaboration.

5.3 STUDY III - THE EDUCATORS' PERSPECTIVES ON EDUCATIONAL CHALLENGES

Results from the study III contributed by identifying of educational challenges in teaching and learning of how to master the area of complex trauma for non-trauma surgeons, as described by the educators. The educators in this study had extensive international experience of education and training within civilian and military trauma care, contributed to the field as researchers and were involved in the development of international guidelines. As educators they had significant influence on the development of educational strategies and methods. Results from the study contributed with a new perspective on what is needed for managing complex trauma case. Decision making was regarded as especially central in education and training. According to the educators, a particular mindset is required for decision making when managing complex trauma cases which can be distinguished from what is normally the case in e.g. emergency medicine. Eight educational challenges were identified which represent particularly difficult aspects to teach and master in the area, and which were viewed as crucial for optimal decision making in the management of the complex trauma patient. The challenges were also ranked by the educators starting with the most difficult challenge for the educator to teach or for the learners to master (Table 2).

Table 2. Educational challenges in civilian and military complex trauma care verified by nine international trauma experts (E1-E9). "X" = Stated as an educational challenge, "(X)" = depends on the setting, "–" = No educational challenge.

Educational Challenge	E1	E2	E3	E4	E5	E6	E7	E8	E9
1. Thinking physiologically	X	X	X	X	X	X	X	X	X
2. Damage control surgery	X	X	X	X	X	X	X	X	X
3. Priorities and time management	X	X	X	X	X	X	X	X	X
4. Impact of environment	X	X	X	X	X	X	X	X	X
5. Managing limited resources	X	X	X	(X)	(X)	X	X	X	(X)
6. Lack of general surgical skills	X	X	X	X	X	X	X	X	X
7. Different cultural behavior	X	X	X	(X)	–	–	–	–	(X)
8. Ethical issues	X	–	X	–	–	–	–	X	–

Thinking physiologically was ranked as the most difficult and important of the identified educational challenges, when it came to both teaching and learning complex trauma. The physiology of a critically ill trauma patient determines the priorities in management, and was therefore seen as most important to learn. According to the educators the pitfalls for non-trauma surgeons in education and training were related to the lack of knowledge and experience about the nature of complex trauma. Initially the focus should be to think physiologically, and to avoid becoming overly obsessed with the exact nature of an injury to a specific organ. The educators described the non-trauma surgeons as often being

"anatomical" in their thinking and the risk of "compartmentalization" in their reasoning about the patient as they tended to focus excessively on a specific organ. Several non-trauma surgeons were accustomed to elective surgery on a physiologically stable patient with focus on a specific part of the body. A patient suffering from complex trauma may however be physiologically affected due to, e.g., high energy from a gunshot and massive bleeding. A narrow focus on the treatment of specific organs in such a case is not adequate until the physiology of the patient is under control.

Damage control surgery - An approach to surgical management which aims to minimize the physiological insult, by doing only the immediate surgery required, such as stopping the bleeding in a shocked patient, and controlling contamination. The patient is then resuscitated in the Intensive Care Unit (ICU), and all remaining and definitive surgery is deferred to later. This contradicts normal surgical convention which dictated that the surgery should be fully completed at the initial operation. The challenge in stimulating and teaching the learners to extend their reasoning into the broader physiological perspectives was considered as important to fully understand the concept of damage control surgery. This challenge represented the surgical solution to a physiological problem, used by specific approaches and techniques.

Priorities and time management constituted the different interpretations of priority of care in the understanding of "when to wait, and when not to wait" and was regarded as central by the educators and related to the mindset in decision making. The challenge for learners in education and training was to start treating the patient without knowing precisely what was wrong, without having the confidence and knowledge to use the limited time well. According to the experts, the learners tended to overdo the management and treatment of the complex trauma patient which resulted in lack of valuable time needed to save the life of the complex trauma patient.

Impact of environment in the extreme military medical environment was hard to visualize, and therefore difficult for learners to relate to. The challenge for non-trauma surgeons seemed to be twofold: to work during extreme conditions, and to understand the impact of an extreme environment on the physiology of the complex trauma patient.

Managing limited resources was identified as a challenge for the mindset in the decision making during time pressure. The learners were used to the situation at their civilian hospitals, with some redundancy regarding personnel and medical equipment. In a military medical setting these resources are limited, and the educators maintained that the learners had difficulties in learning how to adapt to such situations.

Lack of general surgical skills were highlighted by the educators according to the increasing subspecialization and use of high-tech equipment in elective surgery. The lack of equipment and general surgical skills becomes most challenging in the military medical environment. This puts a great demand on the non-trauma surgeon to be able to apply general surgical skills with confidence, when otherwise using mostly highly specialized elective techniques.

Different cultural behaviors could be challenging for the educators, when performing education and training in different countries but the most substantial challenge was to be able to handle subcultures in multidisciplinary groups. The learners in the DSTC military version course were multidisciplinary with different professional backgrounds in relation to the focus of surgical complex trauma care.

Ethical issues were stated as highly important - to always do the best for the most, no matter whether it is to treat or to palliate. A challenge expressed by the educators was that the learners needed to deal with ethical challenges beyond those which they are accustomed to in usual healthcare, but which had not been highlighted in the content of the education. The results from the study with the identified educational challenges contributed as basis for identifying and introducing design principles for the design work of virtual patients in study IV.

5.4 Study IV - Design of virtual patients for a blended learning environment

Two virtual patient cases were designed and developed on the basis of authentic cases and in iterative process with close collaboration with trauma experts and teachers: one about a gunshot injury (branched) and another about a blast injury (linear). The design work made use of some of the previous course materials but specifically addressed the challenges which have previously been voiced by senior health professionals participating in the courses as well as by the trauma experts. A particular focus was on creating challenging decision making tasks in the complex trauma cases (Figure 7). A number of design decisions have guided the design work.

The most important design principles were *Striving for a sense of presence in a realistic scenario*. Efforts were made to support the user's experience of being a health professional managing a trauma patient throughout the decision-making in the case and not being unnecessarily disrupted.

Another principle was *promoting agency for the user as a decision-maker*. The design strived to create conditions for the user to practice the role of being an active decision-maker and not restricting possible options throughout the case and thereby allowing explorations also of unexpected or suboptimal decisions.

A third principle was *fostering reflection and interaction*; asking users to comment on their decisions in free text just as they are about to make the decision was intended to foster reflection.

Lastly, *providing feedback* to the user on their performance was a key issue throughout the development project and different types of feedback were considered. One solution was to provide both standardized, overall comments about the entire case at the end combined with individualized feedback on the individual user's choices regarding a limited number (2-4) of key decisions in the case.
The virtual patient cases were presented for the trauma experts to verify the contents of the

cases and that these addressed the previously identified challenges of thinking in terms of physiology (rather than anatomically) and considering priorities and time management. While there was agreement that the cases addressed certain challenges (dealing with the impact of the environment and managing limited resources in trauma care) other challenges were not addressed (dealing with ethical challenges).

To further evaluate the virtual patients, these were tested with participants who considered them realistic and appreciated them for providing opportunities for practicing decision-making in complex surgical trauma cases. The target group were also satisfied with the feedback but would have preferred more individualized feedback. The open, branched structure was also appreciated.

The experts had expectations about what would be challenging for non-trauma surgeons and in which parts of the decision making process they would make wrong decisions. These expectations were used to construct the options (choices) at critical decisions in the cases. The users paths through the virtual patients can therefore be analyzed to study whether the users in fact do have problems with in the way that the educators expect. Results from analyzing the log files show that half the participants manage to complete the case on their first attempt and between 65% - 80% manage to choose the most optimal options at the critical decisions. However, as low as only 50% only managed to choose the optimal option on their first try indicating that the virtual patient cases pose challenges for the target group and have the potential of being meaningful exercises. Analysis of the users' paths through the virtual patients' needs to be analyzed further in greater detail and in more cases. Previous studies identified gaps in the design of blended learning and integration of face-to-face learning with online learning [19, 20]. The results from the design work contributed to the knowledge about design of blended learning as support for senior health professionals during education in civilian and military trauma care, and specifically about virtual patients as support for learning.

The findings, together with results from previous studies, served as input when developing design principles for blended education in the management of complex trauma patients. These were on the one hand the design principles mentioned above guiding the design of the virtual patients and on the other hand design principles guiding the educational design of blended learning for education in complex trauma care. The study resulted in the development of a blended educational model based on the principles, the two virtual patients, and the theoretical framework about trialogical learning and its design principles. The digital component of the blended model were the virtual patients offering flexible learning opportunities in the area of military medical environment avoiding some of the limitations associated with traditional face-to-face teaching.

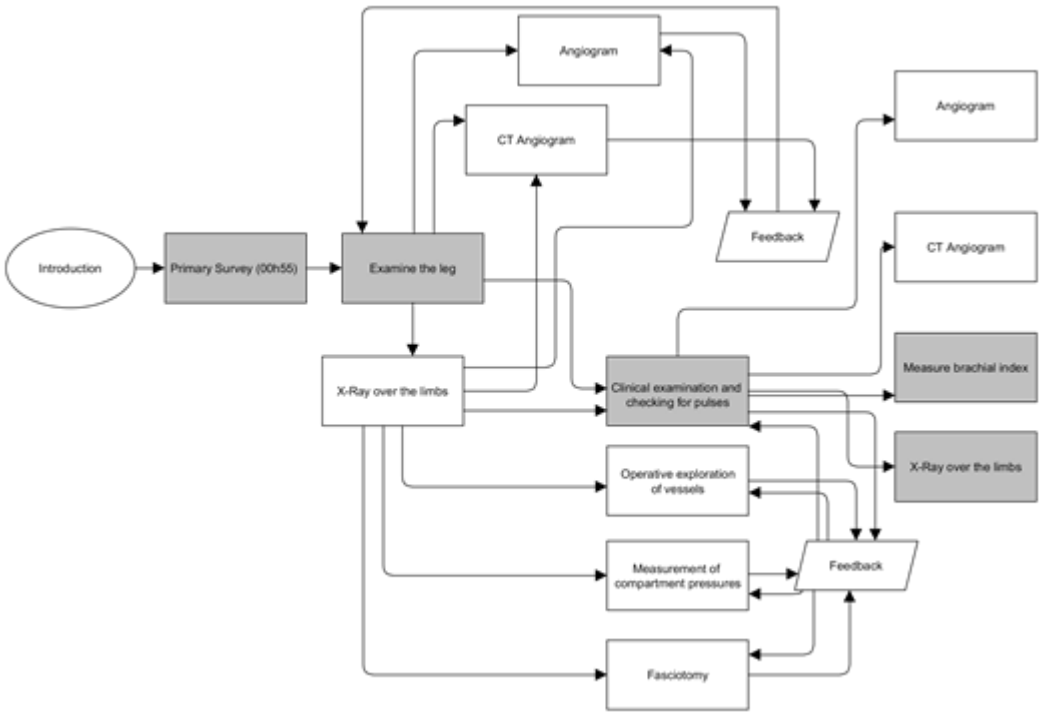

Figure 7. A subset of the gunshot injury case showing that users were able to select paths leading to different consequences. The sequence of darker nodes corresponds to the optimal pathway.

6 DISCUSSION

The present thesis aimed at increasing knowledge about the design of blended learning for civilian and military trauma care and to study the educational challenges in the area, and finally developing design principles and virtual patients as support for blended learning.

The different stakeholders – the representatives of the educational systems in the different Nordic countries, the course participants and the educators – seemed to agree on the core issue that healthcare personnel in the Nordic countries lack adequate amounts of personal experience in managing complex trauma cases. While the volumes of trauma cases fortunately are low in the Nordic countries, all stakeholder groups agreed that there is nevertheless, an urgent need for more training and more competence. When it comes to identifying the gaps in the area, the different stakeholders however drew attention to quite different and even contradictory paths for how to develop education in the area. The representatives of the educational system - not surprisingly - emphasized gaps on an organizational level. The challenges of recruiting specialists and evaluating the impact of education and training were stressed. More collaboration between countries on education and research in the field was considered to be a priority. The learners, i.e., the healthcare personnel participating in courses, shared the concern that they were not getting enough practice in managing complex trauma cases. For this group the priority was to find more time for practice, preparation and reflection. This group framed the problem as a somewhat quantitative one; more time for practice was the main issue. The third group of stakeholders, the educators, also shared the same concern. However, this group focused on other challenges in trauma education. For this group, the educational challenge was not merely a lack of collaboration or a lack of practice and instead described the specific difficulties in training non-trauma physicians. In their view, the main challenge is adopting a qualitatively different way of thinking about the complex trauma patient – a specific mindset – which differs from that which is normally held by the non-trauma physician.

Another striking difference in the responses of the different stakeholder groups was the kind of competence that was in focus. The learners not only strived to acquire more knowledge and skills for themselves, but also called for more multidisciplinary team training as this was considered lacking in the military medical environment. In contrast, the educators consistently emphasized the reasoning and decision-making of the individual physician. The representatives of the educational systems represented different traditions regarding this issue.

The findings from this thesis have contributed with knowledge about the different perspectives on teaching and learning and the design of blended learning as support for education and training and as expressed by key persons in military medical branches, educators and learners. Results presenting the identified educational challenges from different perspectives such as military medical system, learners and educators and served as basis for understanding the complex problems.

Results from the present thesis in study I and III confirmed the identified gap of lack of expertise and knowledge in several countries about the management of complex trauma patients and the need of international collaboration in education because of the lack of

volumes in education and training. International collaboration was highlighted as important, especially on Nordic basis and through joint education and training. Political support for international missions differed and affected the health professionals' possibilities to practice their skills in the extreme military medical environment. Military medical simulations such as virtual patients, and as a second step, full scale simulations were valuable support for training.

The most difficult aspect of learning in management of the complex trauma patient was the lack of real practice in the extreme military medical environment, which also confirms results from previous studies [4]. Limited time available for preparation and reflection during the course and the lack of support for education and training from home hospitals were challenging according to the learners. The learners were used to technology-enhanced learning in previous education and addressed the need of online elements in education as support for releasing time and as support for the learning process during education in management of complex trauma patients.

Results about educational challenges from study II and III about the learners' and educators' perspectives contributed to deeper understanding of the complex problem of providing education in management of complex trauma patients for non-trauma surgeons. These challenges were viewed as part of what was described as a special "mindset" required for the management of complex trauma patients. The mindset entailed a way of thinking and making decisions which is different compared to what non-trauma specialists in the Nordic countries with low volumes of trauma were used to. The optimal way of treating complex trauma patients might seemingly be in conflict with practices and ethical principles that non-trauma specialists normally were used to. Supporting the development of knowledge and expertise in management of complex trauma will thus require significantly changing the health professionals' way of thinking about and approaching the patient including how to handle ethical issues.

Previous research highlighted the importance of incorporating new pedagogies, learning theories, and instructional methods when transforming teaching and learning in blended learning environments. A contribution from the present thesis to the design of blended learning is also an educational model aimed to support health professionals' learning in civilian and military trauma care (Figure 8). The model made use of learning theory when developed suggestion of how to apply the model in an existing course [23, 26, 39, 50]. The trialogical approach supported the design of blended learning and the learning process as well as collaboration and creation of shared objects, like the virtual patients. The blended learning approach inspired the combination of digital media with more traditional face-to-face teaching. The use of virtual patients is one such tool and the aim is to allow data and discussions from the virtual patient cases feed into the face-to-face discussions when participants and instructors meet. The Trialogical approach to learning also guided the work to emphasize certain design aspects. The trialogical approach emphasizes in particular collaborative learning, and by providing possibilities for discussing the cases online learners can learn in collaboration with others. Another trialogical design principle inspired striving for sustained learning beyond individual courses so that the participants' discussions are available to new participants in a new course so that learners do not always

have to start from scratch but are able to build on what the previous participants already produced.

In addition to the theoretical framework, the results especially from study II and III about the educational challenges contributed to identification of what kind of blended components would be suitable when integrating face-to-face teaching and learning with online learning. Previous research has focused on the learners' perspectives in an emergent area such as blended learning and these studies have contributed with important knowledge also for educators [20, 23]. However, there has been a need to complement research about the learners' views with the educators' perspectives. Previous studies have identified research gaps regarding the educators' perspectives on teaching and learning and the design of blended learning [20]. In this project, study II confirmed the learners' need for more training opportunities, but it was the input from the educators that was particularly valuable for designing the details of the virtual patient cases. The educational challenges that the educators identified helped focus the virtual patients on the most challenging aspects of complex trauma care. And the experienced educators turned out to have many expectations on what would be difficult for the non-trauma physicians. Such expectations were useful in the design of the decisions to be taken in the virtual patient cases. The analysis of log data of the participants' use of the virtual patient cases in study IV confirmed that the participants in a considerable number of cases indeed experienced the decisions as difficult and chose non-optimal choices. The main value of the participants' input has come in testing and evaluating design proposals.

While these groups have proved very valuable, it is a well-known observation from many design projects that the target groups and stakeholders of a new design may provide valuable input to the design project, but they are rarely designers. The role of the designer is not only to collect data from all those involved, but also weigh the importance of different opinions that are voiced and balance any tensions between differing viewpoints that may occur. In this project, different views were, as mentioned, expressed by the different groups. But not only were such differences seen between groups, contradictory positions were also noted within the groups. For instance, the expert group did not show full consensus regarding what was an educational challenge in teaching management of complex trauma patients for non-trauma surgeons nor whether these were present in the virtual patient cases. It was thus clear that the design could just be a simple function of the input data from the various stakeholders.

One case of differing views on an overall level within a group was clear in the results from studies I and III. Some of the key persons in the military medical branches and the educators considered digital support as barriers for teaching and learning, others considered that digital support in education could only contribute to the support of theoretical knowledge, while others considered that technology offered opportunities to support the participants' learning and as drivers for innovation in the education system. The key persons in military medical branches and the educators have significant influence on the development of innovative educational strategies and methods, and could be either barriers or drivers for new innovative educational strategies and methods.

The international focus today is extended civilian and military collaboration in the

management of complex trauma [7]. To be able to meet new demands, education and training as well as research and innovation are highlighted as being of great importance. One of the greatest challenges is to identify and develop educational methods without exclusively focusing on individual skills, and the focus needs to be shifted from individual into the team.

6.1 METHODOLOGICAL CONSIDERATIONS

The studies in the present thesis builds upon each other using a design-based research approach, findings from one study contributed with deeper information into the research question and affected the design of the next study as typically for iterative processes. Design-based research is a research approach focusing on complex problems and aims to understand the world of educational practice and take place in a real-life setting, where learning normally takes place. Characteristics for design-based research is the use of different kind methods and in close interaction and collaboration with practitioners [56, 57]. The Nordic context was identified as the setting of the thesis because of the ongoing, international development on an extended civilian and military collaboration. Design-based research typically focuses on the practice in reality, but complex trauma is uncommon in the Nordic countries and is to be seen as a challenging area in which to do empirical research. The military medical education systems in the Nordic countries differ from those of other countries, especially the Swedish one. The commonality of the Nordic model is that the Armed Forces and civilian medical systems share the same human resources, physicians and nurses. The reduction of military resources in Sweden as a consequence of the historical 200 year period of peace, makes it quite unique, but also challenging to relate to and even more importantly, to support the civil military collaboration in education and research. In relation to this context, only a limited number of publications could be found in the literature search with blended learning topics and within the context of civilian and military trauma care and education and training. Because of this context the project team worked with international trauma experts, who were used to the management of complex trauma patients, both in the civilian and military contexts. Investigation of established trauma structures, observations and video recorded resuscitations were performed at civilian major Academic Trauma Centres in Johannesburg, South Africa. This contributed to an exclusive opportunity to investigate and learn about other trauma systems and their management of complex trauma cases, but the differences compared to the Nordic context also offered challenges of how to transfer the knowledge into the Nordic context. The trauma system in Johannesburg, South Africa had a higher incidence of complex trauma, and was therefore seen as the second best option to get access to empirical data and compensated in some way the lack of Nordic data. The internationally network of trauma experts contributed with access to the civil military educational setting and also supported the access to get in contact with the learners.

In study I interviews with key persons in the military medical educational systems were performed due to the limited number of research publications in this area. To get access to the respondents, the Surgeons General representing each country needed to identify the

respondents, provide military clearance and give permission for interviews. The selection of the respondents was therefore regulated. They were all serving as officers at the rank of major or above in the armed forces with great influence of the development of military medical education, though few of them were working with education at daily basis. This probably affected the findings related to teaching and learning as well as the access to reality. The interviews were performed in Denmark, Norway and Sweden which contributed to personal established relations in the field and exclusive discussions which contributed to a deeper understand of the complexity in the research field which would not have been possible otherwise.

In study II, data was collected by following methods: observations, survey and semi-structured interviews during an international course DSTC military version. The course was identified as the setting for studies II-IV because it was a part of a pre-deployment programme for physicians and nurses and the course was also provided in both civilian and military contexts. The course has served as an exclusive empirical context, which made it possible to investigate the setting through observations and also to collect data several times because the course was running once per year. This contributed to a deeper understanding of the complex research problem and possibilities to return to the empirical setting. The challenge in the data collection was related to the sample of the study which might have affected the results, and could not be seen as representative, but contributed to a deeper understanding of barriers and drivers in educational development in the field. The sample consisted of 51 physicians and nurses, one online post-course survey was conducted through email to 42 of the 51 participants and 21 responded. The discrepancy was due to the fact that nine participants could not be reached because of incomplete contact details. The time period to conduct the online post-course survey was chosen in consideration to that several of the respondents were on international military medical duty, which might also explain the discrepancy. 11 respondents volunteered for interviews, six surgeons, two anaesthesiologists and three specialized nurses. The sample for the interviews consisted of professionals representing the team in managing complex trauma cases, which made it possible to transfer results to the Nordic context.

In study III, different methods were combined to collect data: semi-structured interviews and video recorded resuscitations at a civilian Academic Trauma Centre, in order to identify and analyse what trauma experts (the educators) described as the challenges in teaching and training specific to surgical decision-making, and their beliefs about the typical problems that non-trauma surgeons may encounter. The sample consisted of eleven international trauma experts with profound expertise from Canada, New Zealand, Norway, South Africa, Sweden, United Kingdom, and USA. The experts were active in education and research as well as in clinical practice on an international basis. The experts volunteered individually for interviews, and were recruited from an international organization the IATSIC. The working process was iterative according to the DBR approach but the data from different methods was extensive and made it difficult to develop and test several design ideas. On the other hand, the extensive data contributed to a unique and exclusive empirical anchoring of deeper understanding about educational challenges in teaching and training, needed when developing new national and international programmes for civilian and military trauma care.

In study IV, the focus was on the design of virtual patients as components in a blended learning environment and addressing the specific challenges in complex trauma education. Data collected from observations, semi-structured interviews, surveys, video recordings, case descriptions and log files were reviewed and analyzed during the design process [59, 60, 64, 65]. The design work was performed in close collaboration and interaction with participants from three groups: one group with eleven international experts in complex trauma, the other group consisted of twenty-one physicians and nurses who were course participants in the course. Participation was voluntary and an open question to volunteer to participate in the research project was communicated to the whole group of course participants (n=47) of whom twenty-one of these accepted. The third group consisted of the project team with one PhD student, one medical informatician and four supervisors with complementary competencies such as: education, complex trauma, military medicine, medical informatics and human-machine interaction. The design work itself included numerous design meetings, workshops, and interviews with the group of experts, as well as surveys and log files from users trying out the virtual patients. The work focused on the design of an example of how to integrate face-to-face and online learning into blended learning. The work also focused on the specific context of complex trauma by designing virtual patients, and basing the design on authentic trauma cases to recreate scenarios. The recreation included the decision-making challenges that are specific for the area of complex trauma and as a fruitful path to support the learning of healthcare personnel who are in need for training in the area. Two virtual patients were developed, verified and tested by the educators and learners and were seen as valuable for stimulating the mindset in decision making by supporting the reasoning. Another valuable approach was to collect data about the learners' reflections on their decision making as they worked on the virtual cases, therefore text boxes were included collecting such data in connection to all important decisions. The approach did however not work particularly well as these text boxes were often left empty. In future iterations a different approach is planned; to present such a text box even before any alternatives are shown to prompt learners to reflect on their choices before just clicking on an option. Such an approach can have the potential to collect valuable data about the learners' decision making in context. Further iteration would be necessary to analyze outcomes from the results about the learners' paths through the virtual patients, and combining evaluation included the reflections of the learners with analyses of log files appeared to be a valuable path but several more cases and analyses are needed. Development of several virtual patients in the context of civilian and military trauma would contribute to a representative knowledge about the design of blended learning as well as a deeper understanding of the mindset required for decision making in complex trauma, one of the keys when identifying key decision points needed for developing the nodes required for the structure in virtual patients.

7 CONCLUSIONS

Key persons in the Nordic military medical system see a lack of expertise in the management of complex trauma and see a need for quality improvement in education, evaluation of the transfer of education to practice and feedback of the outcomes of education and training. A need for increased international collaboration was called for. The existing education has a long tradition of being oriented toward practical skills training and both skeptical and more positive views to blended learning were voiced. Senior healthcare professionals representing the learners in this area also highlight a lack of experience and competence about complex trauma care and the need for more training in extreme military medical environments. The need for multidisciplinary team training was emphasized by this group as well as blended learning as support for learning. The educators with extensive experience of education and training within civilian and military trauma care emphasized decision-making in the area and described the importance of having a certain mindset when managing complex trauma cases. Eight typical educational challenges were identified and ranked by the participating educators. To address some of the challenges, two virtual patients were designed based on authentic cases. Course participants appreciated the virtual patient cases and viewed them as realistic but expressed a need for more feedback. A pilot test confirmed that the decision-making in the cases posed challenges for the target group in the way the educators had predicted. A number of design principles were suggested for designing blended learning in the area on an overall level as well as on the level of designing the virtual patients. New innovative and interactive educational methods and design of blended learning are needed to increase the knowledge of management of complex trauma in an effective way and to support collaboration. The thesis contributed knowledge about one way of designing a blended learning model for civilian and military trauma care. The next step will be to test the blended learning model in a national and multinational environment.

8 IMPLICATIONS

Results from study III identified challenges specific to the education and training in decision-making of the complex trauma patient. The challenges represented those aspects seen as being particularly difficult to teach and master in the area, yet were seen by the educators as required for decision making in the management of these cases. These challenges in combination with the learners' perspectives and experiences of learning form a valuable basis for the implications when designing blended learning. Educators need to radically review how trauma training is presented for non-trauma professionals and handle the identified challenges.

Increasing knowledge of blended learning in military medicine has been successful: An accepted military medical course has been altered so as to integrate parts of blended learning using virtual patients as support, to stimulate reasoning and practice decision making in complex trauma. Virtual patients were web based scenarios which aimed not only to stimulate the mindset for the decision making in trauma, but also to assist visualizing an extreme or austere environment. Health care professionals often have difficulty to imagining and preparing for these situations.

Education and learning support such as virtual patients, pays special attention to the most difficult challenges, and builds opportunities for unlimited training, before face-to-face teaching/learning, during face-to-face teaching/learning by creating the conditions for more interaction and discussion about difficult cases. The virtual patients also serve as online components supporting the integration of face-to-face teaching and learning into blended teaching and learning (Figure 8). These virtual patients have been developed together with international experts, and tested and evaluated by senior health professionals during this research project. This work has generated useful experience, and insight, into how to design blended learning and based on trialogical learning theory. The virtual patients in the present thesis support reasoning in decision making in management complex surgical trauma, and also serve as online components in the development of one example of an educational model as support for blended learning, based on the trialogical learning theory (Figure 8).

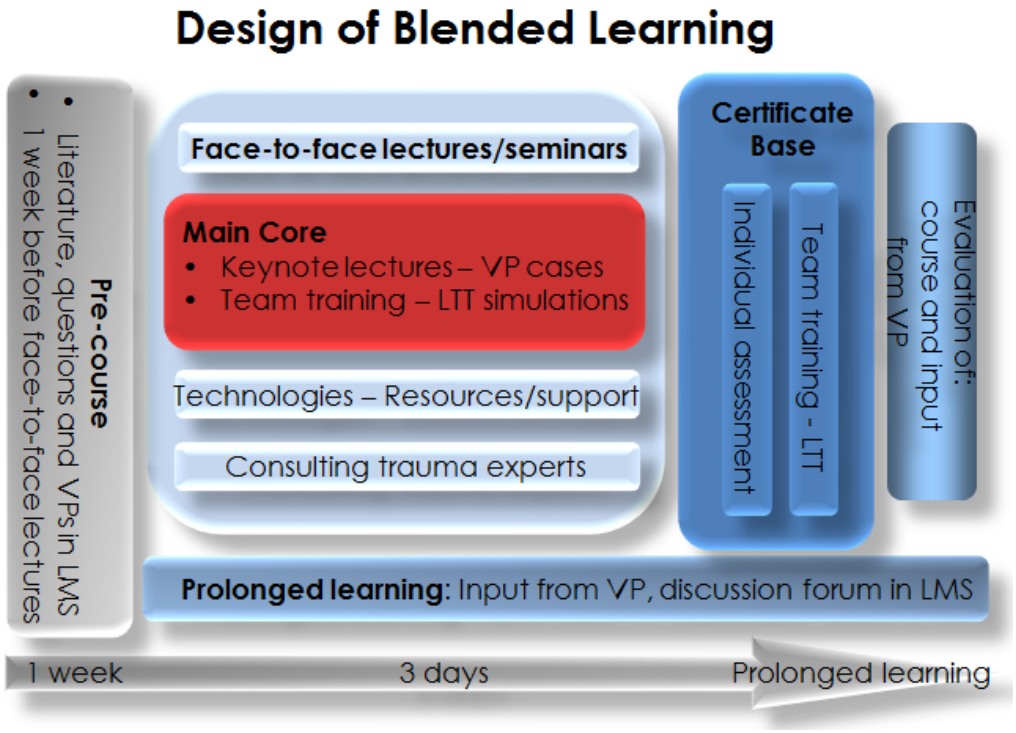

Figure 8. The educational model supporting blended learning as one example of how to integrate face-to-face teaching and learning with online components and based on the trialogical learning theory.

The educational model will be tested further on in national and international trauma courses and the outcomes from this research project has also resulted in two new projects; one development project and one research project.

9 ONGOING AND FUTURE WORK

Test and evaluation of the suggested educational model including the virtual patients from this research project is planned to take place during a national course in trauma, planned as a pilot course for health professionals in the management of trauma patients at hospitals in Sweden. The virtual patients representing the online environment will be tested and improved with the aim of integrating these, in a face-to-face course as support for blended learning. An outcome from this research project is a new research project which is planned to start during 2018 and will focus on decision making and the development of several new virtual patients, into a library of web-based scenarios in disaster medicine and trauma.

As a second step, the educational model is planned to be tested and evaluated in a multinational collaboration with around 30 nations during 2018-2019 in one of the world's biggest multinational live exercises. One of the overall aims in this multinational collaboration is to focus on research and innovation in relation to education and training in civilian and military settings to be able to meet new educational demands globally. A core challenge, in both settings, is to identify training methods that not only sharpen individual skills, but also cover team training and training standardization. One of the objectives during the multinational exercise is to try out new advanced education and training methods.

The Armed Forces need extended cooperation, and development of knowledge and skills regarding design and integration of blended learning and other innovative technologies in education.

The research team of the present thesis has experience of constructing courses with a blended learning design, based on problem based learning similar to the trialogical methods, namely the Remote University Network, a cooperative project between Stanford University and Gothenburg University [22, 23]. Another expected outcome from this research project during 2018, is a pilot project about artificial intelligence (AI) as support for decision making in management of complex trauma patients. The project team from the present thesis is discussing and developing the idea of using the virtual patient as an interface to a medical decision support system (MDSS) supported by artificial intelligence (AI), and based on databases of clinical trauma registries from Sweden and South Africa. The pilot project will investigate the possibilities of developing decision support aimed for clinical practice and learning by making use of trauma registries and the support of AI.

10 SAMMANFATTNING (SUMMARY IN SWEDISH)

Våldet accelererar i många länder, men konkreta handlingsplaner och tillräckliga åtgärder har saknats. Den nordiska civila och militära medicinska modellen kännetecknas av att samhället delar på medicinska resurser som läkare och sjuksköterskor. Nya pedagogiska strategier och metoder samt kunskap om pedagogisk design kan bidra till att stärka medicinska resurser, dela kompetenser, samordna resurser och samarbeta i utvecklingen av en civil och militär traumavård. Det övergripande syftet har varit att bidra till ökad kunskap om design av blandat lärande. Avhandlingen bygger på fyra studier:

Studie I undersökte likheterna och skillnaderna i militär medicinsk utbildning i Danmark, Finland, Norge och Sverige, samt i vilken grad e-lärande tillämpades. Resultaten var motstridiga, vissa var negativt inställda medan andra var positiva och såg potential för innovativ utbildning. Kontextuell medicinsk kunskap och modern pedagogisk kompetens identifierades som avgörande framgångsfaktorer för utveckling av blandat lärande. **Studie II** identifierade och analyserade utbildningsutmaningar genom en kurs, som förberedde läkare och sjuksköterskor för arbete under extrema militärmedicinska förhållanden. Den största utmaningen i lärandet var bristen på övning i extrema miljöer. Blandat lärande betraktades som stöd för lärande. **Studie III** analyserade utbildarnas utmaningar inom undervisning och träning. Utbildarna representerades av internationella experter inom komplex trauma, verksamma inom utbildning, forskning och klinisk praxis i civil och militär kontext. De identifierade utbildningsutmaningarna låg till grund för designprinciper samt utveckling av virtuella patienter. **Studie IV** introducerade designprinciper samt utvecklade, verifierade och testade virtuella patienter. Dessa baserades på de utbildningsutmaningar som tidigare identifierats och bidrog med möjligheter till utbildning om beslutsfattande utan de begränsningar som föreligger i traditionell klassrumsundervisning. De virtuella patienterna bidrog med onlinekomponenter som kunde integreras med det didaktiska lärandet och utgjorde en komponent i ett förslag av en utbildningsmodell.

Slutsatser: Nya innovativa och interaktiva utbildningsmetoder och kunskap om design av blandat lärande behövs för effektiv kompetensutveckling om hanterandet av traumafall och stöd för utvecklat civil och militärt samarbete. Utbildarnas perspektiv påverkar utvecklingen avsevärt och kan därför hindra eller stödja utvecklingen. Nyckelpersoner i de nordiska försvarsmedicinska utbildningssystemen, internationella trauma experter, seniora läkare och sjuksköterskor var ense om att det var angeläget att utveckla utbildning inom traumaområdet men pekade ut olika och ibland motstridiga utmaningar och lösningar. Ett speciellt sätt att tänka och resonera ansågs avgörande vid hantering av komplexa traumapatienter enligt traumaexperterna. Två virtuella patientfall designades som fokuserade på ett antal identifierade utmaningar. Kursdeltagare uppskattade de virtuella patientfallen och betraktade dem som realistiska men önskade mer återkoppling. Ett pilottest bekräftade att beslutsfattandet i fallen var utmanande för gruppen på det sätt som utbildarna hade förutsett. Designprinciper och en utbildningsmodell föreslogs för utveckling av blandat lärande inom civil och militär traumavård och kommer testas nationellt och internationellt.

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"…You shall thank your gods, if they force you to go where you have no footprints to trust on…"

(Karin Boye, 1955)

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12 COMMUNICATION AND ADDITIONAL WORK

Results from the research project have been presented and communicated at several international conferences:

Medicine Meets Virtual Reality: The abstract *"How e-learning can support medical professionals for work under extreme conditions"* was presented together with a poster during the conference during 7-9th of April 2016, Los Angeles, USA.

47th World Congress of Surgery: The abstract *"Educational Challenges in Complex Surgical Trauma according to International Trauma Experts"* was awarded as one of six prize presentations in trauma at the International Society of Surgery (ISS) World Congress of Surgery. Arranged by the American Association for Surgery and Trauma (AAST) together with the International Association for Trauma Surgery and Intensive Care (IATSIC) during 13-17th August 2017 in Basel, Switzerland.

NATO Annual Discipline Conference (ADC): LS was invited as a speaker and communicated results from the research project by presenting *"Educational Challenges in Training for Complex Surgical Trauma"*. Discussion and a survey, which investigated the need of extended international collaboration in research of education and training, were also performed during NATO ADC 24-26th of October 2017 in Budapest, Hungary.