From storyboard to practice: My Virtual Operating Room

Zeynep Taçgın[1]

Abstract

Innovative educational research integrates technological resources in a learning environment for finding the most appropriate method to increase the desired learning outcomes. This kind of research includes two fundamental stages. First, the learning material is designed and developed using suitable learning strategies and techniques. At the second stage, the developed product is applied to the target audience for the evaluation of the environment. The results of assessment direct the developer to redesign the material until the best version of the product is reached. Because of this interconnection the design reshapes and continues during development. This process explains why a well-designed learning environment is highly cumbersome and requires time, a qualified team and money. This article tells the development story of myVOR (my Virtual Operating Room) – from getting the idea off the ground to a finished product. myVOR is an immersive virtual reality (VR) learning environment, and the project has taken six years to make. Three different versions of myVOR have been developed over this time. The initial and latest versions were experientially tested on users. This study not only explains the distinguishing features of myVOR for each version but also summarises the findings of empirical studies to conduct the progress of learning with immersive VR.

Keywords

Virtual Reality; Learning Environment; Immersive; VR; Simulation

The nature of research depends on identifying a problem and offering solutions to solve the issue in practice. These problems and solutions are infinite under the umbrella of science, and each finding of the scientific studies only provides a drop of water to the knowledge of the ocean. Some of the areas have priority like defence, health and education. Structuring the research on these fields might provide some advantages like increased funding and greater impact.

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I am passionate about technology, and throughout my professional life, I work to integrate innovative technologies into learning environments. My journey in educational technologies started with distance education and material development. Approximately 10 years ago, the dazzling and vivid representation of the virtual and augmented reality environment started attracting my attention. I imagined creating a surgical simulator that doctors could use to define the individual data and specifications of their patients. Then, they can practise surgery on the virtual patient in order to reduce the risk and anticipate possible complications before the real operation.

I have a special interest in the medical field. Even though I am not a doctor, I know that gaining practical experience is extremely challenging because of the high-risk conditions (Ten Cate; Kneebone et al.; Kneebone; Law et al.; Windsor; Ota et al.; Jones et al.; Ward et al.). Using mixed reality systems might be an adequate option to make this dream real using intuitive learning (Huang). While I was thinking about this project, every day a new problem needed to be resolved such as the anatomy of a virtual patient, interaction types, speed and/or angle of the virtual objects, and registration of responses.

myVOR projects

I quickly discovered this kind of project was huge. Developing the environment not only requires use of emerging technologies, but it also needs a multidisciplinary team that includes doctors, coders, animators and designers, as well as significant funding. I decided to put strict parameters around the scope of the project. This project should overlap the requirements of learners and should be doable using fewer resources; it needed to be real. I simplified the scenario and determined an adequate method to offer a basic version of this dream.

Initially, I based my project on existing resources. I contacted a nurse to reinforce the theoretical background of this project (Taçgın). I interviewed her and some of her colleagues to discover the problematic topics for teaching. Then, I reviewed the nursing literature to specify the learning subjects. I wanted to use gesture control to teach the skills and procedures. After interviewing five surgical nurses, I noticed that they had consensus about a lack of practice during their training. After taking advice from an older surgical nurse academic, I decided to develop this VR simulation for teaching preoperative surgical procedures and concepts to nursing students.

Nursing education uses an observation-based shadowing technique (Wyoming) to teach practical skills. This technique is not always enough to provide sufficient experience (Kneebone); for this reason, nurses have technical performance issues early in their professional lives (Undre et al.). They can lack knowledge with regard to the procedures as well (Pupkiewicz, Kitson and Perry). The nursing faculties and hospitals use manikins[2] in the skill labs (Herrmann-Werner et al.) to reinforce learners' practical skills. Learning scenarios (Kneebone et al.; Kneebone; Herrmann-Werner et al.; Ota et al.; Paige et al.; Ramnarayan Paragi Gururaja et al.), web-supported learning

[2] Manikins are the anatomical and interactive model of the human body.

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environments (Ramnarayan Paragi Gururaja et al.; Ward et al.; Whitson et al.; Kneebone) and problem scenarios (Sachdeva, Pellegrini and Johnson; Whitson et al.; Jones et al.; Ward et al.; Ramnarayan Paragi Gururaja et al.; Davis; Davis et al.) are used to overcome the limitations of traditional learning techniques. Each of these alternative methods has other restrictions such as instructor dependency, expensive devices and a lack of debriefing.

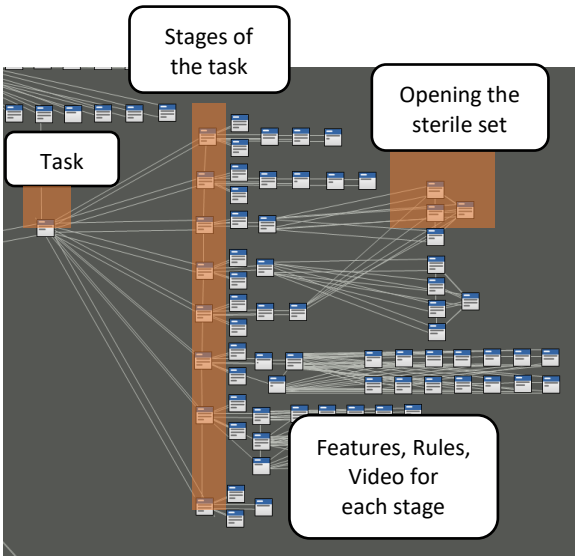
After analysing these requirements, I prepared a project form for funding and organised the research team for developing myVOR (my Virtual Operating Room). After the project was approved (EGT-C-DRP-200716-0392),[3] I gained insights about nursing terminology under the consultancy of an expert nurse who supported this project from the beginning until the end. Then, I prepared the storyboard[4] to represent the features of essential simulation over eight months. I used the catalogues of medical instruments for realistic design and learned a few procedures about preoperation. I used Twine[5] (Figure 1) for the main storyboard and added the specifications of the required instruments of the virtual operating room and learning scenarios. The storyboard (Figure 1a, Figure 1b) also included the relationship between the procedures. I designed two other storyboards to represent the interface of myVOR including menu and navigation components (Figure 1e, Figure 1f), and theoretical knowledge (Figure 1d) of the simulation.

After the storyboard was completed, I used the prepared 3D assets, but they were not enough to design a complete operating room experience to teach preoperative procedures to the nursing students. As seen in Figure 2, the team modelled more than 200 3D surgical instruments using Solidworks. We transferred and restructured these 3D models using the Unity game engine. The nurse checked the suitability of the environment, instruments and the learning scenario for each step. The initial version of myVOR (Figure 3) was developed in five months with collaborative teamwork.

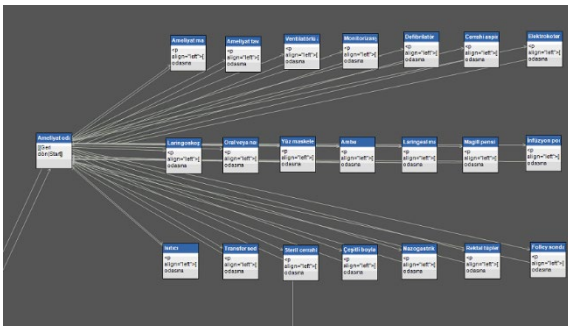
The project and material development had to be completed before I could start the data gathering phase of this research project. My research questions were:

- Was myVOR effective to teach the preoperative process to the nursing students?
- What experiences do the students learn using VR?

[3] The initial version of this project received ethics approval from Marmara University Medical Faculty (ID: 09.2015.242/70737436-050.06.04-). All participants signed consent forms.
[4] A storyboard is graphical representation of the product, which includes pictures, notes, dialogs or interactions.
[5] Twine is a web-based storyboard platform.

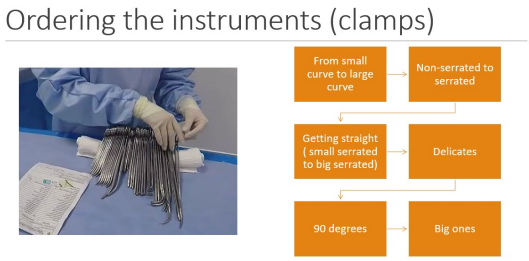


(a) Twine: procedures

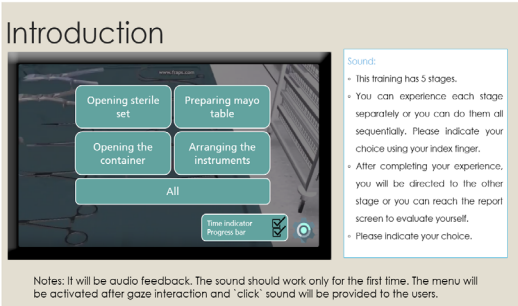


(b) Twine: instruments

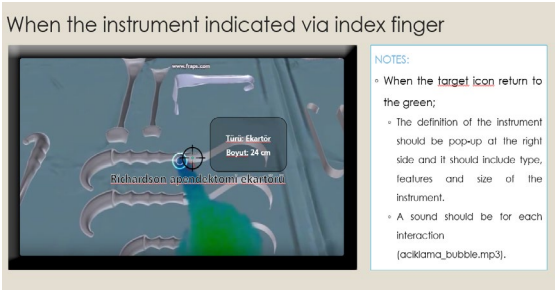
(c) Twine output for a sample instrument



(d) Rules for ordering instruments



(e) Menu interface



(f) Interaction types and features

Figure 1. The sample storyboard screens.

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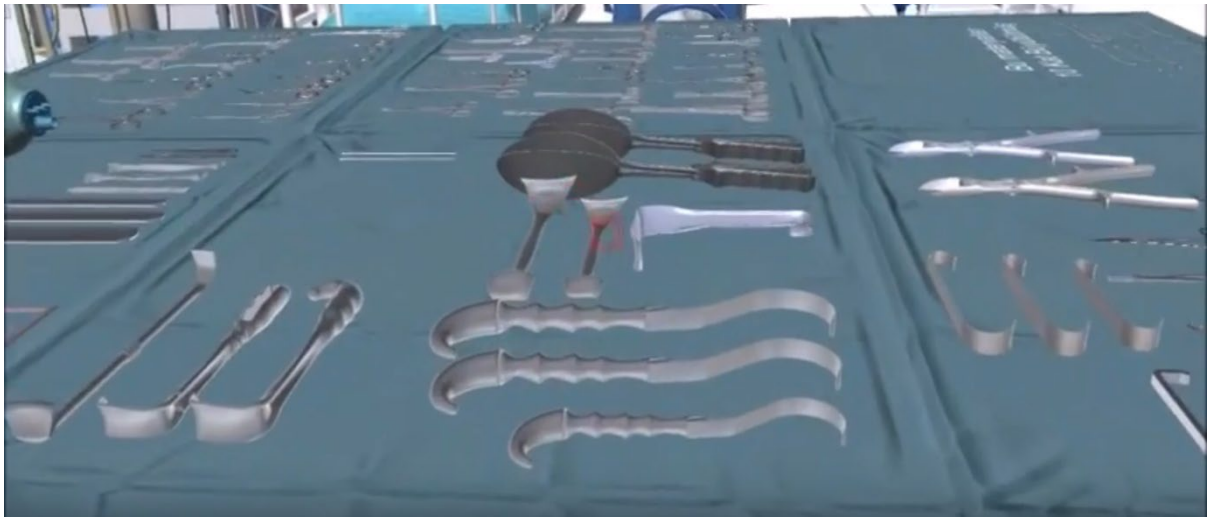

Figure 2. The designed instruments.

The learning scenario of myVOR started with the menu screen (Figure 3a). Using this interface, users could start the simulation, look at the sample real-life videos (Figure 3b), evaluate themselves via the report screen (Figure 3f) and activate/deactivate the time indicator or progress bar. After starting the simulation, they completed a total of 12 tasks of preoperative processes in the application area (Figure 3c). As seen in Figure 3d and Figure 3e, they interacted with the virtual objects using their physical hand movements.

I applied myVOR to the 14 third year nursing students who completed the internship and took related lectures about the preoperative process (Figure 4). In the first session, they struggled with the Head-mounted Display (HMD) cables and interaction methods. I understood that they did not have enough theoretical knowledge to complete the learning scenario of myVOR despite having taken lectures and an internship. Despite this, the students loved experiencing VR and were amazed by the technology. I added hints and instructions for the second session. In this session they were more confident using VR, and the added learning components worked well. In the third session, students were spending more time and trying to investigate the functionalities of myVOR. They were watching sample videos to see the correct implementation and using the report screen for self-evaluation. The majority of participants implemented the scenario correctly, and even they were shocked that they learned. After the last session, 11 of them achieved more than a 70-point score as a result of a paper-based exam. According to Bloom's mastery learning model, 70/100 is the minimum score to be successful. Depending on this model, it is possible to say that the initial version of myVOR helped the learners to reach the desired learning outcomes.

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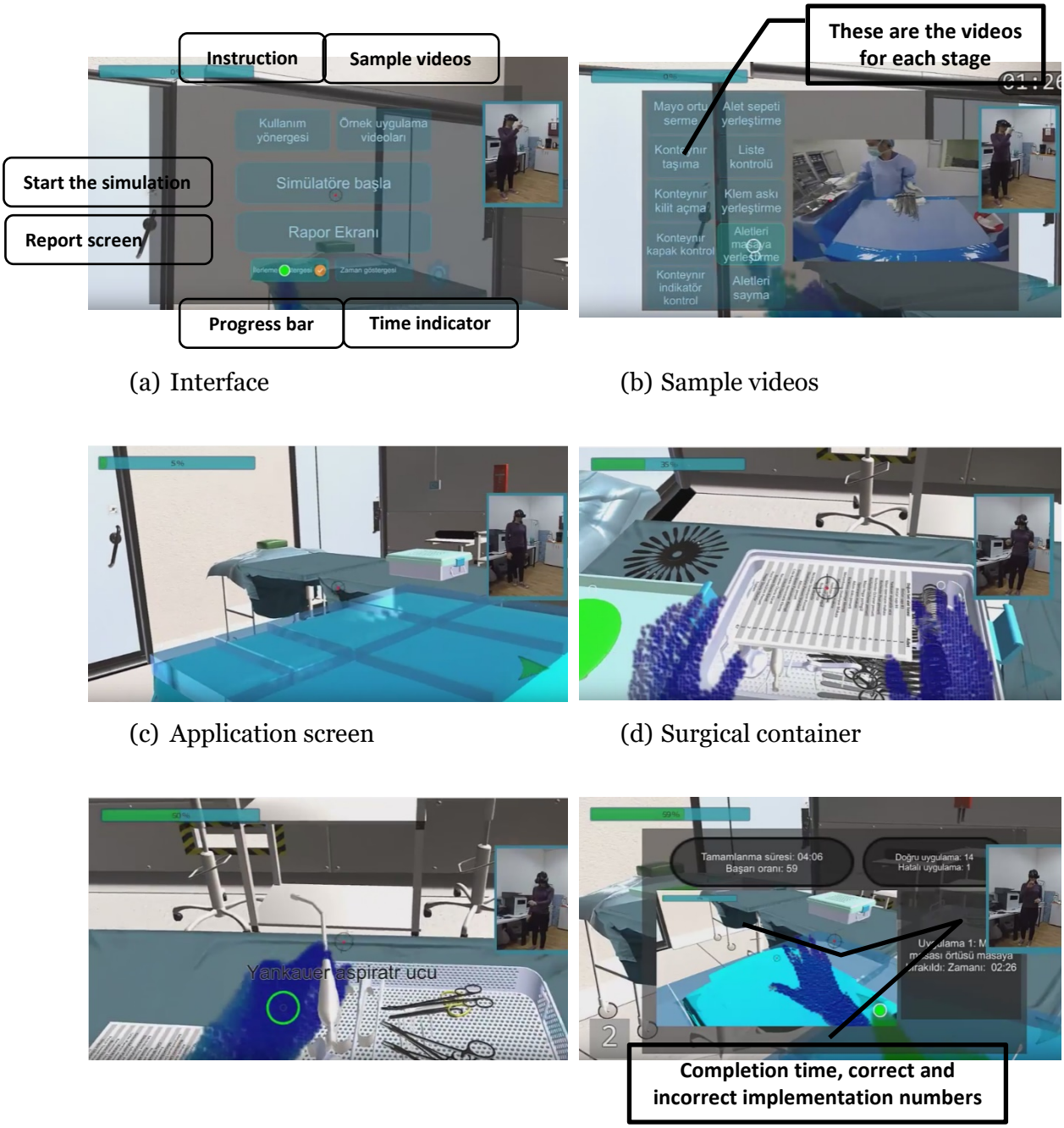

(a) Interface (b) Sample videos

(c) Application screen (d) Surgical container

(e) Interaction (f) Report screen

Figure 3. The interfaces of myVOR.

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(a) (b)

Figure 4. The implementation sessions.

The findings of the research proved the effectiveness of a well-designed VR simulation but also hinted at problems to solve in future research. For instance, the first version of myVOR used a Meta HMD to provide gesture interaction. This HMD was 3DoF;[6] therefore, moving into the VR had to be managed by someone else.

For this reason, I used the keyboard to direct learners after they told me where they wanted to go. The Meta[7] was bulky and heavy which caused neck ache for some users after the sessions. Meta was also sensitive to the sunlight because of the integrated depth camera. These factors negatively affected the quality of immersion.

I continue to develop and make myVOR better for learners. I organised another project which received funding (FEN-B-131216-0542), and the same core team continued on this project. This time we used a newer HMD as Meta 2. It was more comfortable, and the graphics were better. The goggle type was for augmented reality (AR)[8] instead of VR. We embedded only the intractable components and learning scenario to the AR version of myVOR (Figure 5). After learning that some of the procedures can change hospital by hospital and doctor by doctor, we used a machine-learning algorithm to provide constructed feedback to the learners. We used the correct implementations of 10 expert nurses to teach the surgical instrument arrangement to the AR system. This system worked well but then the company Meta closed (Robertson "Ar Headset Company Meta Shutting Down after Assets Sold to Unknown Company"), and the AR version of myVOR was not sustainable on the Meta anymore.

[6] 3DoF refers to track rotational motion for pitch, yaw, and roll.
[7] A Meta is a depth camera integrated augmented reality HMD.
[8] Augmented reality refers to enhancing perceived reality using digital components.

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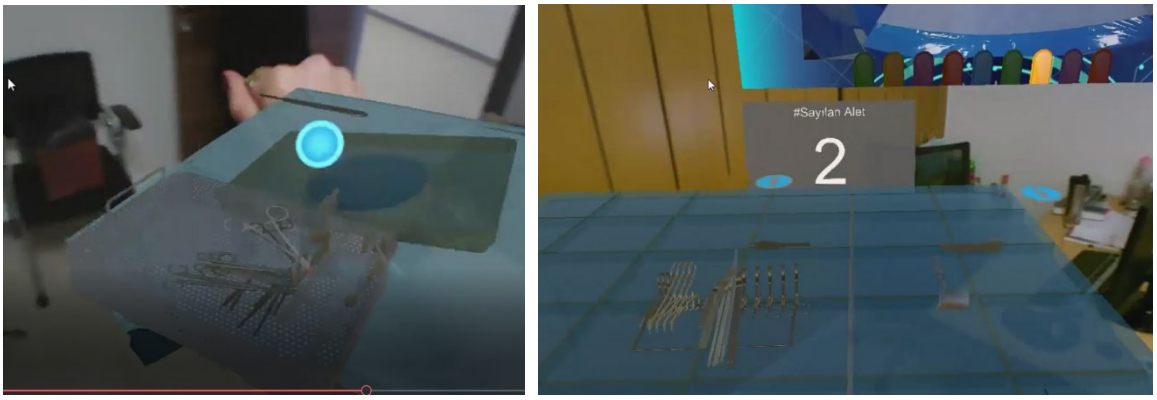

(a) (b)

Figure 5. The interfaces of the AR version.

These devices are expensive, and development is highly cumbersome. A year later, standalone HMDs were released to resolve the cable issues (Trivedi). They did not directly support the gesture recognition, but the controllers were more ergonomic.

Oculus Quest was released in 2019 (Robertson "Oculus Is Trying to Make the Quest the Only Home Headset That Matters") and I used the new version of Unity game engine (Unity) to increase the immersion using high-fidelity graphics. Oculus Quest is light, has 6DoF and a high-quality display (Oculus). It consists of two controllers that provide haptic feedback[9] as well. Oculus also released an easy to use application program interface (API) for developers.

I used the Oculus Quest to develop a second version of myVOR (Figure 6). I completed this project in three months. myVOR2 has no menu screen or particular learning scenario. I used transparent panels for presenting information because we do not see separate menus or buttons in our physical reality (Alger; Sherman and Craig). I added haptic and audio feedback for interaction. In this version, users were free to discover the operating room, learn the names of the instruments, watch the real-life videos and practise in it. They can also follow their status using the progress bar and see the learning outcomes and hints using the panel.

[9] Haptic feedback refers to providing feel of touch using vibration or other systems.

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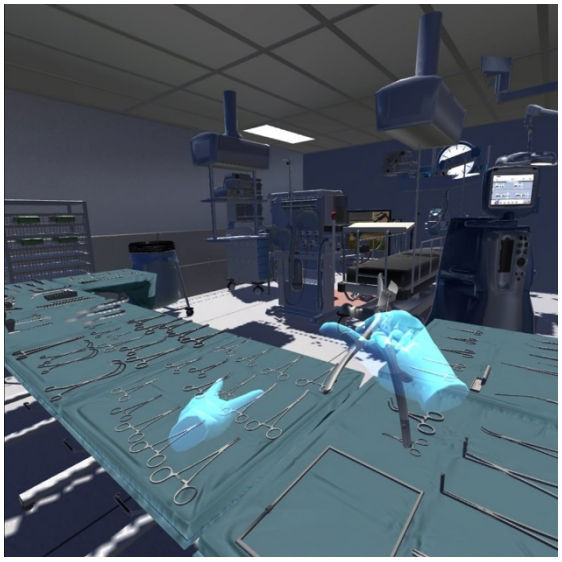
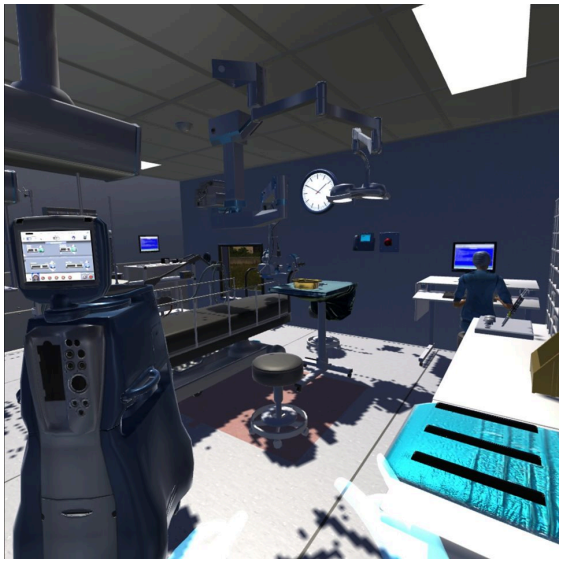
(a) Working place



(b) Interaction



(c) The operating room

(d) Instruction

Figure 6. The interfaces of myVOR2.

Three nursing academics and six instructional designers applied myVOR2 four times (Protocol number: H19221). They were amazed by the presence (Dede) of this version, and they claimed that they felt like they were in the operating room. Despite the comfortable and easy to use goggles, they required at least two or three repetitive applications to gain familiarity with this technology. They did not experience neck ache, and they were free to interact with every object in the virtual room. After providing tasks and hints in myVOR2, they spent more time in the application and tried to interact with all the objects, including shelves.

Discussion

Learning tools and techniques have been transformed with technological developments. Virtual and augmented reality (AR/VR) learning environments are highly popular as a result of the represented authentic high-fidelity visuals and interaction opportunities (Buttussi and Chittaro; Heydarian et al.). These systems provide an opportunity to observe the structured virtual components beyond the perceived reality (Lee).

Constructivism in education is a paradigm that provides an opportunity to learners for structuring their individual knowledge (Wang and Hannafin; Macleod and Sinclair). Active participation (Martín-Gutiérrez et al.; Hussein and Nätterdal) is essential for this student-centred learning strategy which uses experiential, discovery, inquiry and situated learning for designing environments (Tacgin). Using AR/VR provides the advantages of using the simulation; thus, learners are able to experience high-risk conditions repetitively in a safe environment (Alqahtani, Daghestani and Ibrahim). They can see the mechanism and systems of intangible concepts (Alqahtani, Daghestani and Ibrahim; Aguinas, Henle and Beaty Jr). They can even be a mitochondrion to transfer energy in a cell in the virtual environment.

Experiencing a situation by learning in immersive VR (IVR) also facilitates learners' knowledge acquisition (Luo and Mojica Cabico) (Lu and Liu; Pérez-López and Contero). Encapsulating the perception of users via IVR environments provides a psychological presence which means "feeling like you're in there". Correspondingly, attention time (Tang et al.; Jetter, Eimecke and Rese; Di Serio, Ibáñez and Kloos) of learners increases when learning a particular subject.

The primary purpose of instructional design is to improve learning outcomes, and it is of paramount significance in creating useful educational materials (Taçgın & Arslan, 2016). The results of the experimental study presented in this article showed that the initial version of myVOR facilitated the learning of students and helped them to gain desired learning outcomes.

Applying traditional instructional design models does not usually overlap the features of IVR technologies. The principles of developing well-structured AR/VR learning environments is still evolving (Goodwin, Wiltshire and Fiore; Kirkley, Tomblin and Kirkley). For this reason, designing learning environments should be systematised using adequate learning theories, information technologies, systems analysis, and educational research and management (Morrison et al.). This process should be managed as a project using the epistemology of the scientific methods (Wang and Hannafin; Macleod and Sinclair). I suggest applying the design-based research methodology and designing the IVR environment during the development phase. The following design stages of myVOR present a pathway to plan immersive virtual reality learning environments (IVRLEs).

The development of myVOR was managed using design-based research methodology (Wang and Hannafin) that included iterative evaluation and development stages until

the final version was reached (Cengizhan; Barab and Squire; Barab). This methodology is used to find new educational models as well (Hoadley).

Recommendations

The story of myVOR can be instructive in creating immersive VR environments and using them as a learning tool. Depending on the project, I would suggest applying these key elements:

- Applying the stages of project management helps to see the big picture and subsystems.
- Collaborative teamwork is a necessity, and you need at least a subject expert, an instructional designer and a coder for developing AR/VR environments.
- Designing learning environments requires adapting adequate learning strategies to enhance the environment using proper learning components. Use scientific methods to guide the selection of these components.
- Designing IVR should be an iterative process during the development phase.
- The product should be tested on the target audience before being considered final.
- Using IVR requires to be familiar with the usage of technology before learning.
- Setting tasks motivates users to spend more time in the learning environment.

Additional Resources

- The first version of myVOR: https://www.youtube.com/watch?v=fiCKNVYc5Ao&t=11s
- The second version of myVOR: https://www.youtube.com/watch?v=rjbzTvmFrq8
- The third version of myVOR: https://www.youtube.com/watch?v=KarOiSSPVgo

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