Simulation-based Medical Training

Simulation-based Medical Training: A User-Centred Design Perspective

By

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PREFACE

This volume explores the development process of a VR and web-based medical training system from a user-centred perspective. It highlights the importance of user participation in this context by analysing two case studies concerned with the development of a VR and web-based medical training system for Spinal Anaesthesia. This research investigates who should be considered as users, when and why users should be involved in the development process and how to utilise their guidance efficiently. In order to analyse these aspects, empirical data was collected from the case studies by applying participant observation, document analysis and interviews. The analysis of the data is based on literature discussing users and the development of computer systems in Information Systems (IS) and Human-Computer Interaction (HCI).

The findings illustrate the relation between user participation and the development process of a VR and web-based medical training system. User groups, along with their input and degrees of participation and influence are classified. The findings show how a democratic arrangement between users and developers is beneficial and maybe even mandatory in order to utilise the users' guidance efficiently. In this arrangement, the use of prototypes is instrumental in bridging the expertise and knowledge gap between users and developers.

The results of this research may aid other research teams developing VR and web-based medical training system in deciding *if*, *why* and *how* to involve relevant user groups in the overall development process.

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CHAPTER ONE

BACKGROUND TO STUDY

Summary of research

This volume explores the relation between user participation and the development process of a Virtual Reality (VR) and web-based medical training and assessment system[1]. It presents a perspective on VR and web-based medical training and assessment where user participation is an integral and necessary part of the development process of such systems.

The subject of how to involve users in the development of computer systems has received much attention within Information Systems (IS) and Human-Computer Interaction (HCI). Recently, this literature has focussed on how to involve users at the right time and in the right form, depending on the context of a system's use. To date, there is little written on user participation and the specific context of VR and web-based medical training systems. Developments of such systems are dependent on a number of aspects, such as understanding complex medical elements, identification of training objectives, validation of training, etc. In this volume it is discussed how users (trainers, trainees, medical educators and others) can aid the process of achieving these aspects.

The primary research question that this research sets out to answer is: "What is the relation between user participation and the development process of a VR and web-based medical training and assessment system?". This question has two parts: "What were the roles of the users in the development process during the two case studies?" and "How was user guidance accomplished during the two case studies?".

In qualitative research, a hypothesis is generally not stated during the initial stages of a research process (Kaplan and Maxwell, 1994). Research questions evolve with the researcher's understanding of the activities and behaviours under study. However, if the research in this volume was approached as a quantitative study, the research questions would translate

[1] Training in this field refers to the acquisition of skills, cognitive or psychomotor (Gallagher et al., 2005)

into the hypotheses: a) The development process of a VR and web-based system consists of separate phases, b) users have certain roles in this development process and c) users are instrumental in guiding developers in the process of developing such systems.

This research's perspective on user participation is illustrated through a qualitative, empirical data analysis of two case studies. The case studies present two research projects concerned with the creation of a VR and web-based medical training and assessment system for Spinal Anaesthesia. In order to understand the development process' dependency on user participation, an analytical framework based on literature from IS and HCI as well as empirical findings is applied. This framework is used to determine user-related factors such as user groups, user input, methods used to involve the users, degree of participation and influence over the development process. It also provides a frame for dividing the development process into discrete phases. The analytical framework is applied to the two case studies to investigate the relation between user participation and the phases of the development process of the VR and web-based medical training and assessment system.

Research context and issue

VR and web-based medical training systems are developed from within a highly specialised area. Hospitals are under pressure from governments, legislators and the general public to deliver safe and efficient high-quality medical care. Medical trainers, teaching hospitals and medical training bodies need to review their current ways of training junior doctors (Bradley, 2006; Aggarwal and Darzi, 2006). Junior doctors practicing potentially hazardous procedures on patients has up until recently been regarded as a "necessary evil" (Reznick et al., 2006). However, Reznick et al. (2006) argue that this is in conflict with the demand for providing safe medical care to patients. As a response, medical trainers and educators are looking for alternative ways of teaching medical procedures. VR and web-based training has emerged as a potential alternative (Vozenilek et al., 2004).

There is a need to involve users (trainers, trainees, medical educators, medical society, etc.) to create "appropriately" designed VR and web-based training systems. John (2008) argues that the guidance of domain experts, along with other factors such as appropriate use of technology, training theory and validation of training, is critical for the success of simulation-based medical training system. Also, Berg (2001) argues that it is necessary to include users in the development and implementation

process of health care technologies. In addition, Lettl (2007) describes how users can play a significant role in the process of developing new and innovative technologies for supporting health care. Shah and Robinson (2006) argue that users provide valuable input to the development of new medical devices during different stages of the development process.

However, there is little literature available discussing the potential roles of users when developing training systems in the context of VR and web-based medical training. In addition, there is little discussed in literature in how to effectively utilise guidance from domain experts and other potential users during the development of such training systems. In contrast, there is extensive research on user participation in the field of Information Systems. In this field of research, several studies provide empirical evidence on the usefulness of user participation in a computer system's development (see, e.g., Lin and Shao, 2000). Successful user participation depends on a range of factors. For example, research has indicated that for the participation to be effective, the users have to believe that the development is meaningful and not feel forced to contribute (Hunton and Beeler, 1997). Cavaye (1995) argues that user participation depends on aspects such as top management commitment, willingness to participate and ability to participate.

User participation is also a key perspective in the discipline of HCI. The discipline of HCI is concerned with understanding the relation between users, tasks and the machine (Dix et al., 2004). In HCI, users are considered to have a central role in the development of useful and usable computer systems. Dix et al. (2004) argue that computer systems have to be designed so people (users) have the freedom to use the system as they please and it must also allow them to make mistakes. To achieve this, the user has to be the number one priority when designing a computer system. Usability evaluation is a specific method that can be used in the development process of a computer system to involve users. It is used to investigate how well a user is able to perform certain tasks on a system and how they perceive it (user satisfaction) in order to improve on the system's usefulness (Nielsen, 1994).

Participatory Design (PD) is another approach which promotes user participation (Asaro, 2000). PD is based on a democratic development arrangement where users are encouraged to participate in the development process to ensure that their opinions and ideas influence the final design of a system.

Aim of research

Two specific arguments which relate to user participation are of particular interest to what is discussed in this volume. The first argument is that user participation is **context-specific** (Marti and Bannon, 2009). The authors state that user participation has to be considered in relation to a system's intended use, who the users are and whether they can contribute to the development process. The authors also state that the role and value of a user varies depending on what stage a development process is at. The second argument is that the real value of user participation is gained when a development process is dependent on **specific domain expertise** (He and King, 2008). The authors state that the challenge within user participation is to identify appropriate domain experts that are willing to participate in the development process and to know how to utilise their expertise efficiently. Hence, in order to benefit from user participation, it has to be established how to "*involve the 'right' users at the 'right' time in the 'right form'*" (Lettl, 2007, p. 53).

The aim of this volume is to highlight the importance of user participation in the context of VR and web-based medical training. More specifically, the aim is to identify who should be considered as users, when and why they should be involved in the process and how to utilise their guidance efficiently.

This volume provides a novel perspective on the development process of VR and web-based medical training systems. The perspective is based on applying existing approaches and views of user participation from IS and HCI to empirical data collected from two case studies. This perspective may support researchers in this area to involve users in the development process of VR and web-based medical training systems and as a result help to develop appropriately designed systems. In particular, this work illustrates a) how the development process of a VR and web-based medical training system can be described as discrete, but interdependent phases, b) the different roles of users during the phases of the development process and c) how the expertise from users can be utilised in order to efficiently guide developers in the process of creating such systems.

Structure of this volume

Following this introduction, Chapter 2 provides a background to the context of VR and web-based medical training. It contextualises the research within the current discussions of medical training and presents a

few examples of where VR and web-based technology has already been used for medical training and assessment. This chapter also argues why it is important to involve users in this context.

Chapter 3 presents the approach applied for investigating the research questions. The approach consists of collecting data from two case studies by using participant observation, document analysis and interviews. Coding and interpretive writing have been applied to formatively analyse the collected data.

Chapter 4 describes the framework that is used to analyse the relation between user participation and the different phases of the development process. The chapter discusses relevant user literature and adopts an existing approach of a system's development process to separate the case studies into discrete development phases.

Chapter 5 analyses the empirical data that was collected during the first case study. It provides examples on each development phase and how each phase was dependent on user participation. User groups, forms of user input and how users were involved in the development process are identified.

Chapter 6 analyses the relation between user participation and the development process during the second case study. This follows the same format as that of Chapter 5.

Chapter 7 provides a summarising analysis of the results from the data analysis of the two case studies. It analyses the different user groups in detail, how their participation influenced the development process and how user guidance was accomplished.

Finally, Chapter 8 draws conclusions from the results of the summarising analysis and discusses the contribution of this volume.

Chapter 2 outlines why there is a need to improve medical training and how VR and web-based technology has been used in medical training. In this chapter it is argued why user participation is important in this context.

CHAPTER TWO

VIRTUAL REALITY AND WEB-BASED TRAINING

Factors influencing the use of VR and web-based training

It is argued that there is an urgent need to reform worldwide medical training and revise existing medical curriculum (Aggarwal and Darzi, 2006; Bradley, 2006; Harden et al., 2000). Bradley (2006) describes insufficiently prepared junior doctors with little practical experience as a major drive for this reform. A survey of junior doctors showed that they found their practical skills training inadequate and were frequently asked to perform procedures of which they had no experience (Mason and Strike, 2003).

The traditional model of learning procedures on live patients under supervision of a trainer, commonly referred to as the apprenticeship-model, has been criticised. A number of different arguments have been given. According to Reznick et al. (2006), the apprenticeship model has been regarded as a necessary evil due to a lack of satisfactory alternatives. They argue that it is unethical to train on live patients and that exposure to rare patient conditions depends on chance. They also argue that it is difficult to standardise training as each individual patient is different and it is expensive to involve patients in the training. Maran and Galvin (2003) state that it is difficult to formally train doctors in how to deal with ambiguous medical situations because of the restricted availability of patients for training. Ziv et al. (2006) describe the contradiction between using live patients for medical training and simultaneously trying to ensure the delivery of safe health care. At the same time, Bradley and Postlethwaite (2003) argue that the medical sector has to ensure lifelong learning, training and professional development of doctors.

It is these and similar concerns which need to direct the development of VR and web-based medical training systems. If training issues are addressed appropriately, it is likely to result in a system that is able to counteract at least some of the aforementioned drawbacks of the

apprenticeship model. In order to address training issues appropriately, it is mandatory to involve medical trainers and trainees in the development process.

The current issues in medical training have led to an on-going, worldwide change in how medical procedures are trained (Issenberg et al., 2003). New approaches are being sought, which would allow junior doctors to efficiently learn, practice and be assessed on both routine and uncommon medical procedures in safe and controlled environments (Vozenilek et al., 2004).

VR and web-based training has been used to train and assess doctors' skills in safe and controlled environments and has been widely discussed as a potential way of improving medical training. If applied correctly, such technologies offer great potential for addressing the current needs of medical training, see, e.g., Scalese et al., (2008), Dawson (2006), Friedrich (2002), Ziv et al. (2006). Among the benefits of such systems are diagnostic screening (Satava et al., 1998; McCloy et al., 2001), customisable patient reproduction (Issenberg et al., 2005), objective assessment (Champion and Gallagher, 2003; Chou and Handa, 2006), immediate feedback (Chou and Handa, 2006), patient rehearsal (Kneebone and Aggarwal, 2009) and intelligent computer-based tutoring (Champion and Gallagher, 2003). At the same time, it is crucial to validate that the training works and can be transferred to improved performance in the operating theatre (Salas et al., 2005; Sutherland et al., 2006).

Integrating aspects that can provide efficient training and assessment in a VR and web-based system is challenging. The identification of relevant training objectives[1] and to translate them into system requirements requires the input from medical trainers and medical experts. Such experts also need to be involved in the validation of a system.

VR and web-based medical training systems

VR can be defined as immersive, computer-generated environments, which uses technology to visually and physically interface the user with the virtual environment (Brooks, 1999). In medical training, these environments can be populated with virtual, interactive patients to simulate medical procedures and scenarios.

Haptic technology can be used to create physical interfaces with virtual environments. Haptic technology refers to computer-controlled robotic

[1] The development of simulation-based training has to be guided by relevant training objectives (Henriksen and Patterson, 2007)

equipment (so-called haptic devices) that can track and interface the user with sensations of virtual objects through force feedback or vibration stimuli (Srinivasan and Basdogan, 1997). See Figure 2-1 for an example of a haptic-based medical training system.

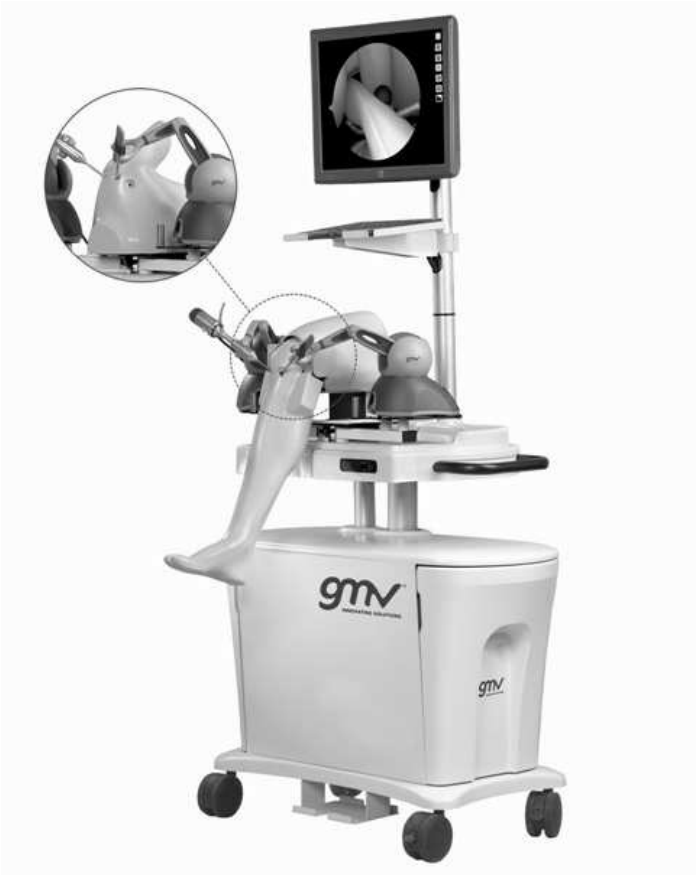

Fig. 2-1. Example of a VR-based medical training system for arthroscopic knee and shoulder surgery (*Image courtesy of GVM*).

VR-based systems can be used to recreate complex medical procedures. Medical training systems that utilise VR-based technology have been developed for procedures such as ultrasound guided needle puncture (Vidal et al., 2008), minimally invasive surgery (Basdogan et al., 2007),

transferring knowledge of bio-elasticity (Nakao et al., 2006), chest tube insertion (Cline et al., 2008) and palpation (Howell et al., 2008). The case studies reported in this volume utilised VR-technology as part of the medical training system that was developed for Spinal Anaesthesia (see Chapter 5 and 6).

VR-based systems offer the opportunity to train cognitive and psychomotor skills. However, the development of such systems relies on the guidance from medical trainers and medical experts to help developers understand the skills necessary for performing a procedure.

Web-based training provides distributed, interactive learning environments that can be accessed from anywhere with a computer connected to the Internet (Kahn, 2001). Web-based systems have been applied to the undergraduate and postgraduate training in the US as an attempt to enhance the traditional teaching model (Henriksen and Dayton, 2006). The web has also been used to teach surgical skills online (John et al., 2001). Recent advances in web technology have meant that interactive medical procedures and anatomy can be displayed directly in a web-browser (John, 2007). John (2007) describes how the web can be used in general medical education, diagnosis of patients, training of medical procedures and collaborative training.

The web has also been used to create "Virtual Patients" (Ellaway et al., 2009). A virtual patient is a web-based simulation of a real life patient. It can be used to train novices in how to diagnose patients. An example of a system simulating a patient for diagnosis is OpenLabyrinth[2], see Figure 2-2. OpenLabyrinth is a web-based training tool that presents text, pictures and different options in order to diagnose a patient. The system is based on real patient data and reacts dynamically depending on the user's clinical decisions.

Another web-based tool that has been used to enhance the learning of doctors is Learning Management Systems (LMS). A LMS provides a web-based platform for managing learners and course material. Such systems can manage several hundreds of users simultaneously and are used to electronically present learning material and managing exams. The open-source system Moodle[3] and the commercially available Blackboard[4] are two examples of LMS that have been used in medical education. A LMS was used as part of the medical training system that was developed during the second case study (see Chapter 6).

[2] http://labyrinth.mvm.ed.ac.uk/ (accessed 4th March, 2010)
[3] www.moodle.org (accessed 19th Nov, 2009)
[4] www.blackboard.com (accessed 19th Nov, 2009)

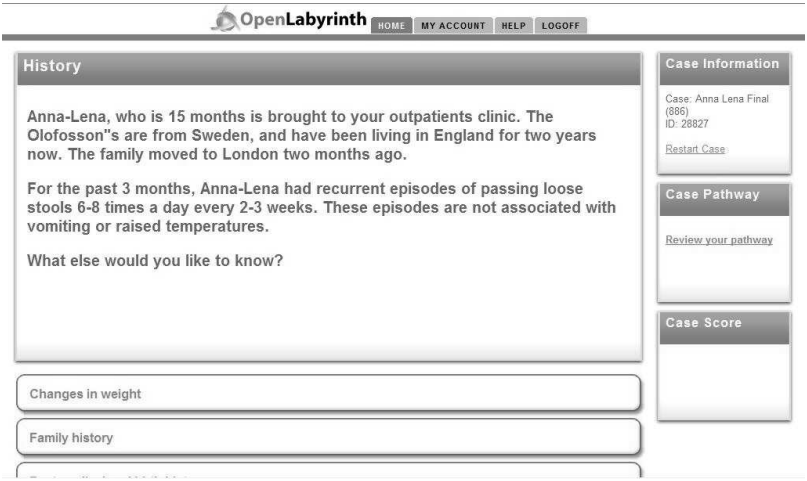

Fig. 2-2. A screen shot of a Virtual Patient being diagnosed using OpenLabyrinth. [5]

Web-based systems offer new opportunities for training medical procedures. They offer the opportunity to train procedural skills and to teach skills in how to react in complex medical situations. However, to create such systems, developers are dependent on the specialised expertise and skills of medical trainers and medical experts.

Summary

Chapter 2 describes the context of VR and web-based medical training and argue that the development process of such systems is dependent on users' participation and input. This dependency will be addressed in the following chapters by analysing the roles of the users and their guidance of the development process during two case studies. The investigation of user's role will focus on how users supported the identification of training objectives and helped ensure a system's validity and usefulness. The investigation of how user guidance was accomplished will focus on how the medical expertise and specialised skills of users were utilised during the development process of a VR and web-based medical training system. Hence, this research will address the following two questions (as

[5] The figure is a screen-shot taken from: http://labyrinth.sgul.ac.uk/openlabyrinth/mnode.asp?id=qgxlrdbarsx9qarsx9qgxlrdb1rx7jz (accessed 19th Nov, 2009)

mentioned before): 1) “What were the roles of the users in the development process during the two case studies?” and 2) “How was user guidance accomplished during the two case studies?”.

CHAPTER THREE

DATA SOURCES, DATA COLLECTION AND DATA ANALYSIS TECHNIQUES

This chapter describes the methods used for collecting and analysing empirical data from user participation during the development process of a VR and web-based medical training system.

Data sources

Two research projects are used to analyse the relation between user participation and the development process of a medical training system. The first project was Design Based Medical Training (DBMT). This project is referred to as *Project 1* hereafter. It was an open-ended research project with the aim of improving the training of Spinal Anaesthesia by using VR technology (see Chapter 5 for more information). The second project was Competence Assessment Procedure for Medical Procedures (MedCAP). This project is referred to as *Project 2* hereafter. It involved the design and implementation of a VR and web-based competence assessment procedure for Spinal Anaesthesia (see Chapter 6 for more information).

Data collection: Qualitative research

The research described in this volume uses a qualitative approach for collecting and analysing data. Qualitative research is concerned with generating theoretical interpretations of empirical data for describing behaviours, activities and social interactions (Myers, 2000). It is used for understanding *how* and *why* behaviours occurred, compared to quantitative research which is usually concerned with *what* happened and whether that observation is statistically valid. A main difference from quantitative research is that qualitative research is open-ended and tries to generate new ideas and theoretical propositions, rather than trying to answer pre-defined hypothesis for generalising to the entire population (Myers, 2000).

According to Nandhakumar and Avison (1999), the collection and analysis of qualitative data is considered as a suitable approach for generating theoretical interpretations of context-specific development processes of computer systems. Based on the findings of Nandhakumar and Avison (1999), it was deemed appropriate to apply qualitative investigations to this volume, given that the desired outcome was to generate theoretical interpretations of user participation within the development process. The quantitative approach will aid to understand and describe behaviours and activities of users and developers in relation to the development process.

Participant observation in the field

Qualitative research generally requires the researcher to do observations *in the field* (Patton, 2002). According to Patton (2002), being in the field helps to capture the context of the study. It also helps to avoid relying on previously held conceptualisations of the field and aids in identifying patterns and routines which the habitants might not be aware of themselves.

One particular method for doing observations in the field is participant observation. The method is used for engaging the researcher in a community and actively participating in its activities in order to gain an in-depth understanding of underlying behaviours (Marshall and Rossman, 2006). Participant observation is commonly used in qualitative research for collecting empirical data. This requires an extensive time in the field to understand observed behaviours and activities.

The investigations conducted in this volume were influenced by participant observation. To investigate user participation, the development of a medical training system and the relation between both, the author of this work participated as a system developer during Project 1 and 2. The two projects gave the author the opportunity to participate unobtrusively as part of a development team. The author had full access to project material (documents, emails, pictures, minutes from meetings etc.) and interacted regularly with the rest of the members of the development team. The author participated actively in the majority of the development process. Participant observation generated new perspectives of medical training systems development. It helped identify and refine relevant research themes and categories from analysing empirical data (see Chapter 3 – *Data collection and analysis process*).

Field notes

Field notes are considered an important aspect when doing fieldwork (Patton, 2002). According to Patton (2002), no specific guidelines on how to take notes exist; it depends on the researcher's style and the setting. In the setting of this volume, field notes were taken for collecting observational data of the development process during the two projects. However, as the projects required the researcher's active participation, it proved difficult to take extensive field notes *during* meetings with the development team. It has been argued that observations should be as unobtrusive as possible (Seaman, 1999) and also that the technique of field notes has to be adapted to each unique observational situation and context (Patton, 2002). To suit the specific study circumstances, general notes were taken on a wide range of aspects of the project, such as design decisions and action points. Observations, possible reflections and high-level analysis of the process were added to the field notes *afterwards*. The notes were transcribed and were used in the final analysis of user participation and the development process.

Interviews

Interviewing is another common method for gathering data in qualitative enquiry (Seaman, 1999). Interviews provide clarification on aspects that arise during participation observation. Hence, interviews and participant observation are often used in combination during field studies.

Short, informal interviews were conducted in conjunction with participating observations during Project 1 and 2. The interviews consisted of only one or a few questions. The participants' responses allowed the users' perspective on the development process to be gained, which might have otherwise been missed. The questions were generally asked during work with the users, e.g., a design session or a project meeting. However, the questions were asked in a manner that did not distract from the on-going activity.

At the end of the two projects, the key participating clinicians and developers were interviewed using semi-structured interviews. Seaman (1999) says that semi-structured interviews can help both to confirm aspects that were expected prior to the interview, as well as generating new, unanticipated data. They facilitate open-ended discussions in addition to pre-defined questions. The overall goal of using semi-structured interviews for this volume was to get the clinicians' view on the development process, as a complement to the observations. The questions

posed to the clinicians during the final semi-structured interviews were based on findings from the formative data analysis process (see Chapter 3 – *Data collection and analysis process*). However, unexpected issues emerged from the interviews as well. The interviews were recorded and transcribed and were used in the final analysis.

Documents and artefacts collection

In qualitative studies, documents and artefacts are often considered as valuable sources of information when studying a specific context or situation (Kaplan and Maxwell, 1994). The two projects resulted in a large quantity of documents and artefacts. For example, the physical distance between clinicians, developers and other team members forced the development team to rely on instant messaging and emails.

According to Prior (2007), documents are representations of human interaction and create a structure to a community, not only in regards of the content, but also how they are used and created. Prior (2007) argue that documents can hold an extensive amount of information about a community, which consequently requires careful consideration and analysis. Documents and artefacts are included in the final analysis of this volume for creating a rich description of the activities involved in the development process of the two projects. The documents are analysed based on their content and how user participation influenced how they were used and created during the development process. Examples of documents include project proposals, minutes from meetings, emails, chats and assessment and learning material. Examples of artefacts include 3d models of anatomy, pictures of patients and anatomy, CT[1]-data and the resulting system.

Quality of data collection

The collection process of qualitative data is considered to have a major impact on the overall quality of research (Klein and Meyers, 1999). Klein and Meyers (1999) argue that the **relationship between researcher and participants** affect the quality and "truthfulness" of the data. The presence of the researcher might alter participants' responses during interviews or how they act in front of the observer (Kaplan and Maxwell, 1994). The researcher in this work participated as a member of the development team

[1] Computed tomography (CT): A medical imaging method for aquiring three-dimensional images of bodily structures (internal and external).