Chapter 7
Practicing Interprofessional Team Communication and Collaboration in a Smart Virtual University Hospital

Ekaterina Prasolova-Førland, Aslak Steinsbekk, Mikhail Fominykh and Frank Lindseth

Abstract A smart university must utilize different technical solutions to offer its students varied and innovative learning environments optimizing the core learning activities. Contact with patients is at the core of medical and health care education, often taking place at a university hospital. However, students from one profession seldom get the chance to practice in a hospital setting with students from other professions, and they seldom see the whole patient trajectory during clinical practice. Establishing a smart virtual university hospital mirroring a real life hospital can prepare students for direct patient contact such as practice placement and clinical rotation, and thus optimize and sometimes also increase their time on task. Such a virtual arena will support student learning by providing adaptive and flexible solutions for practicing a variety of clinical situations at the students' own pace. We present a framework for a smart virtual university hospital as well as our experiences when it comes to developing and testing solutions for training interprofessional team communication and collaboration. In the main part of the work reported here, medicine and nursing students worked in groups with the clinical scenarios in a virtual hospital using desktop PCs alone and with virtual reality goggles. In the evaluation, it was found that all the students agreed that they had learned about the value of clear communication, which was the main learning outcome. Using virtual

E. Prasolova-Førland (✉)
Department of Education and Lifelong Learning,
NTNU Norwegian University of Science and Technology, Trondheim, Norway
e-mail: ekaterip@ntnu.no

A. Steinsbekk
Department of of Public Health and General Practice,
NTNU Norwegian University of Science and Technology, Trondheim, Norway
e-mail: aslak.steinsbekk@ntnu.no

M. Fominykh
Faculty of Logistics, Molde University College, Molde, Norway
e-mail: mikhail.fominykh@himolde.no

F. Lindseth
Department of Computer and Information Science,
NTNU Norwegian University of Science and Technology, Trondheim, Norway
e-mail: frankl@idi.ntnu.no

V.L. Uskov et al. (eds.), *Smart Universities*, Smart Innovation,
Systems and Technologies 70, DOI 10.1007/978-3-319-59454-5_7

reality goggles, almost all the students reported that they felt more engaged into the situation than using desktop PCs alone. At the same time, most also reported 'cyber sickness'. We conclude that a smart virtual university hospital is a feasible alternative for collaborative interprofessional learning.

Keywords Smart virtual university hospital · Virtual reality · Medical training · Collaborative learning · Virtual operating room · Educational role-play

7.1 Introduction

Patients are the major focus of medical education at all levels. The majority of the student contact with the patient has traditionally been through practice placement and clinical rotation in different health care settings, primarily in hospitals; however, the availability of time for interacting with patients in real life situations is associated with a number of challenges.

First, the increase in the number of students means that each student can interact with the patients less frequently, which is partly ameliorated by increasing the number of patients. Second, there has been a constant drive for many years to reduce the length of each patient's stay, meaning patients spend less and less time in hospitals and other health care institutions. Improvements in hospitals' effectiveness include ideas such as implementing clinical pathways (predefined patient trajectories optimizing the flow of selected patients through the hospital) and the increase in the number of day and outpatient patients. These in combination lead to significantly less time for contact between students and patients. Consequently, students get less time on the task, which is paramount for preparing them for their post-graduate work. Thus, there is a need for smart solutions that give the students more time on tasks or make the time with the patients more effective.

Another aspect relating to interaction with the patient is the increase in team-based work in health care. In a modern hospital, a patient is treated not by a single health-care specialist, but by an interprofessional team with complex collaborative procedures and practices. This means that medical and nursing students need to practice on complex interactions within a team of professionals. Although this is increasingly acknowledged as a central competency by the practice field, it is not implemented in the universities due to practical challenges. Students from different professional health care educations typically have practice placement separately from each other to not overburden those in the clinic. This means that a hospital department can have medical students present at one time and nursing students at another to avoid overcrowding of students in the ward. If there are more students than staff and patients, it would be very difficult to get the everyday work done.

The last aspect concerns the possibilities of a student following a patient over time. When students are on practice placement, they are in one unit at the time. This means that they only see patients while they are in direct contact with the unit. Even if the students have practice placement in other units, they will encounter different patients there. Thus, they are usually not given the opportunity to follow the individual patient trajectory. One consequence is that the students get little experience in understanding the totality of the patient's situation, but also a lack of understanding of how the health care system is organized, the complete process of transition from one unit to another (i.e. seeing it from the perspective of both units involved), and how this organization is experienced by the patients. The transitions are found to be the especially weak points. Students, therefore, need to be skilled in how to ensure the quality of services when the patient moves from one unit to another.

To meet these and similar challenges, there is a need for smart flexible solutions that can utilize collaborative technologies and digital learning resources. These are some of the hallmarks of smart education [1], which is a central concept within Smart universities. By 'Smart university' we mean a university that 'involves a comprehensive modernization of all educational processes' [2]. A smart university exhibits a number of various 'smartness levels' or 'smartness features', such as adaptation, sensing, inferring, self-learning, anticipation, self-organization and restructuring [3].

In the work presented here, we focus primarily on the "Adaptation level" within the smart university framework [3]. The adaptation level concerns issues like the ability to modify teaching and learning strategies to better operate and perform the main business and educational functions. In our case, it is about adapting to the challenge of preparing the students for the changing situations in health care as well as about how we can modify our learning strategies to give students ample time on task with individual patients and preparing them better for team based work along various patient trajectories. In particular, we have focused on the adaptation to the new platforms and technologies, variation in interfaces, and a new style of learning and teaching.

Our solution has been to use Virtual Reality (VR) and to create a smart virtual learning environment. We thus use virtual "technology supported learning environments that make adaptations and provide adequate support" [4]. We have aimed to make a virtual learning environment that will support student learning by providing adaptive and flexible solutions for practicing a variety of clinical situations at the students' own pace, adjusting to the student's level of expertise and scheduling limitations.

Based on information through contacts, web sites, and publications referenced in the next section, it is evident that several world leading universities and hospitals, especially in the US, UK, Australia, and New Zealand, have adopted 3D virtual simulation as a part of their educational programs. Examples include virtual hospitals/medical faculties at the University of South Florida, Imperial College of London, and Auckland University Hospital. Such environments typically include an array of different facilities such as emergency rooms, intensive care units, nursing simulations, and general information for the public. Other examples include the Maternity Ward at Nottingham University and the Emergency Preparedness Training at University of Illinois (secondlife.com).

Our own initiative has been partly inspired by these projects but seeks to achieve a more coherent approach to the development of smart online virtual educational solutions that are embedded in a holistic system to make them more accessible and easier to use. This is done by utilizing an established and integrated framework.

We have worked with the long-term idea of establishing an online Virtual University Hospital (VUH) to create such a holistic system and to be a venue for learning, research, and development. The idea is to make a virtual mirror of the St. Olav's University Hospital (St. Olav), which is integrated with the faculty of Medicine at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. St. Olav is newly built and is one of the most modern university hospitals in the world with a state of the art technological platform and modern clinical buildings. Furthermore, the teaching and research facilities are integrated and distributed within the hospital.

As the success of such a smart virtual university hospital is dependent on the activities provided within the framework, we have concentrated our efforts on developing and testing solutions. In short, we have made a virtual part of a hospital in the virtual world Second life (SL) with patient rooms, meeting rooms, operating theatres etc. We first developed mono-professional scenarios for training post-graduate nurses in a surgical environment, anesthesia, and intensive care [5, 6]. Then we moved on to a larger project known as VirSam (virtual communication and collaboration, in Norwegian VIRtuell SAMhandling), where we focused on training for third year nursing and fourth year medical students in interprofessional team communication and collaboration.

The VirSam project is the focus in this paper, but we will describe the activities leading up to this project in some detail as it shows the process we have gone through to adapt our teaching and learning to smarter solutions.

7.2 Background

7.2.1 Virtual Reality in Health Care Education

Numerous modes for virtual learning currently exist, e.g. flexible low-cost 3D virtual simulations, 3D virtual environments, and associated infrastructure accessible over the Internet. This technology can benefit the educational process due to low costs and high safety, three-dimensional representation of learners and objects, and interactions in simulated contexts with a sense of presence [7, 8]. It has been suggested that this technology can "considerably augment, if not eventually, revolutionize medical education" [9].

Many studies reported the potential of 3D virtual worlds for educational activities when they have mostly been used on regular desktop computers [10]. Nowadays, these virtual environments can be used in combination with advanced VR technologies, such as motion tracking and head-mounted displays (HMD)/VR goggles to increase the sense of immersion and, therefore, improve the experience. This makes it more believable and transferable to real life. VR goggles are a type of on-body VR devices that are worn on the head and have a display in front of the user's eyes [11, 12]. Most of these devices consist of a display and a tracking system. It allows much greater immersion because the user can control the direction of the view in a virtual world in exactly the same way as in the physical world—by turning the head. The displays of VR goggles have larger fields of view and provide a stereoscopic image, making the experience more believable. One example of this is the Oculus Rift (http://www.oculusvr.com/), which has characteristics making it stand out from its predecessors. At the same time, the device is relatively affordable and, therefore, suitable for educational context [13, 14].

3D virtual environments have been widely used in the healthcare domain, including both desktop-based virtual worlds and other VR applications. Examples include training facilities for nurses and doctors [15–17]. These can be found in palliative care units [18], health information centers, and anatomy education [19, 20]. Such training is, on several occasions, reported to provide a cost-efficient and user-friendly alternative to real-life role-plays and training programs [18]. As demonstrated in several studies, "virtual worlds offer the potential of a new medical education pedagogy to enhance learning outcomes beyond that provided by more traditional online or face-to-face postgraduate professional development activities" [21].

Studies have shown that VR simulations contribute to enhanced procedural skills, with clear transfer of training to clinical practice [22]. A variety of surgical VR simulators have been developed (e.g., dental, laparoscopic and eye surgery) which have shown clear benefits for medical training [23]. The use of VR technologies goes beyond procedural skills. Possibilities for synchronous communication and interaction allow using these technologies, at the moment mostly with the desktop interface, for various collaborative learning approaches [24], as well as facilitate situated learning [25] and project-based learning [26] approaches. In addition, virtual learning environments can also support interprofessional and distributed medical teams working together on complex cases [27].

Desktop-based environments have been augmented with VR elements, such as HMD, for treatment of various neurological and psychiatric disorders including autism, phobias, and post-traumatic stress syndrome, the latter especially in military settings. For example, the Virtual Afghanistan/Iraq system has undergone successful clinical trials in using exposure therapy for treatment of combat-related post-traumatic stress syndrome among veterans [28].

While VR can be used for pain treatment as well [29], there is still little research on smart virtual learning environments in the field of healthcare education. There are, as mentioned above, examples of individual projects, but there is a lack of research-based innovation and research on implementation where such solutions are integrated into existing everyday teaching. For example, Cates [22] and Ruthenbeck [23] have requested more research on the use of VR/virtual environments for procedural training at different levels of medical education and exploration of solutions with greater levels of interactivity and increased realism.

7.2.2 Communication and Team Training

While most of the existing VR simulations focus on training of cognitive and psychomotor skills, there is a lack of solutions that support team and communication training that are essential in modern medical education [17]. For example, Pan et al. suggest further exploration of 'immersive VR' to increase understanding of the social dynamics between doctor and patient [30]. While medical simulation sessions often claim to include team training, they are generally not designed to achieve team training competencies [31]. Furthermore, many medical schools do not have the expertise necessary to implement team-training programs on their own [31].

This emphasizes the need to focus on interprofessional team training as an integral part of the educational program at a smart VUH. Weaver et al. identify identifies the following most common team competencies targeted in medical team training programs: communication, situational awareness, leadership, and situation monitoring. Instructional methods include information-based methods such as lectures, demonstration-based methods such as videos, and practice-based methods such as simulation and role-playing [32]. The latter is a common modality found in 68% of training programs [32, 33].

Baker et al. looked at an array of existing medical training programs, including both simulation-based and classroom-based programs [34]. The former included Anesthesia Crisis Resource Management and Team-Oriented medical simulations and typically take place in a simulated operating room with patient simulator/mannequin, monitoring/video equipment, and pre-post briefings [34]. The classroom-based training programs include MedTeams, Medical Team Management, Dynamic Outcomes Management, and Geriatric Interdisciplinary Team Training. These programs typically include lectures, discussions, and role-plays [34, 35].

Many existing programs focus on team-training within closed environments such as operating rooms and emergency care units [36] while interprofessional team training is important for improving patient safety and breaking down the traditional discipline-based barriers [36]. This motivated the development of the Triad for Optimal Patient Safety program (TOPS) [36].

Another interprofessional training program, originally developed by US Department of Defense and the Agency for Healthcare Research and Quality, is TeamSTEPPS (Team Strategies and Tools to Enhance Performance and Patient Safety) [37]. This framework has gradually reached international acceptance and has served as the main inspiration for our work in this project with developing interprofessional team training simulation. TeamSTEPPS is "an evidence-based framework to optimize team performance across the health care delivery system" [38]. It has several important features, with one of them being the four team competencies: Communication, Leadership, Mutual Support, and Situation Monitoring [38].

It is necessary to develop reliable methodological tools for developing learning content and evaluating learning effectiveness team training in virtual learning arenas [17, 27]. Research is also needed to gain knowledge of what are the good solutions and how they should be adapted to meet students' needs.

7.3 Project Goal and Objectives

The main goal of this project is to increase the students' time on tasks by offering smart online 3D virtual learning environments (with and without VR interface) that provide the learner with practice opportunities, to be completed at their own pace, where patient access is increasingly difficult to achieve. This is done through enhancing the PBL (problem based learning) approach and facilitating online environments for small tutor groups and flexible self-regulated learning, "anytime, anywhere".

7.3.1 Challenges in Medical Education

The medical doctor program at NTNU, where this study was based, has a PBL based curriculum and is based on "spiral learning". This means that the same topics are repeated throughout the study with increasingly advanced level. The system mainly follows the organ system, having one organ (or another topic) in the focus at the time. The teaching is based on learning objectives that are detailed for each semester and there are no fixed set books (students have to find literature themselves based on, e.g. recommendations from teachers). Furthermore, and different from many other programs, there are no separate subjects. This means that when new learning activities are integrated, it is not done on the level of a subject. Instead, the new learning activities are integrated into an ongoing learning activity according to which organ system/topic and the complexity level the activity concerns.

Referring to the McMaster University PBL model as developed by Barrows and Neufeld, which the medical school at NTNU has partly followed, the case-based and explorative methodology consists of three key components: PBL, self-regulated learning, and small group tutorial learning [39]. The method thus acknowledges the complex interplay between the social and individual aspects of learning, as later more fully elaborated and expanded in Nonaka and Takeuchi's SECI (Socialization, Externalization, Combination, Internalization) model for learning and knowledge development [40].

While many medical schools, including NTNU, have adapted the PBL approach for curriculum development and teaching and learning strategies, there is little evidence to suggest that medical schools and postgraduate institutions are sufficiently successful in helping students becoming effective self-regulated learners

[41]. Acknowledging that the medical profession is “in a perpetual state of unrest” [42], developing the self-regulated learner becomes an important aim in itself. The process of becoming an effective self-regulated learner can be greatly supported by technology [9] and offer new possibilities [21].

Solely focusing on the self-regulated learner would obviously be a dead end, though. The community aspect of learning and knowledge development also needs to be included. Drawing upon seminal work of Lave and Wenger [43], Engeström [44], and Brown and Duguid [45], we suggest that the learning process and creation of knowledge is also characterized by narratives, collaboration, and social constructivism. An increasing body of research from different disciplines has suggested that the ability to visualize represents a particular difficulty for many learners. Amongst these disciplines are economics, electrical engineering, the medical disciplines, and biology [46, 47]. The common problem is the ability to perceive unseen forces, patterns, and the transition from 2D (i.e. on paper) to 3D (i.e. “real life”).

7.3.2 Smart Virtual University Hospital and VirSam

Based on the context and challenges presented above, we have a vision of a smart approach that integrates educational activities delivered virtually with other educational activities that prepare the students for practice. We have, therefore, worked within the VUH framework introduced in [5, 6]. We identified initial requirements, facilities, and technological solutions for the VUH as an arena for educational activities, for personnel, for students, and for the public [5]. Some examples of these are presented in Table 7.1.

To start the process of filling the VUH with content, some minor projects relating to mono-professional communication and collaboration were started. The first solutions were used for training nurses undergoing specializations in surgery, anesthesia, and emergency care [5, 6]. This gave us valuable experiences in both

Table 7.1 Educational activities in a virtual university hospital

Activity	Content, facilities and technological solutions
Patient simulation	Operating room, patient ward, emergency area, virtual humans, interactive hospital equipment, VR interface
Procedure training	Various hospital departments (operating room, patient ward, emergency area), information using videos and posters, interactive hospital equipment, VR interface
Lectures, e.g. anatomy	Classrooms, lecture halls, 3D interactive models of organs and the human body, posters, videos, VR interface
Role-plays (team training, patient communication)	Operating room, patient ward, emergency area, reception/outpatient clinics, interactive hospital equipment, VR interface

setting up the VR environment and planning a more complex infrastructure and logistics.

We decided to continue with the topic of communication and collaboration. The pressing problem that students from one profession seldom get the chance to practice with students from other professions inside a hospital setting is that they seldom see the entire patient trajectory during clinical rotations. This was the motivation for starting the VirSam project. We received funding from the NTNU's Top Education program for a demonstration project, which is reported on here.

The primary objective of the part of VirSam reported here was: to provide fourth year medical and third year nursing students with the possibility of interprofessional communication training in a smart virtual environment. The secondary objective was to investigate the students' experience with different technological solutions for experiencing VR. This was done by having them use both a desktop version and a set of VR goggles.

7.4 Methods and Technologies for Supporting Interprofessional Communication and Collaboration

7.4.1 Developing Technical Solutions

We chose to use SL as the platform for developing the VR part of our VUH. SL remains one of the most stable, developed, and populated virtual environments, though there are most definitely certain limitations. We developed our virtual hospital on the base of NTNU virtual campus in SL to make it easier for the students to navigate there. Another advantage of using an established platform was the possibility to buy ready-made models in the SL market place.

The virtual environment and avatars for role-playing have been designed in accordance with the learning goals we have set and after consultations with specialists and examinations of the corresponding facilities in the real hospital of St. Olav. We have made the following rooms:

- *Patient room* is the room designed for inpatient visits, which typically contain a hospital bed, some medical devices, patient terminal (TV etc.) as well as a chair, table and washing basin.
- *Waiting area* is an ordinary waiting area that one can find within all ordinary hospital clinics, consisting of a reception desk, sitting chairs for patients and relatives, and a table with magazines and papers.
- *Sluice* is a room that health personnel use for the delivery of patients on their way to a surgery.
- *Operating theatre/room* is a place where surgeries are conducted. The room is usually equipped with operation lamps, different medical equipment, and an operating table for the patient.

- *Emergency room* is a room where emergency patients are received for initial examination. The room bears several similarities to the operating room.
- *Intensive care unit* is a room with several patient beds divided by curtains, with some monitoring equipment, where the patients can be placed for observation after surgery.
- *Meeting room* is where the personnel meet to discuss situations among themselves or where they have, for example, discharge meetings with patients.

The goal was to create a virtual environment realistic enough to give a feeling of being in a real hospital. For example, the virtual operating room was modeled after the one at the Department of Neurosurgery at St. Olav's hospital (Fig. 7.1).

The same design approach was applied to the entire interior. Several equipment artifacts were designed after those found in the real hospital as some of the virtual equipment purchased earlier on the SL marketplace had limited functionality and could mostly be used as an illustration.

An important aspect of using VR is that avatars represented the "players". Thus, to make the experience as real as possible, effort was put into making the avatars and their appearance realistic in term of clothing, gender and general look. The surgical nursing avatars' uniforms were originally pale green and the ward nurses' ones were white. Additional uniforms in other colors for anesthesia, emergency, and intensive care nurses have also been made. In addition, we purchased 'skins' (faces for old people) and other avatar accessories (e.g., a hijab and jewelry, patient gowns) at the SL marketplace.

We made avatars to represent different patient types (children, with foreign background, with serious condition(s), etc.) as well as their relatives. The avatars for the relatives and patients had to match the description in the scenarios, for example, a 'mother', 'pregnant woman' or a 'person with immigrant background' (Fig. 7.2 left). The patient and the staff avatars contained more details and were dressed in accordance with the standards adopted at the Norwegian hospitals.

Apart from avatars operated by the students themselves, we have made virtual patients (programmable agents). The virtual patients could be static or dynamic. The static avatars are placed in the waiting room and hospital corridors. In addition, some beds in the intensive care unit are used to create an illusion of a busy hospital. The dynamic virtual patients are agents programmed to simulate certain diseases for

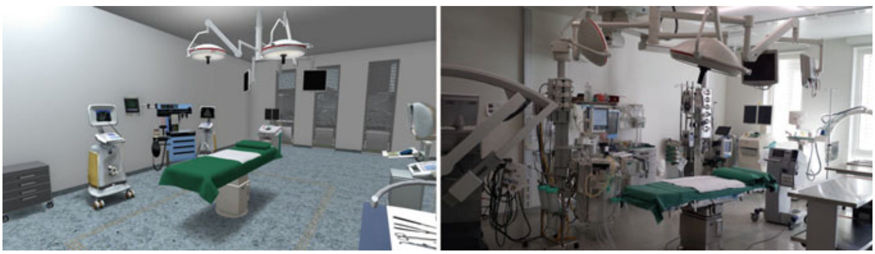

Fig. 7.1 Virtual operating room (*left*) versus a real one (*right*)

Fig. 7.2 A pregnant virtual patient played by a student (*left*) and a dynamic artificial/programmed virtual patient with student avatars around (*right*)

diagnostic training and include a 'boy' avatar with diabetes and an 'old man' avatar with a heart attack. These avatars exhibited certain symptoms (by body language and facial color) and were accompanied with blackboards and pop-up menus where the user can get additional information, order tests, and choose a course of treatment (Fig. 7.2 right). Depending on the chosen treatment course, the virtual patients exhibit pain, recover, or die.

7.4.2 *Instructions to the Students*

The prerequisite for taking part in this system is that the students must have access to a computer with SL installed. Therefore, we made instructions showing how students could download the SL browser to their laptops, set up a user account, and do some experimentation with the VUH environment beforehand. We also gave the students a presentation of the VirSam project and a one hour long SL tutorial on such topics as camera controls, avatar navigation, familiarizing with the environment, voice communication, and fetching a gurney for patient transport. Later, we developed a short (12 min) video lecture giving the same information in condensed form.

The students log into the VUH with designated avatars. To do the role-play, the students are provided with the description of the clinical situation and role cards for the different roles they can choose, which are described in detail below. Improvisation during the role-play is important in order to mitigate the technical limitations and make the role-play realistic. The technical aspect concerned things that are different to realize in a virtual environment. For example, it is not possible (or difficult) to control facial expressions and perform medical examinations and manipulations. In such situations, the students need to explain what they are doing/planning to do orally. The students are not given instructions on what to say. Thus, they must improvise continuously during the role-play. They are instructed to use their previous experience to play their role, meaning that there has to be some adaption to the role.

Although it is possible to develop solutions as described above with virtual patients (Fig. 7.2 right) with information given on blackboards, this solution is not technically elegant, and it is difficult to incorporate the required flexibility. Therefore, the students were informed that, in one of the clinical scenarios, there would be a game master who had information about the tests and examinations that ought to be done, as well as the results to these. To activate or get access to this information, the students were instructed to clearly say which tests and examinations they would have done. The game master was instructed to only give information on what the students asked for. The game master was to not give out information not asked for.

7.4.3 *Learning Outcomes and Clinical Scenarios*

Since the purpose of the project was to develop and evaluate smart solutions to give students competencies in interprofessional communication and collaboration, all the work was guided by the following learning outcomes that the students were expected to reach:

1. Practical skills in conducting role-playing in a virtual world,
2. Understanding the importance of:
    (a) clear and structured communication that is comprehensible to all parties,
    (b) clarifying the patient's wishes to set common goals for treatment and follow-up,
    (c) making sure that all roles and responsibilities in a team are properly clarified and distributed,
    (d) asking questions and listening to each other in order to obtain joint understanding of the situation,
    (e) making sure that everybody suggests solutions and contributes to the decision-making process, and
3. Knowledge of collaborative team processes along the patient trajectories at the respective departments and agencies involved.

These outcomes have been mostly inspired by the TeamSTEPPS framework [37, 38] and consultations with subject experts. To achieve these learning outcomes, effort was put into developing clinical scenarios mirroring the real life work in hospital departments. Two clinical cases, geriatric and gynecological, were developed by specialists from the corresponding clinics at St. Olav's hospital, based on a template provided by the authors. The template was inspired by literature review in the previous section and focused on the communicative and collaborative aspects of interprofessional teamwork during different types of patient trajectories.

Furthermore, we wanted to explore the usability of VR in presenting a condensed version of different types of patient trajectories. It was, therefore, chosen to make the geriatric scenario an example of a long-term trajectory lasting several weeks. The gynecological scenario, which was a sub-acute condition, represents a short-term trajectory lasting only a few hours.

In the following, the details of the two clinical scenarios are presented as it was presented to the students. In each scenario, there are several roles, including the role of the patient. A medical student is supposed to play the roles of a medical doctor or a surgeon and, likewise, a nurse student is supposed to play the roles of a nurse. Otherwise, there are no instructions as to who shall play the other roles, i.e. this is left to the students to organize.

In addition to the general description of the scenarios, the students are given one role card describing the role they shall play. For the role as nurses and medical doctors/surgeons, very little information is provided in order for students to use their own experience during the role-play. The motivation is to challenge the students in a safe environment in order to test out their skills and knowledge. For the roles as patients or relatives, some more information is given regarding behavior. For each role, there is information on the corresponding role card, which is not disclosed in the description of the scenarios, such as what the players should get out of a situation.

7.4.4 Geriatric Scenario: Long-Term Patient Trajectory

The geriatric case represents long-term patient trajectory from admission to home care.

Practical information. The role-play may have from 3 to 6 participants. With 6 participants, the roles are patient, doctor at the geriatric department, a nurse at the ward, a relative of the patient, a municipal employee, and a game master. With 5 participants, the role of the relative is omitted. With 4 participants, the municipality employee is also the game master. With 3 participants, there is no municipal employee and the patient is also the game master. The game master acts as an information provider who has information about test results etc., which may be disclosed to other participants upon request.

Clinical situation. The scenario takes place at the inpatient ward at the geriatric department. An elderly patient, 84 years, is hospitalized after a fall at home. The patient spent several hours at the hospital A&E (accident & emergency) department prior to transfering to the geriatric ward in the evening. According to information from the A&E department, a home care employee found the patient on the floor of his home. It is unclear how long the patient has been lying on the floor, but it was probably for several hours. The patient is described as confused and anxious and cannot account for the events himself. The patient has severe pain in the back and is rather thin. It is reported that, according to the home care services, the patient has recently complained about dizziness and feeling shaky. He usually uses a walker. The spouse of the patient died one year ago. He has two children and four grandchildren. He lives in an apartment on the 3rd floor with a lift. The patient is normally fairly self-reliant, but uses home care services for certain tasks such as taking on/off compression stockings. He also gets his medicines in a so-called multi-dose system where the medicines are pre-packed. He also has a remote control safety alarm. His past diseases include hypertension, diabetes, and osteoporosis with previous compression fractures. The drugs he takes include Metoprolol depot, Albyl E, Furix, Metformin, Calcichew-D, Alendronate, Sobril, Imovane, and Codeine as needed.

Role-play. There are 4 scenes to be played. Those who are not participants in the specific scenes are residing in the background or the waiting room in the virtual hospital. Their primary function is to observe.

Scene 1: *The first evaluation.* The scene takes place inside the patient's room in the geriatric department shortly after the arrival of the patient at the ward. Participants include the patient, doctor, nurse, and relative of the patient (Fig. 7.3). The main purpose of this scene is to make an initial assessment of the patient's situation. The doctor and nurse need to clarify who does what and inform the patient and the relative. The scene is concluded with the doctor and the nurse summing up what needs to be done to clarify the situation (e.g., which tests to be done) before leaving the patient room and proceeding to the meeting room.

Scene 2: *Interdisciplinary planning meeting*. The scene takes place inside the meeting room. Such meetings normally are held at a fixed meeting time on the first business day after the patient's admission to the geriatric ward. Participants are the doctor and the nurse (who are often joined by a physiotherapist and an occupational therapist). The purpose is to present the patient (hospitalization cause, findings so far), clarify the treatment objectives and actions, and start planning the discharge of the patient. A designated game master provides information about the test results and findings from examinations that were requested in scene 1. The scene

Fig. 7.3 The opening scene in the geriatric case, the nurse and doctor talking to the patient and his daughter in the patient room

concludes with the doctor and nurse summing up a course of action before the doctor leaves the room.

Scene 3: *Phone call to the municipality*. The scene takes place inside the meeting room. The time is a given number of days prior to the planned discharge date (i.e. several weeks after scene 2). Participants are the nurse and a municipal employee. The goal of the call is to start the discharging process and clarify how the municipality might contribute with personalized home care or a temporary admission of the patient to a rehabilitation or nursing home. Ending the telephone call concludes the scene.

Scene 4: *Discharge Meeting*. The scene takes place inside the meeting room a given number of days after scene 3. Participants are the patient, the doctor, the nurse at the ward, the relative(s) of the patient, and a municipal employee. The purpose is to plan the patient's discharge as well as any necessary further action, such as home care. Toward the end of the meeting, the participants sum up the further action plan for the patient.

7.4.5 Gynecological Case: Short-Term Patient Trajectory

The gynecological case represents a short-term sub-acute patient trajectory from admission to surgery preparations.

Practical information. The role-play takes place at the gynecological department and may have from 3 to 6 participants. Depending on the number of available players, the participants are the patient, the doctor of the gynecological department (also surgeon), the nurse on the ward (core participants with 3 players), the surgical nurse (if 4 players), the husband (if 5 players), and the anesthetic nurse (if 6 players). The same person can potentially play the ward nurse and surgical or anesthetic nurse, depending on how many people are participating.

Clinical situation. The patient is a 30-year-old woman with no children (Para 0) who arrives at the gynecological department with suspected ectopic pregnancy (pregnancy outside the uterus). Her husband is also in his 30 s. She became acutely ill at work, coming to the emergency room with severe pain in her lower abdomen. At the emergency room, a pregnancy test was taken that unexpectedly turned out to be positive. Therefore, a tentative diagnosis of ectopic pregnancy has been set. The findings on the examination include tenderness by bimanual palpation of the uterus corresponding to the right adnexa (surroundings of the uterus). A vaginal ultrasound shows no intrauterine pregnancy. Some free fluid in the (ovarian) fossa and a donut-like structure corresponding to the right adnexa of the uterus can be seen on the ultrasound, confirming ectopic pregnancy. It must be removed on the same day with laparoscopic surgery under general anesthesia. Prior to the operation, the surgical team should go through a 'safe surgery' checklist with the presentation of the team and the planned procedure.

The patient's symptoms include severe pain, weak and ongoing vaginal bleeding, and paleness. The labwork showed the u-hCG +, quantitative HCG > 1000 Hb 8 (low).

Role-play. There are three scenes to be played. Those who are not participants in the specific scenes are residing in the background, the waiting room, or outside the operating room in the virtual hospital to observe.

Scene 1: *Assessment and informing the patient.* The scene takes place in the patient's room and the participants are the patient, husband, ward nurse, and doctor. The purpose of this scene is to make an assessment of the patient and explain the situation to her. The patient has just arrived to the gynecological department from the emergency unit and is lying in bed. The husband is sitting in a chair. The nurse enters the room (or is in the room from the beginning), performs some tests and asks questions before explaining that the doctor is coming soon. The doctor enters the patient's room and the nurse presents her findings. Afterwards, the doctor 'performs an ultrasound' and explains the diagnosis, the need for surgery that will follow immediately, and how it will be done. Shortly after, the doctor leaves the room and the scene ends with the nurse also leaving the room to fetch a gurney that will transport the patient to the operating room.

Scene 2: *Transfer and information exchange.* This scene takes place between the patient's room and the sluice. The participants are the patient, husband, ward nurse, surgical nurse (and possibly anesthetic nurse). The goal of the scene is to transfer the patient to the sluice and provide all of the necessary information to the surgical staff. The nurse fetches the gurney and the patient is placed on it before being transported from the patient room in the ward to the sluice. The husband of the patient follows. In the sluice, the surgical nurse (and possibly the anesthetic nurse) is waiting for them. In the sluice, the nurses exchange information relevant to the upcoming surgery. The husband is not allowed to follow the patient further. The scene ends with the surgical and anesthetic nurses rolling the gurney into the operating room.

Scene 3: *Preparing for surgery.* The scene takes place in the operating room and the participants include the patient, doctor/surgeon, surgical nurse, and anesthetic nurse (Fig. 7.4). The patient is 'placed' on the operating table. The doctor and the surgical or anesthetic nurse explain to the patient what they do during the preparation of the patient for surgery. The patient is 'put under general anesthesia' (e.g., being asked to count back from 10). The scene is concluded with the team undergoing the 'safe operation' checklist.

7.4.6 Methods for Testing the Solutions

All the cases and scenarios were tested during the same day and all of the required data was acquired during the test run. The role-play was performed in two phases with a desktop (phase 1) and VR goggles (phase 2). The students were divided into groups and played out both clinical scenarios.

Fig. 7.4 The last scene in the gynecological case with the nurse and doctor making the preparations for sedating the female patient

In Phase 1 (desktop version), the six students in one group were located in six separate rooms with their own PC where SL was installed. They communicated with each other in the group through their avatars and used the voice chat function in SL. The remaining students stayed in the classroom and followed the play either on their laptops through their own avatars or on a big screen connected to a laptop. After the first group had finished their first role-play, the players and observers switched places.

In Phase 2, the students in one group were placed in a lab where every student received one PC set up with SL and VR goggles (Oculus Rift development kit versions DK1 and DK2) (Fig. 7.5). In this setting, the students did not use SL's voice chat for communication due to the proximity to each other as well as the fact that using the voice chat would have created feedback. Instead, they used their own voice to communicate. A microphone was placed on the table to transmit the sound to the classroom where the non-playing group was seated to observe the role-play.

In the beginning of the role-playing session, the students were assigned one of the roles from each scenario and received role cards describing their characters as well as a general case description that included the situation description, preliminary diagnosis, clinical data, and the different scenes in the scenarios (as presented above). The students were told to follow the scenes, but at the same time to improvise their role as best as they could by applying their knowledge and previous experience.

After each role-play, each student group spent 5–10 min reflecting on their experience within the group. After finishing the role-plays, all the students gathered in the classroom and participated in a joint discussion/group interview session.

The data in this study was collected from several sources. The role-play in SL was recorded as a screen capture (with sound). The role-play was observed both in SL and in 'real life' by the authors. The group interviews were recorded with video

Fig. 7.5 Students use VR goggles to participate in role-play. They sit at different angles depending on where they are in the virtual environment

camera and sound capture that was later transcribed verbatim. In addition, 16 of the students filled out a questionnaire consisting of both multiple-choice questions using a Likert scale, ‘check-box’ questions, and open questions.

7.5 Outcomes

A total of 18 students, including 14 third-year nursing students and 4 fourth-year medical students, participated. The participants were divided into three groups, each group containing one or two medical students. Of these, 16 responded to the questionnaire. Among these, there were three male and ten female nursing students and two male and one female medical student.

Ten students reported that they had little to some experience with virtual environments and 3D games. Only three students did not have any prior experience. When asked to give examples, the majority (10 of the respondents) mentioned Sims. Other games such as World of Warcraft, Minecraft, Destiny, Runescape, and Skyrim, as well as other Oculus demos, were mentioned. When asked to describe their computer expertise, the students almost equally divided between “somewhat good”, “good”, and “very good”.

None of the students had experienced working with students from other health professions before.

7.5.1 Learning Outcomes

There were three questions in the questionnaire asking to what extend the students have achieved the learning outcomes (see details in Sect. 7.4.3). The options given to the students were "achieved", "partly achieved", or "not achieved".

All the participants answered that they achieved the learning outcome we thought were the most important during our work: understanding the importance of a clear and structured communication that is comprehensible to all parties. Some of the other learning outcomes, especially (b) and less so (c) and (d), were not fully achieved (Fig. 7.6).

The majority of the students (14) reported that they achieved the learning outcome of understanding the importance of involving all parts in the decision-making process. As appears from the interviews, the roleplaying session allowed looking back and reflecting on one's own and other's roles and contributions. As one of the students puts it: "…Afterwards all feelings are like that: 'Oh my God we did not think of the blood pressure and this and that …I should have had a greater role'".

Most of the students (13) answered that they achieved practical skills in conducting role-playing in a virtual world, while only three students replied partly achieved.

More than half of the participants (9) answered that they achieved the knowledge of collaborative/team processes during the treatment and monitoring of patients at the respective departments. Seven students answered "partly achieved".

7.5.2 Experiences with the Second Life Technology

This topic contained five questions, including four five-point Likert scale questions and one open question. Most of the students (14) agreed or strongly agreed that

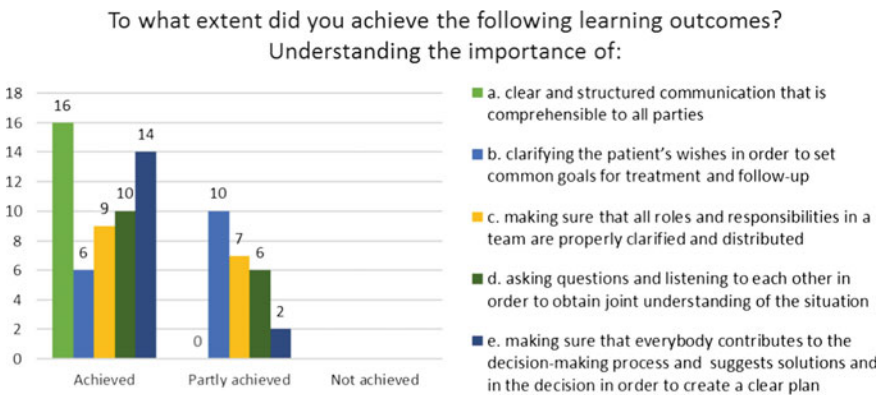

Fig. 7.6 Achieving learning outcomes

familiarizing with SL went quickly enough, while only two were neutral on the subject. Similarly, the majority (9) disagreed that it was difficult to move the avatar, and only four agreed or strongly agreed.

The next two questions received more equally distributed answers. It was easy or very easy for ten participants to observe others in the virtual environment, but five were neutral. Communicating with others was easy or very easy for nine, but difficult for five other participants.

When asked to comment on their positive and negative experiences in an open question, 11 participants provided input focusing on various topics as listed below (the number of participants mentioning them is given in brackets). The positive topics included:

- Rich learning experience (2)
- Good practice for communication/dialog (1)
- Fun experience (1)
- Easy to use technology (1)
- 3D environment resembles real hospital spaces (1)
- Experience causes reflection and learning (1)

The negative topics included the following:

- Difficulties with sound, including identifying who is speaking (4)
- Difficulties with navigation in 3D and view camera (2)
- Annoyance because of delays caused by technical problems (2)
- General difficulty with technology without support personnel (1)
- Difficulties in getting subject information in "game" settings (1)
- Difficult to quickly get into a role (1)

7.5.3 Experiences with Using VR Goggles

All the students participated in the role-play using VR goggles. Two Likert-scale questions were asked to measure participants' perception of presence and physical discomfort when using these (Fig. 7.7). It was clear that using VR goggles lead to increased immersion, but at the same time also physical discomfort was a result, generally accompanied by nausea.

The open question asking to provide comments regarding the use of VR goggles received 14 answers in total. The positive and negative topics are given here, with the number of participants mentioning them given in brackets. Positive feedbacks included:

- Experience is more realistic/easier to immerse in the scenario than on desktop (6)
- Smooth experience overall or in short periods (2)
- Fun experience (1)

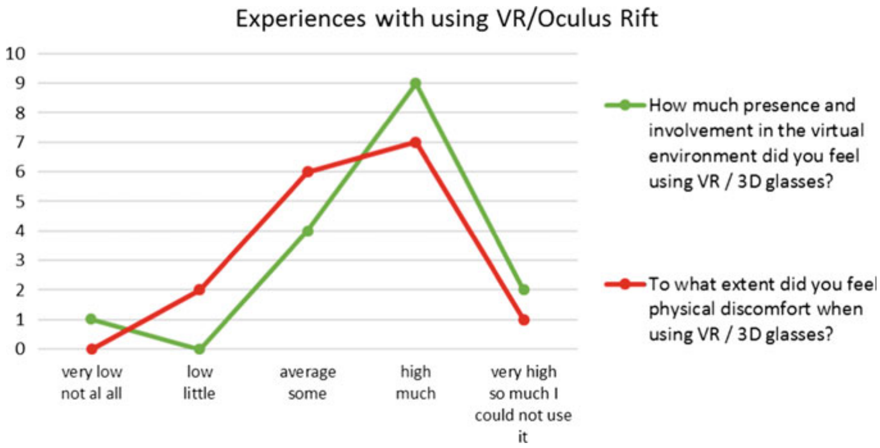

Fig. 7.7 Experience with Oculus Rift: presence versus discomfort

During the interview, the students were asked to compare the VR experience with 'traditional' face-to-face PBL (problem-based learning) sessions. One of the students mentioned that during such sessions "you will need to create those images in your head yourself…It requires more acting skills in a way", while with the VR glasses "you get immersed in (the situation)". Another student noted: "when we had the glasses on, we had really a lot patient contact". The general feedback during the interview was also that it is positive that we (the project team) are early with adopting the VR technology.

Negative feedbacks from the questionnaire included the following:

- Nauseous and dizzy feelings generally, over time, when looking around and when moving in VR (10)
- Technology is unstable and/or crashes (3)
- VR glasses are heavy (1)
- Experience is tiring for eyes (1)
- Difficulty controlling the avatar (1)
- Experience is confusing (1)

Apart from these issues, it was noted during the interviews that the novelty of the technology acted as a disruptive factor: "I think we have been more 'persons' when we used 2D … Because when we used 3D, there was too much focus on other things".

7.5.4 Preferred Technical Setup

In order to better understand how different role-playing modes functioned, we asked two questions suggesting alternatives and two open questions.

The participants gave the following answers when asked which visual interface they prefer for training interprofessional collaboration (number of answers in brackets):

- Oculus Rift/VR goggles (2)
- PC/Desktop VR (4)
- dependent upon the collaborative situation (10)

Regarding communication, the students were asked about which solution they preferred (number of answers in brackets):

- to be in the same room with other participants (8)
- to sit separately (4)
- dependent upon the collaborative situation (4)

When asked about preferred training interprofessional interaction, the students answered the following (number of answers in brackets):

- in a student group with teacher (7)
- in a student group without a teacher (1)
- dependent upon the collaborative situation (8)

The open questions showed that the students' answers were mainly influenced by technical aspects. Most commented on the discomfort associated with the VR goggles, but that sitting in the same room (which they did when using the VR goggles) was better due to it being easier to hear what the others said. On the other hand, some students commented that sitting apart in separate rooms reduced the amount of small talk. For example, one of the students mentioned during the interviews: "When you sit at separate rooms you know that somebody listens. So you will have to read and think". Another student, preferring sitting in the same room with VR googles on, said, "I got nauseous, but felt to be more present … there was more 'flow'".

When asked about suggestions for technical improvements, especially regarding interprofessional interaction, the students' answers mainly concerned the lack of technical possibilities. Among the things mentioned were (a) making it easier to perform detailed maneuvers such as touching the patient or doing clinical examinations or tests, (b) having a map showing the lay out, (c) automatically getting information like lab results, and (d) more interactive equipment.

7.5.5 *Role-Play in the Virtual World*

A set of seven Likert-scale questions was asked to collect feedback on the role-playing experience. The first three questions were related to the appearance of different key elements (Fig. 7.8). Most of the students agreed that the inpatient ward gave a good representation of the real one. This was the part of the virtual hospital where most effort had been put into in order to make it as identical as possible to real life in terms of interior, colors, texture etc. The participants were more neutral about the appearance of the operating room. The clothing of all avatars was mostly found appropriate.

Two questions considered the realism of the scenarios. All 16 participants agreed or strongly agreed that the geriatric scenario was realistic, while only five gave such answers to the gynecologic scenario. The rest of the groups were neutral or unsure about the gynecologic scenario. As one of the students stated during the interviews, "Everything I learnt, came out. So for me it was very real". At the same time, the fact that the role-play took place in a virtual environment allowed some experimentation during the patient communication as noted by one of the participants: "In a real situation it would be hard to say (to a patient): "You have fallen before, it is important to prevent falls", but since it was not real, it was possible to say it anyway … You can train on saying things…if you have a patient who is in denial".

The last two questions evaluated how engaged the students felt in the role-play and how fun they thought it was. All the participants agreed or strongly agreed that they felt engaged, while all except one also answered that it was fun to play. One of the factors contributing to the engagement might be the freedom and flexibility the role-play provided, as mentioned during the interview: "I think it was good that we had the time to talk. Because it differs how you are as a nurse and a doctor. Some doctors communicate very little…some nurses chat. So I think it is good that we had some flexibility here. Because it gives more space for how you want it to be".

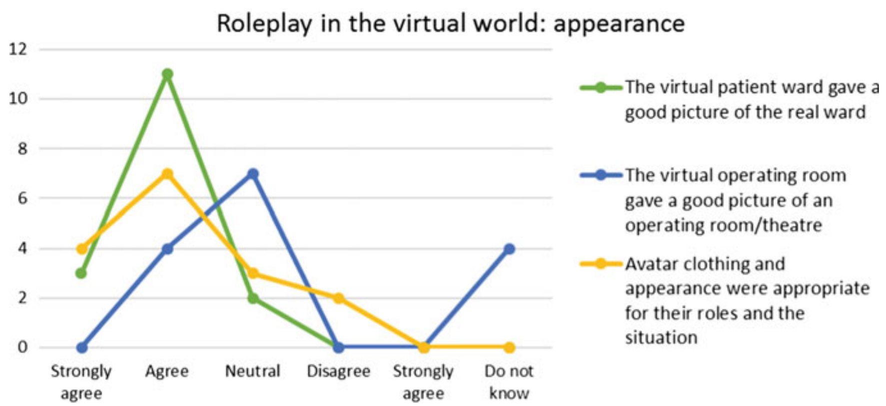

Fig. 7.8 Role-play in the virtual world: appearance

An additional open question was asked to collect suggestions for other similar simulators or scenarios. The suggestions included (a) to generally play more scenarios, (b) play scenarios that are normally not trained in physical reality, (c) play scenarios with difficult patients, and especially (d) play emergency scenarios. Also, during the interviews, some improvement suggestions were given for roleplaying the existing scenarios. For example, it was noted that sometimes knowing one's role was somewhat difficult and it "requires a bit more exercise and warm-up to get into the role". The proposed solutions included "more information to each scene", watching a film about activities at the ward before roleplaying, and spending more time on practicing.

7.5.6 Virtual Simulation and Learning

In a set of eleven Likert-scale questions the participants evaluated how much they learnt playing the scenarios in the simulator.

The majority of the participants agreed or strongly agreed to the general statements related to suitability of Virtual Hospital as a learning platform, with the largest proportion stating that it was relevant to their own study (Fig. 7.9).

The participants showed a similar overall experience when answering more specific subject matter questions. The majority agreed or strongly agreed that the simulation gave them a better understanding of workflow and work distribution in various clinical situations and gave a realistic picture of challenges in interprofessional teams (Fig. 7.9). This is also supported by interview feedbacks where one of the students remarked: "I think it is good to be able to see the whole picture… having done it virtually first and going into practice at the geriatric ward no so long afterwards.…These collaboration meetings…you understand what it is about and you can actually see that this is how this is actually done".

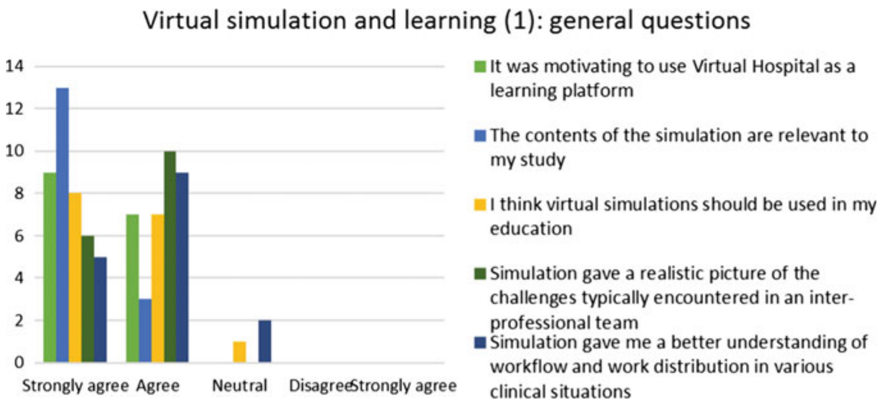

Fig. 7.9 Virtual simulation and learning: general questions

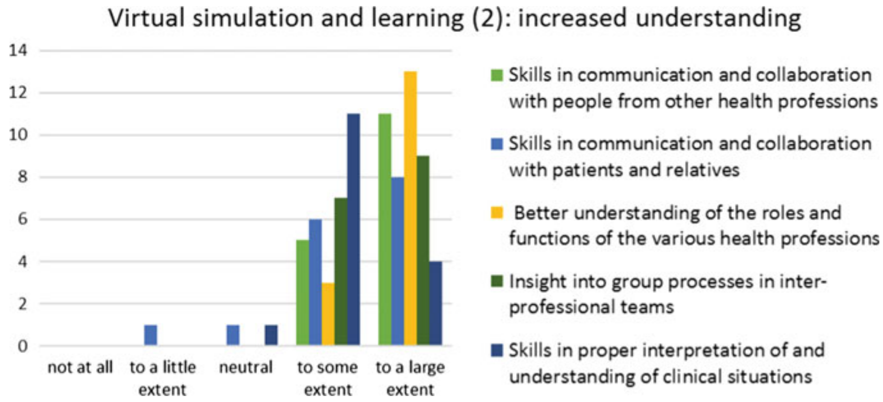

Fig. 7.10 Virtual simulation and learning: increased understanding

The majority of the students answered that they obtained a better understanding of the roles of the other professions involved (Fig. 7.10). In particular, as appears from the interviews, some nursing students felt that the virtual learning environment allowed them to define their roles in relation to the ones of the medical students in a 'safer' way: "People can hide a bit behind their roles and at the same time come with their opinions, be a bit tougher in a way…when you meet medical students, which might feel a bit stressing for us, as they are in a way are our superiors in a hospital…here we meet them a more neutral arena. I think this is a very nice learning base, one can express yourself but also joke a bit". At the same time, most of the participants believed that the virtual simulation could give the students better communication skills among themselves, colleagues, and patients, as well as a better understanding of group processes in interprofessional teams and clinical situations (Fig. 7.10).

Most of the students agreed that virtual simulation should be used in their education. In the interviews, students compared the immersive role-play approach suggested by VirSam and Skills lab with physical mannequins they are already using regularly. One of the students said: "I think this (VirSam) is much more educational/informative than the cases we get at the Skills lab. Where you got a patient that has this and that and you are supposed to roleplay. I think this quickly becomes very unserious, but here I think we managed to keep it pretty well". It was also suggested that VirSam should "target things we cannot do in the Skills lab".

Two final questionnaire questions asked if the simulator should be used in practice. The answers indicate that the majority of the participants agreed and strongly agreed that (a) the simulator can be used as preparation for practice to become familiar with working tasks in advance and (b) it can prepare students for real clinical situations. As one of the students put it during the interview: "It (simulation) kind of 'defuses' the whole thing comparing to going into practice…. You could actually train on this situation…Then going into practice is not going to be as scary as you thought". It was also mentioned that such a preparation would not only be useful for somebody "who has not been so much at the hospital yet", but also "if one has been in this situation before" as roleplaying will allow going through and reflecting on the experience again.

7.6 Discussion

The most prominent finding, given our aim of providing interprofessional communication training in a virtual environment, was that all the involved students agreed that they had learned about the value of clear communication. Communication is one of the core team competencies in medical team training, as highlighted in the TeamSTEPPS framework [37]. It is described as a competency in how to effectively exchange information among team members [38]. As appears from the interviews, the students have reflected on several aspects of communication during the roleplaying sessions, such as own role, communication with the patient [30] and representatives from other health professions. Our work thus supports the notion that VR can be used successfully to make students aware of the need for clear communication but also practice it in a safe environment; however, this study cannot say anything about whether or not the students actually improved their communication skills as a result of the role-play in the VUH. At the same time, most of the students believed that the simulations provided by VUH could improve communication skills and understanding of various interprofessional collaborative processes in clinical settings. Moreover, the majority of students agreed that training provided by the VUH could be successfully integrated in their education and supplement and support existing educational activities. A detailed analysis of the support provided by different components of the VUH is presented below.

7.6.1 Analysis of the Smart Virtual University Hospital Components

As a smart VUH is a part of a smart university and is based on the same major components (such as software systems, technology, hardware, smart curriculum and pedagogy [3]), we will look at how these components support learning in the context of the virtual St. Olav's hospital in the following:

Software systems and technology. The students appreciated the realism of the VUH facilities. Even if there are clear limitations when developing a smart VUH using commercial virtual worlds like SL, the students' evaluation showed that this did not hamper the possibility of making virtual representations that fulfill the expectation of mirroring real life [7, 8]. Due to different standards in the appearance in the virtual hospital (e.g., the inpatient ward which the student found most realistic had been given most resources to be developed) it can be suggested that, although the overall impression is good, it is possible to improve it further. In particular, the major direction for improvement would be more natural interaction with the environment, such as performing examinations on the patient and operating the equipment. Another central aspect is the quality of voice/sound communication in SL as well as other virtual worlds. High quality sound is paramount for team and communication training. This illustrates the need for exploring additional software systems and platforms as well as more optimal ways of integration with hardware components. Also, creating adaptive solutions for presenting students with better and personalized instructions, educational content, scheduling and feedback would alleviate some of the problems we have experienced during the role-play.

Hardware. The most limiting hardware aspect turned out to be the VR goggles [13]. Despite the fact that the majority of the students felt that the use of VR goggles made the experience more realistic and allowed them to be more immersed in the role-play, almost all of them reported ‘cyber sickness’. This is a practical problem that must be solved to be able to take full advantage of the higher level of immersion. The ‘cyber sickness’ is likely to be remedied by using the new consumer versions of the VR goggles, rather than the development kits we used, which includes better tracking solutions. In addition, with the use of more powerful, stationary computers, as opposed to laptops, we might alleviate this. Other types of VR equipment, such as HTC Vive and Oculus Touch, should be tried out in order to investigate to what extent they provide adequate support for capturing hand movements essential for medical manipulations. Different hardware solutions for quality of sound/voice, but also for general communication and collaborative work support in VR, need to be explored. There should also be solutions for adjusting hardware interfaces and different devices/combinations of devices based on personal preferences, working mode (from home/in a lab), and the educational content (such as communication training vs. procedural training).

Smart curricula and pedagogy. The clinical scenarios presented to the students were chosen based on the possibility to explore different patient trajectories. It turned out that it was feasible to condense both longer (weeks) and shorter (hours) patient trajectories. However, there is a clear potential for improvement in how the whole clinical scenario is presented. The two clinical scenarios and the role cards were presented somewhat differently due to discussions on what was likely to function best. The students clearly preferred the geriatric case, and this will therefore be used as the main model for presenting the clinical scenarios.

It was observed that some students did not remember the scenarios themselves and needed help from the other players about what they should do. Even if this mirrors situations that might happen in real life (i.e. that one has to instruct some team members about what to do), part of this confusion was likely due to lack of clarity in preparation and presentation. This is also probably connected to the fact that almost half of the students preferred to perform the training sessions with a teacher from whom they might receive instructions and feedbacks. If the students had been even more systematically exposed to similar training situations, which is what they will encounter in practice, it is likely that this type of problem would not have arisen.

To extend the learning portfolio of VUH, additional cases need to be developed and integrated. These cases will cover different fields of medicine and clinical situations, such as procedural and communication training or both. Therefore, there is a need for a consistent model and template for developing clinical scenarios for specific learning goals. Apart from being medically correct and relevant for the students' teaching plan, the cases should contain some elements of flexibility and adaptability, making it possible for them to be adjusted to the needs of the concrete student groups (such as group composition and number of students representing different professions). Furthermore, there is a need for flexible and personalized solutions in terms of delivering instructions, guidance, and feedbacks before, during, and after the training sessions. For example, this includes student profiles, recommendation systems, and ways of integrating instructions in different interface modes, such as inside VR goggles. Providing tailored and relevant information during all stages of the learning process in VUH requires full integration of smart curricula, software, and hardware elements.

7.6.2 Further Development of the Smart Virtual University Hospital

With respect to the further development of the Smart VUH, we think that the most important lesson has been that it must contain solutions for adaptability and personalization. We build further on the model outlined in Table 7.1 and envision that a future smart VUH should be thought of as a constellation of software and hardware elements, physical spaces, and learners/teachers. It also needs to possess a set of features and characteristics at different smartness levels [3], as outlined in Table 7.2.

7.7 Conclusions and Future Work

Our work shows that a VUH has the possibility to give students more time on task and prepare them for direct patient contact and clinical rotation.

A smart VUH opens several possibilities for health care and medical education. For example, students reported that they found the virtual learning environment to mirror real life and all agreed that they had learned about the necessity of clear and to the point interprofessional communication. Using realistic cases with different team dynamics made it possible to demonstrate the usefulness of a VUH in practicing team communication along different stages of the whole patient trajectory. In addition, using different patient trajectories gave students experience in team communication. Spending relatively few additional resources when it comes to the set up of the virtual hospital facilitated this.

Table 7.2 Important features of a smart virtual university hospital as an arena for smart education and training

Feature	Description	Smartness level
Scenario building	Methodologies for streamlining the process of creating scenarios from medical cases for different learning goals. Intelligent/adaptable or random scenarios to allow for unexpected changes so that playing the same scenario two times will not be the same. Better possibilities and functionalities for user-driven adaptation of scenarios based on their own teams, communication situations, workflow, procedure, skills, etc. including single and multiplayer modes	Adaptation, inferring, self-learning
Personalized learning path	Recommendations of cases and roles to play by using agent technologies, based on the student's study program, preferences and earlier results. Providing individualized information during roleplays and other educational sessions	Adaptation, inferring
Individual feedback	Evaluation facilities in the virtual hospital (e.g., online quizzes). An individual profile/webpage/app with overview of participation, performance, feedback given and received, suggestions for additional training. Personalized feedback during and after simulations	Adaptation, inferring
Personalized interface and interaction	Facilitating using different interfaces, especially VR interfaces, depending on user needs: desktop or VR goggles (ranging from Oculus Rift or HTC Vive to low-cost alternatives on mobile phones). Increasing the realism of interaction with the environment, other characters and equipment, e.g. through motion capturing devices and virtual patients/agents. Facilities for communication and collaborative work, workspace awareness, also in VR	Adaptation, sensing
Virtual agents	Automatic, autonomous and 'intelligent' avatars/virtual patients as well as recommendations systems. Smart virtual medical equipment, e.g. ultrasound images of a virtual patient that are connected to motion capturing devices (such as changing display of images due to change in player's movement)	Adaptation, self-learning

(continued)

Table 7.2 (continued)

Feature	Description	Smartness level
Modeling of virtual and physical environment	Developing virtual hospital environment based on BIM (Building Information Modeling) models of the real hospital when similarity to a physical environment is important, e.g. pre-practice training. Real-time interaction between BIM-database and the virtual environment, i.e. using view-point and direction to extract what you need and not the whole BIM hospital model	Sensing, self-organization
Mobile, ubiquitous and augmented	Linking materials and activities that are accessible through online and virtual system into the physical world, using location services, mobile and wearable devices, augmented reality, and internet of things	Sensing, inferring
General hardware support	Easy plug-and-play support for new hardware devices. Dedicated areas (VUH labs) where hardware is installed and serviced to allow use of more sophisticated hardware equipment	Adaptation
Integration: portal, scheduling and run-time system	Integration of software, hardware and curriculum into a holistic and coherent set of facilities. Web and app-based portal containing all students need to know in order to participate in training, with individual student profiles, fully student/participant driven including scheduling of sessions. Adaptable and scalable run-time system, adjusting to different number of concurrent users, i.e. by allowing several role-plays in the constellation of facilities including virtual environments and physical spaces/labs. Facilitating self-organization of student groups and personalized flexible scheduling of learning sessions	Adaptation, anticipation
Science system	Automatically extracting information regarding what is working and what is not based on the scenarios played and the feedback given afterwards. Covers both technical features such as type of equipment used and subject-oriented issues such as type of scenarios and type of participants	Self-learning, self-organization, anticipation

One of the assets of role-play in a VUH is the possibility for repetitions and the flexibility allowing the learning environment to be used at any time, making it independent of scheduled teaching. The role-playing facilities in the VUH also provide the students with a safe and accessible environment for practicing some of their tasks. In addition, role-play with VR allows a greater degree of immersion into the situation, something that is especially beneficial in a problem-based learning situation. Based on our experiences and literature review, we can outline three major directions for future work: developing *smart educational content, technology, and an overall VUH framework.*

VUH smart educational content. The major challenge of using smart university hospitals for education is in making realistic cases that mirror what the student will encounter in practice. The cases also need to focus on various aspects of medical team training. This is something that is not straightforward given the existing ambiguity in the literature on medical team training [31, 32]. Therefore, there is a need for guidelines and methods for scenario development, including templates for new cases to be efficiently developed by health care professionals, templates for role descriptions, etc. There is also a need for solutions for personalization and adaptation of cases as well as other educational materials for different students and learning contexts.

VUH smart technology. The immediate technological challenges for facilitating communication and collaboration team training in a VUH include physical discomfort caused by VR goggles and the need for better interactivity. The latter particularly applies to capturing hand movement and supporting manipulations on patients and equipment in the virtual learning environment. Apart from supporting training on procedures, such manipulations will create awareness of the learners' activities in a joint workspace. Supporting such awareness and collaborative activities, in general, in a fully immersive virtual environment constitutes yet another challenge. Such solutions are already emerging and, as the VR technology develops further, we believe that these challenges will be fully addressed in the near future by introducing new hardware devices and software platforms. In addition to the VR technologies, other technologies should be taken into account, such as mobile and ubiquitous technologies and augmented reality. This will also open up another dimension of smartness [4]. Additional software elements should include cross-platform solutions linking web, social media, mobile devices, and new software VR platforms, as outlined in Table 7.2.

VUH framework. A fully functioning smart VUH needs to support a wide range of educational activities, as outlined in Table 7.1. This requires integration of smart educational content, curricula, and organizational aspects with smart hardware and software solutions into a holistic and coherent system. An important direction for future work will, therefore, be developing the framework, principles, and methods further for such integration. This is in line with a similar framework for smart universities.

We are currently working on further development of Virtual St. Olav's hospital. We have received an additional grant from the Norwegian Research Council as a part of the FINNUT program (Research and Innovation in Educational Sector). Apart from creating more realistic hospital models, we are exploring new VR interfaces with better support for manual operations (with HTC Vive) and developing a portal (http://virsam.no). Future evaluations will include larger groups of students to evaluate suitability of the VUH for large-scale student training. We plan to extend the portfolio of cases to include additional clinics at St. Olav's hospital, such as oncology, palliative, and especially emergency/intensive care. We will continue developing the Smart VUH of St. Olav from the conceptual framework aspect as well as the technological realization. We plan additional features such as more interactivity with medical equipment and patients (including virtual patients), additional locations (based on the existing plans and models for the physical hospital), and facilities within the virtual hospital to accommodate new cases, anatomical visualizations, and various VR interfaces (including mobile ones).

Acknowledgements The VirSam project has been funded by NTNU Toppundervisning. We would like to thank the students participating in our evaluation, as well as Marion Skallerud Nordberg, Inga Marie Røyset and Cecilie Therese Hagemann who contributed to the case development.

References

1. IBM: Smarter Education: Building the Foundations of Economic Success, pp. 1–4 (2012). ftp://ftp.software.ibm.com/la/documents/gb/mx/Smarter_Education.pdf
2. Tikhomirov, V., Dneprovskaya, N.: Development of strategy for smart University. Paper presented at the Open Education Global international conference, Banff, Canada (2015)
3. Uskov, V.L., Bakken, J.P., Pandey, A., Singh, U., Yalamanchili, M., Penumatsa, A.: Smart University taxonomy: features, components, systems. In: Uskov, L.V., Howlett, J.R., Jain, C. L. (eds.) Smart Education and e-Learning 2016, pp. 3–14. Springer International Publishing, Cham (2016)
4. Hwang, G.-J.: Definition, framework and research issues of smart learning environments—a context-aware ubiquitous learning perspective. Smart Learn. Environ. **1**(1), 1–14 (2014)
5. Kleven, N.F., Prasolova-Førland, E., Fominykh, M., Hansen, A., Rasmussen, G., Sagberg, L. M., Lindseth, F.: Training nurses and educating the public using a virtual operating room with Oculus Rift. In: Thwaites, H., Kenderdine, S., Shaw, J. (eds.) International Conference on Virtual Systems and Multimedia (VSMM), Hong Kong, December 9–12, pp. 206–213. IEEE, New York, NY (2014)
6. Kleven, N.F., Prasolova-Førland, E., Fominykh, M., Hansen, A., Rasmussen, G., Sagberg, L. M., Lindseth, F.: Virtual operating room for collaborative training of surgical nurses. In: Baloian, N., Burstein, F., Ogata, H., Santoro, F., Zurita, G. (eds.) 20th International Conference on Collaboration and Technology (CRIWG), Santiago, Chile, September 7–10. Lecture Notes in Computer Science, pp. 223–238. Springer, Berlin, Heidelberg (2014)
7. Warburton, S.: Second Life in higher education: assessing the potential for and the barriers to deploying virtual worlds in learning and teaching. Br. J. Edu. Technol. **40**(3), 414–426 (2009)
8. Mckerlich, R., Riis, M., Anderson, T., Eastman, B.: Student perceptions of teaching presence, social presence, and cognitive presence in a virtual world. J. Online Learn. Teach. **7**(3), 324–336 (2011)
9. Spooner, N.A., Cregan, P.C., Khadra, M.: Second Life for Medical Education. eLearn Magazine. ACM, New York (2011)
10. de Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G., Poulovassilis, A.: Developing an evaluation methodology for immersive learning experiences in a virtual world. In: 1st International Conference in Games and Virtual Worlds for Serious Applications (VS-GAMES), Coventry, UK, March 23–24, pp. 43–50. IEEE, New York (2009)
11. Cakmakci, O., Rolland, J.: Head-worn displays: a review. J. Disp. Technol. **2**(3), 199–216 (2006)
12. van Krevelen, D.W.F., Poelman, R.: A survey of augmented reality technologies, applications and limitations. Int. J. Virtual Real. **9**(2), 1–20 (2010)

13. Antonov, M., Mitchell, N., Reisse, A., Cooper, L., LaValle, S., Katsev, M.: Oculus Software Development Kit. Oculus VR Inc., CA, USA (2013)
14. Rubia, E., Diaz-Estrella, A.: ORION: one more step in virtual reality interaction. In: Penichet, V.M.R., Peñalver, A., Gallud, J.A. (eds.) New Trends in Interaction, Virtual Reality and Modeling. Human–Computer Interaction Series, pp. 45–61. Springer, London (2013)
15. Johnson, C.M., Vorderstrasse, A.A., Shaw, R.: Virtual worlds in health care higher education. J. Virtual Worlds Res. **2**(2), 3–12 (2009)
16. Rogers, L.: Simulating clinical experience: Exploring Second Life as a learning tool for nurse education. In: Atkinson, R.J., McBeath, C. (eds.) 26th Annual Ascilite International Conference Same Places, Different Spaces, Auckland, New Zealand, December 6–9, pp. 883–887. Australasian Society for Computers in Learning in Tertiary Education, Auckland, New Zealand (2009)
17. Khanal, P., Gupta, A., Smith, M.: Virtual Worlds in Healthcare. In: Gupta, A., Patel, L.V., Greenes, A.R. (eds.) Advances in Healthcare Informatics and Analytics, pp. 233–248. Springer International Publishing, Cham (2016)
18. Lowes, S., Hamilton, G., Hochstetler, V., Paek, S.: Teaching communication skills to medical students in a virtual world. J. Interact. Technol. Pedag. (3), e1 (2013)
19. Jang, S., Black, J.B., Jyung, R.W.: Embodied cognition and virtual reality in learning to visualize anatomy. In: Ohlsson, S., Catrambone, R. (eds.) 32nd Annual Conference of the Cognitive Science Society, Portland, OR, August 12–14, pp. 2326–2331. Cognitive Science Society, Austin, TX (2010)
20. Huang, H.-M., Liaw, S.-S., Lai, C.-M.: Exploring learner acceptance of the use of virtual reality in medical education: a case study of desktop and projection-based display systems. Interact. Learn. Environ. **24**(1), 3–19 (2016)
21. Wiecha, J., Heyden, R., Sternthal, E., Merialdi, M.: Learning in a virtual world: experience with using second life for medical education. J. Med. Internet Res. **12**(1), e1 (2010)
22. Cates, C.U., Lönn, L., Gallagher, A.G.: Prospective, randomised and blinded comparison of proficiency-based progression full-physics virtual reality simulator training versus invasive vascular experience for learning carotid artery angiography by very experienced operators. BMJ Simul. Technol. Enhanc. Learn., 1–5 (2016)
23. Ruthenbeck, S.G., Reynolds, J.K.: Virtual reality for medical training: the state-of-the-art. J. Simul. **9**(1), 16–26 (2015)
24. Lee, M.J.W.: How can 3d virtual worlds be used to support collaborative learning? an analysis of cases from the literature. Society **5**(1), 149–158 (2009)
25. Hayes, E.R.: Situated learning in virtual worlds: the learning ecology of second life. In: American Educational Research Association Conference, pp. 154–159. AERA, Washington, DC (2006)
26. Jarmon, L., Traphagan, T., Mayrath, M.: Understanding project-based learning in second life with a pedagogy, training, and assessment trio. Educ. Media Int. **45**(3), 157–176 (2008)
27. Alverson, D.C., Caudell, T.P., Goldsmith, T.E.: Creating virtual reality medical simulations: a knowledge-based design and assessment approach. In: Riley RH (ed.) Manual of Simulation in Healthcare (2 ed.). Oxford University Press, Oxford, UK (2015)
28. Rizzo, A.S., Difede, J., Rothbaum, B.O., Reger, G., Spitalnick, J., Cukor, J., McLay, R.: Development and early evaluation of the Virtual Iraq/Afghanistan exposure therapy system for combat-related PTSD. Ann. N. Y. Acad. Sci. **1208**(1), 114–125 (2010)
29. Li, A., Montano, Z., Chen, V.J., Gold, J.I.: Virtual reality and pain management: current trends and future directions. Pain Manag. **1**(2), 147–157 (2011)
30. Pan, X., Slater, M., Beacco, A., Navarro, X., Bellido Rivas, A.I., Swapp, D., Hale, J., Forbes, P.A., Denvir, C., Hamilton, A.F., Delacroix, S.: The responses of medical general practitioners to unreasonable patient demand for antibiotics—a study of medical ethics using immersive virtual reality. PloS one **11**(2), 1–15 (2016)
31. Morrison, G., Goldfarb, S., Lanken, P.N.: Team training of medical students in the 21st century: would Flexner approve? Acad. Med. **85**(2), 254–259 (2010)

32. Weaver, S.J., Dy, S.M., Rosen, M.A.: Team-training in healthcare: a narrative synthesis of the literature. BMJ Quality Saf., 1–14 (2014)
33. Weaver, S.J., Lyons, R., DiazGranados, D., et al.: The anatomy of health care team training and the state of practice: a critical review. Acad. Med. **85**(11), 1746–1760 (2010)
34. Baker, D.P., Gustafson, S., Beaubien, J.M., Salas, E., Barach, P.: Medical team training programs in health care. In: Henriksen, K., Battles, J.B., Marks, E.S., Lewin, D.I. (eds.) Advances in Patient Safety: From Research to Implementation (Vol. 4: Programs, Tools, and Products). Advances in Patient Safety. Rockville (MD) (2005)
35. Flaherty, E., Hyer, K., Kane, R., Wilson, N., Whitelaw, N., Fulmer, T.: Using case studies to evaluate students' ability to develop a geriatric interdisciplinary care plan. Gerontol. Geriatr. Educ. **24**(2), 63–74 (2004)
36. Sehgal, N.L., Fox, M., Vidyarthi, A.R., Sharpe, B.A., Gearhart, S., Bookwalter, T., Barker, J., Alldredge, B.K., Blegen, M.A., Wachter, R.M.: Triad for Optimal Patient Safety P.: a multidisciplinary teamwork training program: the Triad for Optimal Patient Safety (TOPS) experience. J. Gen. Intern. Med. **23**(12), 2053–2057 (2008)
37. King, H.B., Battles, J., Baker, D.P., Alonso, A., Salas, E., Webster, J., Toomey, L., Salisbury, M.: TeamSTEPPS: team strategies and tools to enhance performance and patient safety. In: Henriksen, K., Battles, J.B., Keyes, M.A., Grady, M.L. (eds.) Advances in Patient Safety: New Directions and Alternative Approaches (Vol. 3: Performance and Tools). Advances in Patient Safety, Rockville (MD) (2008)
38. AHRQ: Pocket Guide: TeamSTEPPS. Team strategies and tools to enhance performance and patient safety. Agency for Healthcare Research and Quality, Rockville, MD (2013)
39. Albanese, M.A.: Problem-based learning. In: Understanding Medical Education, pp. 37–52. Wiley-Blackwell (2010)
40. Nonaka, I., Takeuchi, H.: The knowledge-creating company: how Japanese companies create the dynamics of innovation. Oxford University Press, New York (1995)
41. White, C.B., Gruppen, L.D.: Self-regulated learning in medical education. In: Understanding Medical Education, pp. 271–282. Wiley-Blackwell (2010)
42. Cooke, M., Irby, D.M., Sullivan, W., Ludmerer, K.M.: American medical education 100 years after the Flexner report. N. Engl. J. Med. **355**(13), 1339–1344 (2006)
43. Lave, J., Wenger, E.: Situated Learning: Legitimate Peripheral Participation. Cambridge University Press, Cambridge, UK (1991)
44. Engeström, Y.: Activity theory and individual and social transformation. In: Engeström, Y., Miettinen, R., Punamäki, R.-L. (eds.) Perspectives on Activity Theory. Learning in Doing: Social, Cognitive and Computational Perspectives, pp. 19–38. Cambridge University Press, Cambridge, UK (1999)
45. Brown, J.S., Duguid, P.: Organizational learning and communities of practice: towards a unified view of working, learning, and innovation. Organ. Sci. **2**(1), 40–57 (1991)
46. Lawson A.E., Drake, N., Johnson, J., Kwon, Y.-J., Scarpone, C.: How good are students at testing alternative explanations of unseen entities? The American Biology Teacher **62**(4), 249–255 (2000)
47. Korakakis, G., Boudouvis, A., Palyvos, J., Pavlatou, E.A.: The impact of 3D visualization types in instructional multimedia applications for teaching science. Procedia Soc. Behav. Sci. **31**, 145–149 (2012)