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EXPERIENCES WITH A SIMULATED LEARNING ENVIRONMENT - THE SIMUSCAPE©: VIRTUAL ENVIRONMENTS IN MEDICAL EDUCATION

Anna-Lena Thies[1], Anne Weissenstein[1], Ivo Haulsen[2], Bernhard Marschall[1], Hendrik Friederichs[1]

[1]University Muenster (Germany)
[2]Fraunhofer Institute for Open Communication Systems (Fokus) (Germany)

anna-lena.thies@uni-muenster.de, anne.weissenstein@gmail.com, ivo.haulsen@first.fraunhofer.de,
Bernhard.Marschall@ukmuenster.de, friedeh@uni-muenster.de

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Abstract

Simulation as a tool for medical education has gained considerable importance in the past years. Various studies have shown that the mastering of basic skills happens best if taught in a realistic and workplace-based context. It is necessary that simulation itself takes place in the realistic background of a genuine clinical or in an accordingly simulated learning environment. A panoramic projection system that allows the simulation of different scenarios has been created at the medical school of the Westphalian Wilhelms-University Muenster/Germany. The SimuScape© is a circular training room of six meters in diameter and has the capacity to generate pictures or moving images as well as the corresponding background noises for medical students, who are then able to interact with simulated patients inside a realistic environment. About 1,000 students have been instructed using the SimuScape© in the courses of emergency medicine, family medicine and anesthesia. The SimuScape©, with its 270°-panoramic projection, gives the students the impression "of being right in the center of action". It is a flexible learning environment that can be easily integrated into curricular teaching and which is in full operation for 10 days per semester. The SimuScape© allows the establishment of new medical areas outside the hospital and surgery for simulation and it is an extremely adaptable and cost-effective utilization of a lecture room. In this simulated environment it is possible to teach objectives like self-protection and patient care during disturbing environmental influences in practice.

Keywords – virtual reality, simulated environment, medical education

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1 INTRODUCTION

The role of simulation in medical education has considerably increased in the past years, as there is a rising demand for a skills-oriented medical tutoring on the one hand, and a rising consciousness about patient safety on the other (Okuda, Bryson, DeMaria, Jacobson, Quinones, Shen et al., 2009; Ziv, Wolpe, Small & Glick, 2003). This concept comprises, among other aspects, the integration of simulators and simulated patients. We know from the field of cognitive psychology that the retrieval of knowledge and its application functions best, if taught and practiced in a realistic and workplace-based context that offers students the opportunity to gain clinical skills and experience (Bransford, Brown & Cocking, 1999; Issenberg, McGaghie, Petrusa, Lee Gordon & Scalese, 2005; Weller, 2004). Furthermore, a workplace-based training scenario has been shown to be an important factor for higher learning-outcomes when mastering clinical skills (Byrne, Pugsley & Hashem, 2008).

The advantages of medical simulations are that the student is becoming the focal point in the educational process, unlike during clinical care, where the patient is in the main focus and learning is rather a by-product (Kneebone, Arora, King, Bello, Sevdalis, Kassab et al., 2010). Furthermore, the student is allowed to make mistakes without causing harm, which is regarded as a very powerful learning experience (Arora, Sevdalis, Nestel, Tierney, Woloshynowych & Kneebone, 2009; Ziv, Ben-David & Ziv, 2005). Students are able to further focus on mastering basic skills and gaining a degree of competence without the complexities of dealing with real patients. (Weller, Nestel, Marshall, Brooks & Conn, 2012) An environment is required that meets the demands of providing an effective education without endangering patients (Kneebone, 2005) and it is important to allow medical education take place within the realistic context of a genuine clinical or in an accordingly simulated learning environment (Donaldson, 2009; Khan, Pattison & Sherwood, 2011; Koutantji, McCulloch, Undre, Gautama, Cunniffe, Sevdalis et al., 2008; Moorthy, Munz, Adams, Pandey & Darzi, 2005; Undre, Sevdalis, Healey, Darzi & Vincent, 2007). The integration of a virtual learning environment in the curriculum provides the f-protection, coping with disturbing environmental distractions as well as the generation following advantages for the education of medical students:

- Establishment of new medical areas outside the hospital and surgery for simulation
- Teaching aims like self-protection, coping with disturbing environmental distractions as well as the generation following advantages for the education of medical students:
- of relevant information from the surroundings can be taught in practice
- Extremely adaptable and cost-effective utilization of a lecture room

In order to establish the necessary authentic learning environments it is important to reconstruct all possible clinical situations, which may include house calls or emergencies in public settings. Many attempts have been made to provide a variety of simulation environments, including Kneebone et al. (2010) who have developed an inflatable environment where pull-up banners with photographs of clinical equipment are used in order to implement reality. Another project located in Rovaniemi/Finnland is the “ENVI - Virtual Center of Wellness Campus”, a construction that consists of four rooms where students can practice seamless co-operation during the entire healthcare process, from the scene of an accident over to a virtual hospital, and lastly the rehabilitation facility (ENVI, 2010). A slightly different approach was done at the Wide Area Virtual Environment (WAVE) in Maryland which focuses on the creation of a virtual setting. It is a large-scale simulator designed to train medical teams in battlefield and natural-disaster scenarios with three-dimensional (3D) images displayed on three vertical screens. Team members are able to interact with each other and real equipment within a large area of 743 square meters (WAVE, 2012).

These projects however have many disadvantages; some require a lot of storage or space, others have very limited possibilities, and additionally with regard to the size and the technical equipments most can be assumed to be very costly. While there are an abundance of possibilities, their respective approach is difficult to implement both logistically and financially. This is why the Faculty of Medicine in Muenster/Germany has continued to search for ways to present the numerous varying surroundings in benefit of medical education outside the usual confines of day centers and hospital wards. Therefore, we describe the implementation of the SimuScape©.

2 SIMUSCAPE© DEVELOPMENT

In the course of this project and in cooperation with the “Fraunhofer-Institute for Computer Architecture and Software Technology (Fraunhofer FIRST)”, a panoramic projection system that allowed the simulation of different scenarios, such as an intersection or a park, has been developed for teaching purposes. Furthermore, for the projection of any learning environment new techniques for recording and reproducing have been established. The simulation is generated with pictures or moving images and corresponding background noises. In addition, it is necessary that the panoramic projection is wide enough to allow a broad view of the simulated environment as it has to provide the possibility to augment the generated area with simulated patients or simulators.

A circular training room of six meters in diameter has been created in the premises of the Studienhospital, giving students with its 270°-panoramic projection the impression “of being right in the center of action” (Figure 1). The cylindrical building extension comprises an area of about 25 square meters. The screen has a diameter of 6m and a height of 2.3m. The resulting length of the curved projection is 14.43m and the recorded image has an aspect ratio of 6.14:1. The resulting overall resolution of the panoramic image or video amounts to 3968 x 640 pixels. The remainder of the simulated area (floor, walls, etc.) is designed in black. Suitable materials such as carpet on the floor and curtains on the walls were chosen in order to absorb as much noise as possible. Due to the large diameter of the projection area, the students and the simulated patients are able to walk and act freely within a circle of 3.5m in diameter. Outside this range they are partly situated in the projected beam, with the result that they may cast shadows on the screen.

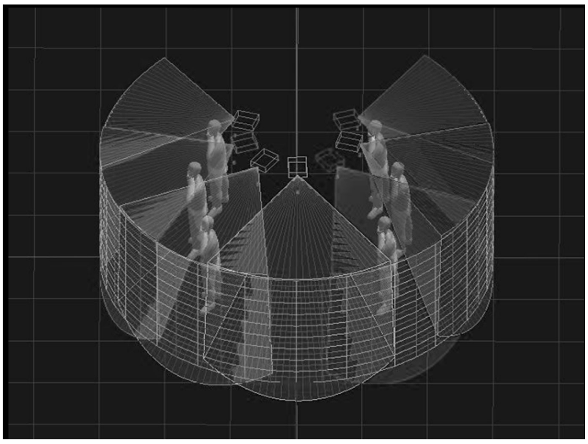

Figure 1. SimuScape© with 270°-panoramic projection

2.1 Still Images

Seven projectors are arranged in a cluster in the projection system. Standard DLP projectors with Short Throw Focus (Optoma ex525ST) have been installed in a height of 2.8m and arranged in a ring with a diameter of 1.2m with a distance to the center of the rotunda of 0.9m. Each projector is installed upside-down and bent slightly downwards. The segments of the photos, taken with a digital camera, are tuned accurately next to each other and are distributed to the projectors. The sound that matches the simulated environment is provided by a 5.1 sound system.

2.2 Recording

For the recording of simple images of real-world environments, real scenes of streets, intersections or parks have been depicted with a camera. Depending on the scenario, people can be seen in the recorded images, for example in the background of a road accident located in the city. When filming in public areas the legal situation in Germany allows for the photo and video material to be used, even if people are depicted on it. However, it should be ensured no scenes are used for teaching units, in which people are shown in embarrassing situations.

2.3 Video Editing

In contrast to still images, the production of surround videos has proven to be more complex. For the recording of the learning environments a camera system has been purchased that corresponded to the need for a simple handling. The acquired camera (Ladybug3; PTGrey, Vancouver, BC, Canada) is a spherical digital video camera that only requires a single laptop for video capturing. The camera itself has a diameter of 12.2cm and a height of 14cm and is also water resistant, meaning it can be used during rain. The externally supplied software that accompanied the PTGrey-camera produces video files with a resolution of 5400 x 2700 pixels. The area required for the projection section (270 x 42 degrees) corresponds to a resolution of 4000 x 656 pixels, which is compatible to the required resolution of the projection system. The Ladybug3 is similar to the cameras used for Google Street View and able to generate a 360 degree image by taking six single videos at once when positioned in the middle of a scene. In concurrence to the video capture, a time-synchronous sound recording is realized with an external surround microphone. In a subsequent step the sound is added to the video. The camera saves the PGR compressed raw material on a hard disk which is converted into a series of frames during the following offline-procedure. The program (LadybugCapPro; PTGrey, Vancouver, BC, Canada) is provided by PTGrey for this process. It is further necessary that these image series are cut and encoded into a film. Optionally, subsequent cutting with Adobe After Effects and Adobe Premiere is possible.

Finally, using Adobe After Effects, the frame rate from the camera is converted to a higher frame rate to create a smoother video experience for the learner. All these separate procedures are composed in a workflow for an entire panoramic film.

Altogether, the workflow is structured into the following parts:

- Capture of video with the Ladybug3 camera and recording the sound with a surround microphone on a laptop. A clapperboard is used to assist in the synchronization of picture and sound and to mark picture intakes, the manual synchronization of the video and audio data is performed in post-processing
- Creation of single images from the raw data using "LadybugCapPro". Optional use of different calibration data for scenes with either close or distant objects
- Cropping (cutting of the desired image area), as well as video and audio editing in Adobe Premiere
- Export of single image sequences and surround audio with Adobe Premiere
- Encoding of the video from separate images in the M2v video format file
- Creation of a show by the Software "ShowManager" that is able to play the video. This software enables the construction of shows from different elements (videos, still images, audio) and the whole projection cluster can be started and controlled.

For the development and conception of the installation and the synchronized reproduction of the video, two programs are required. The ScreenConfigurator software which additionally has an auto-calibration system through cameras, has proven to be effective for the planning and setting up of the installation. However, for the synchronized play out, the ScreenPlayer is used which further handles the geometric correction and the blending on the client computer.

2.4 Cost Calculation

The overall cost of the project has amounted to 110,000 Euro (≈142,000 USD) (Table 1). The remaining costs of about 19,000 Euro (≈24,500 USD) have been used for structural changes of the rotunda.

Hardware image/video	*24,160€/≈31,300$*
Projectors (incl. holders, cables etc.)	*8,800€/≈11,400$*
Camera Ladybug3 (incl. equipment)	*4,200€/≈5,400$*
Hardware sound (recording and playback):	*5,250€/≈6,800$*
Software:	*20,800€/≈27,000$*
• *Fraunhofer FIRST Screen player* • *Adobe Creative Suite Production Premium*	*19,700€/≈25,600$* *1,100€/≈1,400$*
Development costs Fraunhofer Institute *(workflow, conceptualization study and installation of the projection system):*	*33,840/≈44,000$*
Total:	***91,560€/≈118,800$***

Table 1. Cost differentiation of the SimuScape©

3 IMPLEMENTATION

Until the present time, the Studienhospital Münster® and the representatives of the courses in emergency medicine and family medicine have acquired more than three years of experience with the projected learning environment. Approximately 1,000 students have been instructed using the SimuScape© (Figure 2) in the courses of emergency medicine, family medicine and anesthesia. Accordingly, the SimuScape© is in full operation for a total of 10 days per semester (i.e. 20 days per year), which allows for practical situations of the different courses to be carried out in a nearly realistic environment. The remaining time is used for technical development, recording of scenes and the generation of content. The use and application of the SimuScape© is uncomplicated for the lecturers. After consultation with the Studienhospital, a scene is produced within 3-7 days with photo or film. The scene is subsequently operated manually and easily by the lecturer during the teaching units. This provides the possibility to mediate certain teaching aims, such as staff safety in the event of an emergency in an "activity-oriented" context.

Figure 2. Students are able to interact with simulation patients within the SimuScape©

In the specific scenario of road traffic emergency one student performs the role of the emergency doctor and two other students act as paramedics assisting him. On the projection area of the SimuScape© an ambulance is visible which has earlier driven into the scene, as well as fast moving cars in the background. Additionally, the loud honking of the cars which cannot drive past the accident can be heard. The students' task is twofold: First to save the patient, represented by a mannequin, and secondly manage the scene of the accident adequately to ensure staff safety. This is achieved by placing portable warning triangles around the scene of the accident, or in an extreme case, first removing the patient from a dangerous situation such as a highway. The images of the fast driving cars underlined by acceleration noises and the sounds of the blowing horns provide a higher level of stress for the students than an exercise in the normal surroundings of a classroom. Post performance, the student has the possibility to express his impression of how he has felt in the situation and feedback is provided by the students and instructor who have watched the scene. To support the realistic applicability of each scene, the incorporation of a pre-history in the respective video sequences has been included. For example, an arriving ambulance has been integrated into the film making it possible for the lecturer to explain the action more pictorially. In this case the sequence of events is accurately planned for recording purposes and when actors playing patients or other people appear, a script is created. As a result, a man can be seen falling off his bike in traffic and a few minutes later the ambulance arrives accompanied by the sound of sirens. The student, in the role of the emergency doctor, has to take care of the patient in the middle of loud traffic noise and disturbing spectators.

Meanwhile, promising attempts have been conducted at integrating simulated patients into the scenes. The high value of these simulators is that they enhance the students' acquisition of communication skills as well as provide constructive feedback from the patient perspective (Kneebone et al., 2010). According to students first impressions, their attention is primarily focused on patients and thus is being distracted from the environment, which is a very positive outcome as in real life the patients wellbeing should always be paramount. However, sometimes it may prove difficult to focus on a patient as required being that there is many distracting noise and movement from traffic or by-passers. The SimuScape© allows for the practice of ignoring distracting sounds or motions during an emergency. Another factor in proper patient care is that in some cases the surrounding area can be very important in gaining beneficial background information. With the SimuScape©, the possibilities of creating different environments are numerous. Simulated patients can be included and case-specific details can be added. For example; a container of plant poison in the background setting of an unconscious person in order to provide further disease-related information. Further examples for the use of simulated patients and still images as backgrounds are the scenes of a graveyard and the unusual scenery of a toilet at the train station. In one case a graveyard can be seen in the background and an aged lady collapses on a bench after tending a grave (Figure 3). In the other scene the restricted space of a toilet at a train station is visible and the students have to take care of an unconscious drug addict. In both cases the student has to gain information from the context of the scene and care for the patient preferably according to the possible cause - hypoglycemia after too much exercise in one case or an overdose of drugs in the other.

Figure 3. Student takes care of a patient on a graveyard

The SimuScape© also offers opportunities to enhance the learning of students beyond its role in depicting prehospital clinical environments. For instance the course "self-awareness" takes place at the simulated environment. Based on edited images, students are able to experience how elderly people feel who are limited by an eye disease. The broad projection area makes it especially possible for the students to get a realistic impression. One can understand this as important, with empathy and compassion increasingly emphasized in medical didactics.

Additional impressions from the students have been obtained from the EVALuna evaluation system. The online evaluation of each course via the EVALuna system (Binary Design GmbH, Muenster) is a requirement for the registration of exams at the Medical Faculty of Muenster.

The system guarantees anonymous evaluation of each curricular course and students are asked to evaluate the teaching units on a visual analogue scale from 1 ("very good") to 100 ("very poor"). In addition, there is the possibility to enter comments in free text form. The results are regularly published and visible for students and lectures. As the students are asked to evaluate the courses specifically, we do not have data directly asking for an evaluation of the SimuScape©. However, in the courses were the SimuScape© has been used, we have received numerous free text comments in favor for the simulated environment: "The part in the SimuScape was awesome, I felt like actually being at the scene of an accident", "It's a pity not more courses take place at the SimuScape" and "It's a great preparation for clinical practice", just to name a few. Further comments are that the scene feels "real" and they don't think the situation has been only a teaching unit while involved in the generated scene. In addition, some felt really "excited" and "nervous" and they take their task very seriously. Moreover, the students learn that the environment plays a large role as a possible distractor, principally when loud noises from the traffic are present. A small questionnaire evaluating the self-assessment of students has been carried out in the winter semester of 2010/2011 in which cardiopulmonary resuscitation (CPR) has been taught in two groups; one group in a conventional classroom ($n = 37$, control group), and the other group in the SimuScape© ($n = 62$, intervention group). In total 99 questionnaires have been obtained. In the survey, the students were asked to provide a self-assessment by answering eight questions on a 5-point Likert scale ranged from 5 (strongly agree) to 1 (strongly disagree). Means and standard deviations were calculated as descriptive parameters. T-tests were used to test the differences between the groups, the level of significance was defined at $p \leq 0.05$. The statement "The course was fun" has reached a significant level ($p < 0.01$) in the group that has been taught in the SimuScape© (4.37) compared to the control group taught in the classroom (4.03). Other items, for example whether the students feel that they have learned something (control group 4.22, intervention group 4.35; $p \geq 0.05$) or whether they feel secure in applying CPR (control group 3.32, intervention group 3.48; $p \geq 0.05$) have reached a higher level of acceptance for the group trained in the SimuScape©, however, they did not reach a significant level. Some lectures have stated they had the impression that students have taken the situations carried out in the SimuScape© more seriously than when played in the classroom. Due to the easy handling of the SimuScape©, lecturers are not hesitant to instruct using this facility, on the contrary, increasing requests to teach using this simulated environment are being observed.

4 DISCUSSION

As already mentioned, various other projects exist that deal with simulated environments. The ENVI project combines physical environments and simulation mannequins with immersive full-scale 3D simulation projections. On top of all, an input device exists that is used to move through the scenarios, open doors or switch lights on and off. (ENVI, 2010) However, with all these technical devices there is the risk that the students concentrate more on maneuvering through the virtual reality, rather than focusing on the patient. A negative consequence might be that the educational emphasis for course developers becomes overly focused on fidelity and less on the learning objectives. With the SimuScape© it is noted that students as well as lecturers include the simulated environment at the beginning of the scene in their range of attention, however, this effect lessens with every minute of the simulation so that no further interference effects are registered, unless intentional. Another substantial disadvantage of the ENVI project is the space required by its construction and the cost of such a project. The limitations of the inflatable environment by Kneebone are that only hospital settings can be realized. The WAVE project on the one hand allows for training of medical teams in different scenarios but on the other hand limits the focus to teaching non-students in battle field scenarios (WAVE, 2012) rather than educating medical students. With the SimuScape©, a learning environment has been created which can be used flexibly, is changeable when necessary and can easily be integrated into curricular teaching. This enables the presentation of different aspects of medical action beyond the outpatient and inpatient area in a realistic manner. In the projected learning environment of the SimuScape©, medical students can respond actively in realistic situations, which has a high impact on the motivation for the respective course, as well as the lowering of the threshold for certain practical actions. The feeling that a scene is not real dissipates with corresponding pictures or videos accompanied with sound and the student is able to put himself more in the situation.

4.1 Limitations

Problems in the creation of still pictures or videos occur when the individual images, which display a panorama, show moving objects. If people appear on the edge of the picture and move to the corresponding picture, they cannot be found in the previous body posture as the software has limits. The automatic superimposing of the images results in the effect that only half of the presented body or object can be seen. However, it is important that this does not happen or the representation of the reality would lose its credibility. Accordingly, too many changes from one camera image to the next should be avoided and the material in which this effect occurs should not be used. Furthermore, it is important that each reality-reflecting image presents a natural picture-excerpt. This means in particular that the respective surface - whether it is grass, asphalt or carpet - are in clear view. Only when this circumstance is provided, the human eye is able to add the surface of the SimuScape © to the projection, resulting in a realistic impression. Further restrictions are visible during recording. Scenes, in which both proximate as well as distant objects are visible in the overlapping area, cannot be displayed sharply in the whole image. These blurring’s (parallax faults) can be partially corrected in the post-processing. Educational challenges concern primarily the integration of practical actions that have earlier taken place in the classroom into the rotunda of the SimuScape©. The students task is still to focus on the patient, however, now the students must also observe their surroundings in order to establish clues to what has most-likely happened to the patient or to simply secure the place of the accident. This “multi-tasking” is a new feature of teaching and it is the duty of the instructor to observe whether the student heeds attention to all aspects of the scene while saving the patient at the same time. Furthermore, because of the limited space in the rotunda of the SimuScape©, only a restricted number of students can act in the scene. In rare cases it may happen that a student obstructs the projection beam, thus casting a shadow on the screen. However, such an incident occurs very seldom as the focus of the plot is in the middle of the rotunda in a relatively large diameter. Even if a student would briefly obstruct the projection beam, he probably wouldn’t notice it as his attention is primarily on the patient.

5 CONCLUSION AND PROSPECTS

Our experience with the SimuScape© has shown that its implementation in medical teaching gives students a unique opportunity to apply their acquired skillset in a realistic environment. As constant practice is essential for provision of professional help in a real emergency, the SimuScape© provides beneficial training for medical students. The time consuming production of the photo or film sequence is easily compensated for the high flexibility of the application. The SimuScape© requires only one training room that is utilized through changes of settings in many different ways. After a certain time, an archive of various images and videos is obtained, so that it won't be necessary to create a new projection for each teaching session. Moreover, rare environments such as dangerous workplaces in the industry can be created.

For the implementation of a virtual environment such as the SimuScape© we highly recommend paying attention to the appropriate usability because this is crucial for the extent of how often such a resource is used. Videos are basically what constitute the SimuScape©. Images could also be displayed in other ways (i.e. photo walls), but even in this case the advantage lies in the possibility of the rapid changing of images. The SimuScape© offers the opportunity to learn how to act professionally under unfamiliar and often unfavorable conditions in a protected setting. To evaluate the full extent of the effect of the simulated environment on teaching objectives, formal study data are needed. A randomized controlled trial to compensate for these deficits is planned.

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AUTHORS BIOGRAPHY

Anna-Lena Thies

Is a scientific officer at the Medical Faculty of the Westphalian Willhelms University (WWU) in Muenster, Germany, since 2009 and she has been supervising the simulation area 'SimuScape©'. Her special interest is the integration of the 'SimuScape©' in the regular training curriculum.

Anne Weissenstein

Has a medical degree and works as a physician in Cologne. She has been working for many years as a tutor for undergraduate as well as postgraduate students at the Studienhospital in Muenster and is interested in medical teaching and education research.

Ivo Haulsen

Is research manager of interaction technologies and works since 1997 at Fraunhofer (Berlin, Germany). He is currently exploring simulation environments with curved screens and domes.

Bernhard Marschall

Is CEO of the Institute of Medical Education and is since 2002 dean of medical education at the medical faculty of the WWU. He started working on a new medical training facility by using and developing the newest simulation possibilities of hardware and software to create new faces of medical simulation.

Hendrik Friederichs

Is medical director of the Studienhospital, the simulation-center at the medical faculty of the WWU. He has a Masters in Medical Education and maintains a significant interest in undergraduate and postgraduate teaching and education research.

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