Exploring 360°-videos as Realistic Game-based Learning Environments for Work Placement Preparation

Tord Hettervik Frøland[1 [0000−0002−2168−3918]], Ilona Heldal[1 [0000−0003−1149−8820]], Gry Sjøholt[1 [0000−0002−7214−5829]], and Elisabeth Ersvær[2 [0000−0002−9617−9329]]

[1] Western Norway University of Applied Sciences, Inndalsveien 28, Bergen, Norway
{tord.hettervik.froland, ilona.heldal, gry.sjoholt}@hvl.no
[2] Inland Norway University of Applied Sciences, Holsetgata 31, Hamar, Norway
elisabeth.ersvar@inn.no

Abstract. Serious games in immersive virtual reality (VR) environments promise enhanced experiences and engagement, supporting training and learning. While realistically replicating the visuals of real environments can be both difficult and time-consuming, there are many potential advantages from doing so. In real work placements, students enter facilities with variations in types of equipment, rules for navigation, and workflows, adding cognitive load to a usually stressful situation. Allowing them to train and learn in more realistic environments corresponding to their future work placements, with high-fidelity representations, can be time-saving, support core task focus, and help students become more isolated from distractions. This paper presents the VR game 360Phlebotomy, which combines virtual tasks with 360° images and -videos of real laboratories in immersive VR. The game is aimed at helping students become familiar with real workplaces while also learning their work tasks. Current scenarios are tailored to biomedical laboratory science (BLS) education, with a focus on the phlebotomy process, which also serves as the main case in this paper. New environments can be added through a modular scene creation system, with the goal of allowing students to prepare for different work placements. Insights are provided by presenting the design and development process for a prototype tested by five BLS teachers and six BLS students. The results contribute to an increased understanding of the role of context in training and learning and provide a foundation for future work.

Keywords: Serious games · Virtual Reality · Biomedical Laboratory Science · Contextual Learning · Phlebotomy · Workplace Simulations (WPS).

1 Introduction

Work placement is considered an essential step in the learning process of many professions [3, 2]. In some fields, it is also mandatory, particularly in health-care professions [9]. First-hand experience of the real working environment, practical execution of tasks, and gaining a holistic view of the work, help the students know what to expect when they start to work after their studies and to relate what they learn in their studies to a practical setting.

Biomedical Laboratory Science (BLS) is a profession where work placement during education is mandatory. Students may encounter many potential challenges when transitioning from the facilities at the learning institution to a workplace. While the laboratories and laboratory equipment in practice and workplaces have many similarities, some important variations exist from place to place. Variations are even greater when comparing the laboratories and laboratory instruments students use at their schools, because of limited budgets and expensive equipment. The environments and the procedures for performing the same type of work can differ, e.g., a requisition list may be based on different forms at different laboratories. There are also variations in navigation and workflows. Therefore, it usually takes time to familiarize oneself with different practical environments, even for well-prepared and engaged students. Work placements are expensive and limited, making effective use of them important. With BLS teachers already struggling to have time to teach all the course content, additional tools could be highly beneficial.

Serious games and simulations can be helpful additions during the learning process leading to work placements. Self-paced learning, repeatable content, and risk-free environments are some of the possibilities. With immersive virtual reality (VR) having become better and cheaper in recent years, a wide range of supplemental applications are possible. Games and simulations can help students feel better prepared for work placement, make the onboarding process easier and faster, and as a result make work placements even more valuable. However, how to best make use of them, when and where to use them, and which types of games, are some of the open questions regarding games and simulations for learning. There are also technological challenges that need to be addressed relating to development costs, reusability, maintenance, and more.

This paper helps illuminate this theme by exploring how a VR game based on 360° videos and -images can be used for work placement preparation. To the authors' knowledge, this is the first virtual reality solution combining video, abstract VR interaction, and games for phlebotomy learning. Five teachers and six students evaluated the application through user testing, questionnaires, and semi-structured interviews. A summary of the test results is provided. Based on the development and testing of the application, insights and future work are proposed.

2 Background

There are a growing number of initiatives and products aimed at educational innovation of the BLS education through the use of technology, such as e-learning tools available on open-access web pages [22, 6] and virtual laboratories [15]. These tools can provide great benefits for educational institutions which have challenges in having enough time to go through all the material, do not have enough resources to acquire all industry-standard equipment, and have limited opportunities to let their students practice in real workplaces. There are multiple aspects that digital tools may help with, such as providing additional laboratory training opportunities to support student learning in their BLS programs.

One of the primary gaps in current digital environments for BLS learning is that they only depict abstract settings [22, 7, 14, 19, 25, 10, 15]. Abstract environments are valuable, as they reduce complexity and allow students to focus their training on the procedure, but there is a missing step before work placement as they do not allow users to experience the real environments where work tasks are performed. While VR games using constructed 3D environments allow high experiences and support learning skills by moving and interacting in the represented space, much contextual information is missing.

Learning to navigate the working place, perform local routines, and how to handle specific equipment in use, are skills that need to be acquired when entering a new work environment. Work placements are important steps in the learning process and help the students translate what they learn in class into real tasks [3, 2]. In some educational fields, such as BLS, it is expensive to send students into work placement and they have limited time and opportunities to do it. Utilizing the allotted time as efficiently as possible can be of major value to the students. To allow students to prepare themselves for their specific work placement location, and to build on the foundation from regular teaching and digital training in generic environments, there is an opportunity for immersive virtual reality (VR) experiences in realistic environments [16].

Creating valuable training solutions in VR is not straightforward, as there are trade-offs to consider. Solutions such as Labster show great potential [14], but the learning effect when adding immersive VR is potentially reduced as compared to the non-immersive version [20, 18]. Makransky, Therkildsen, and Mayer observed that "In spite of its motivating properties (as reflected in presence ratings), learning science in VR may overload and distract the learner (as reflected in EEG measures of cognitive load), resulting in less opportunity to build learning outcomes (as reflected in poorer learning outcome test performance).". While there may be many influencing factors, potentially related to environment design and interaction capabilities, this raises the question of when and how to use VR. The exact reason for the added cognitive load is uncertain, but more presence and grade of realism are potential factors. While added cognitive load when in VR was a net negative based on the measurements of learning in the mentioned experiment, it can also be leveraged in a positive manner. If the goal is to get familiar with an environment, the added presence is highly valuable, as long as the associated increase in cognitive load is not disproportional to the increase in presence. An increase in cognitive load would also occur naturally when entering a real work environment, as opposed to being at an educational institution or using non-immersive digital media, thus added cognitive load could be directly beneficial in some cases.

The potential for reduction in learning associated with increased cognitive load is one of many aspects that must be considered and handled appropriately when planning to leverage VR. As with any other technology, it is not a silver bullet but needs to be considered with its positives and negatives. With the potentially negative effects of cognitive load in virtual reality training [18, 5], when and how to use the technology is important.

While there are multiple benefits to having fully 3D-constructed VR experiences, creating realistic ones are difficult and time-consuming, especially when humans need to be animated [1]. Local variations in equipment, buildings, and other details might also require a lot of work to create. While these details might not be crucial on their own, when looking at the totality of a work environment, they can be important. A potential trade-off point is using 360° videos and -images as the basis for the environment. Good quality 360° cameras have become affordable and allow for quickly and easily capturing scenes. Though there are some potential associated costs to take into consideration in terms of time used to record at the scene, potentially hiring actors, ensuring spaces are cleared, making sure no sensitive material is present, etc. There is also a tradeoff in terms of interaction capabilities, as scenes are static.

Serious games have the potential to be learning tools that engage and allow for active learning opportunities for students, though their optimal use and development is an open question [4, 8]. A common argument for serious games is higher user satisfaction which also is "used to justify higher learning rates or skills improvement with VR-SGs" [4]. When introducing new IT tools, user satisfaction is of high importance in acceptance of the technology [11], thus game elements can play a key role in successfully introducing VR learning content.

To facilitate the research in this paper, a learning game in immersive VR was created. The game is aimed at helping to learn the phlebotomy procedure by letting BLS students explore visually realistic depictions of their own institution's laboratories as well as work placement facilities. By playing through phlebotomy scenarios at these locations, the students can experience differences in the visuals, workflow, and equipment. The application utilized 360° videos and -images from a university laboratory and its local hospital as the basis for the visual environment of the game. The VR experience was delivered through used of Head Mounted Displays (HMDs).

3 Methods and materials

The design and development of the prototype were done in several iterations, including discussions with BLS students and teachers. While it is difficult to evaluate how different compromises regarding the different representations/visualizations can be applied, the evaluation of this prototype is based on 1) usability evaluations and observations focusing on the game (for learning the phlebotomy process) and 2) interviews focusing on the role of context. The data was gathered through observations, questionnaires, and semi-structured interviews.

Feedback for evaluating the prototype was obtained from five BLS educators and six BLS students. Each user testing session lasted approximately 60-90 minutes. At the beginning of each test session, the participant filled out a background questionnaire. A few minutes were provided at the start for the testers to familiarize themselves with the VR equipment. Afterward, they explored the two environments, filled out the questionnaires, and discussed their experiences during the interview. Each participant played through both scenarios, starting with the one at the university laboratory before moving on to the hospital. The usability questionnaires consisted of a combination of self-determined questions, the user experience schema of Salim et al. [21], a subset of the user experience items proposed by Laugwitz, Held, and Schrepp [17], and 10 open-ended questions. Semi-structured interviews focused on the use of the application and lasted at least 30 minutes per participant. The main themes of the questionnaires and the interviews were previous experiences with, and attitudes toward, serious games and the presented VR games. Notes were taken during the interviews, with no video or audio recordings being taken. The evaluations were performed during May and June 2021.

The study received approval from the Norwegian Centre for Research Data (NSD; number 192536) and followed the rules of the Declaration of Helsinki of 1975. All participants provided informed written consent. All data collected from participants were anonymized before storage on a secure server. Scrambling keys were stored separately from the data material.

3.1 Technology

The game was developed using the Unity game engine [23] for the SteamVR ecosystem [24] with the HTC Vive Pro Eye kit [12]. It is based on 360° videos and -images captured with the omnidirectional Insta360 ONE X action camera [13]. The tests were performed using a high-end Windows desktop PC (AMD Ryzen 5 5600X, 16GB DDR4 RAM, 500GB PCIe SSD, 2TB HDD, GeForce RTX 3070 8GB) and a HTC Vive Pro Eye HMD [12] with Vive Controllers (2018).

The BLS experts in the test group had a general lack of previous experience with games and VR; three users had tried HMDs before, but none of them were familiar with them.

3.2 Prototype Solution Overview

Scenes were created using spherical stitching to project the images onto the inside of a sphere with the user positioned in the center of the sphere. Navigation between image locations is done by interacting with doors and areas of the floor where a green rectangle indicates the possibility to move when targeted. Similarly, interactable objects are also highlighted with a blue rectangle when targeted (see Fig. 2). The user interacts by pointing motion controllers toward an object and pressing the trigger button. To reduce the risk of cybersickness, the scenes fade out and in when transitioning. The learning content of the game was inspired by the serious game StikkApp [10], which is about learning the phlebotomy procedure (blood sampling). For contextualization, two scenarios were created using 360° images and -videos representing the phlebotomy laboratory at the university and workplace simulation at the local hospital (see Fig. 3). An overview of the game contents can be seen in 1.

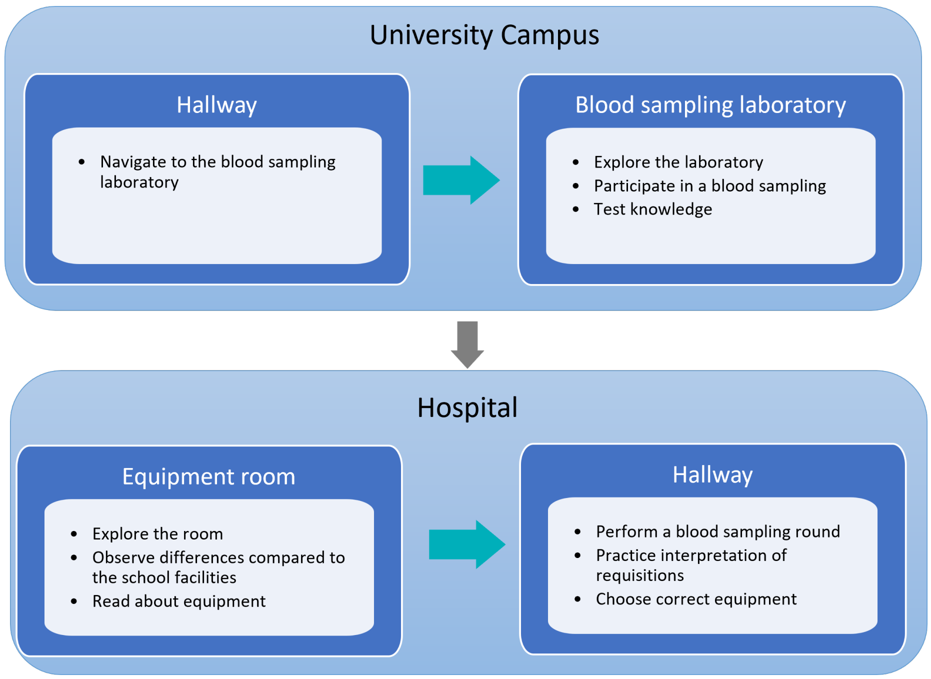

Fig. 1. Overview of the game flow.

The development of the game had some key goals defined:

– Use recorded 360° video and high-resolution 360° pictures of laboratory environments and objects.
– Encourage exploration by including points of interest in each scene that can be highlighted by pointing with a motion controller.
– Create an interactive game experience that helps students familiarize themselves with the environment by performing actions in the game.

In the first scenario, the student walks from the hallway into the laboratory to interact with objects to get information about them, perform a quiz to test their knowledge, and get a first-person view of the phlebotomy procedure. The second scenario places the student in an equipment room for blood sampling at the hospital. This scenario involves exploring the equipment room, gathering necessary equipment based on a requisition, and going through the phlebotomy process. To facilitate active learning of procedures, game elements were incorporated based on feedback from teachers. Quizzes were integrated (see a popup quiz in Fig. 3, left) and selection minigames where the student must properly choose among a selection of correct equipment and related but incorrect equipment, in the correct order.

Fig. 2. In-game screenshots of 360Phlebotomy: 1) A door is highlighted with a green frame to indicate navigation; 2) Equipment is highlighted with a blue frame to indicate an interactable object.

As the students play through the scenarios, their performance is scored, which can act as a motivating factor that also helps them gauge their knowledge level to keep track of their improvement through future playthroughs. Some scoring activities can be seen in Fig. 3, where the student must gather the correct equipment for each patient and answer quizzes on aspects of the phlebotomy procedure. The players are scored throughout the play session and can access their score at a computer terminal in the equipment room. By scoring the player's performance and presenting it throughout the play session, they get an idea of where they need to improve and their current skill level. This way, they can also have personalized goals of improvement between play-throughs.

4 Results

The testing provided insights into educator and student opinions on various aspects of the proposed game and improvement suggestions for the game.

During the play session, some of the participants had to be verbally guided through the game mechanics and goals of the game. The test persons who had previous experience with games and VR did not need much guidance. Those unaccustomed were interested in having a proper in-game introduction to the scenarios and game mechanics.

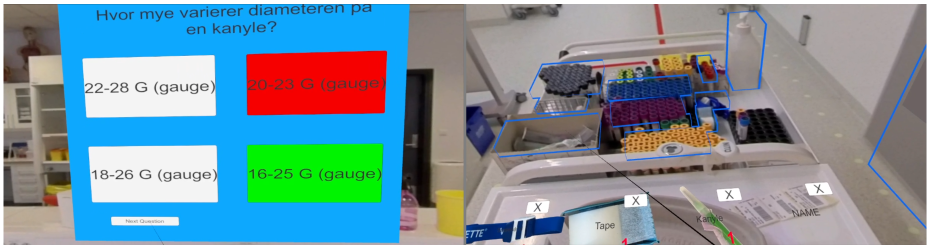

Fig. 3. In-game screenshots of 360Phlebotomy: 1) A quiz at the university laboratory; 2) A trolley with interactable objects at the local hospital.

The participants were generally positive towards the proposed solution and were interested in using an improved version in their teaching. Some concern was voiced regarding the practicalities of setting up VR equipment, though if this would be handled by the institutions IT department, they believed they would be able to perform the instruction and demonstration of the game.

Fig. 4. Test participant selecting equipment for the phlebotomy procedure.

4.1 Environment

The general consent towards the environment was positive, particularly regarding the realism of the visuals. However, the image quality should be improved to allow details to be more distinguishable. The visual experience of the first-person phlebotomy procedure was well received. The current method of transitioning between the two environments is done through a non-descript portal, which the BLS teachers believe should be improved, for example through the use of a menu system. Participants that were tall or short noted some discomfort with the height at which the environment footage was taken. Adding multiple height options was suggested as a solution. The explorative elements of the game were considered too open and a more narrative structure was wanted. Students and teachers believed it would be valuable to use 360Phlebotomy for a game-based virtual tour of the laboratories as a part of work placement preparation.

4.2 Interaction

Through the interviews, BLS teachers noted that they would like to have fewer things around, a better indication of which objects are interactable, an improved scoring system, and more entertainment aspects. More abstract features could be used to guide the student's attention to important parts when performing the process and to help understand where one is in the overall process. The current quizzes included directly copied questions and instructions from the students' handbook. These were instructing them in a straightforward way through the phlebotomy process which was considered too wordy. They believed that reading long texts was not well suited for VR. Some usability problems were experienced with hitboxes of particular objects from a distance. All teachers were positive regarding implementation of eye-tracking, allowing the possibility of visualizing where a student is looking in the environment. Students stressed the importance of eye-tracking being optional. A preliminary hypothesis of this study was that by using eye-tracking technologies to identify focus points during task solving, this information could be used as a valuable discussion point between teachers and students. Through pointing out and reflecting on correct and incorrect focus during puncturing of the vein and conversations with the patient, students should gain a better understanding of the phlebotomy process. However, these aspects need further exploration.

4.3 General improvements

Both teachers and students noted that the type of game could be useful in several other classes in BLS education. Additionally, it was mentioned that nursing students or doctor students could likely benefit from it. The blood sampling procedure would be especially relevant. They could imagine further scenarios that are important for phlebotomy learning, with angry patients, children, etc. To this end, videos of more medical procedures could elevate the learning benefit of the application. Furthermore, adding behavior tree-based interaction between a user and person(s) in the scenes could add to the interactive element of the experience. Inclusion of more game elements was considered valuable for the future.

4.4 Practical considerations/implementation

The development and testing of the proposed solution were impacted by the covid-19 pandemic, particularly making the recruitment of test persons challenging. Because of covid-19, the test participants noted increased relevance of digital tools such as games and simulations because of further reduced opportunities for training and work placement because of restrictions.

With the rapid development of HMDs, BLS educators are uncertain whether to prioritize the affordability of choosing cheaper HMDs or more expensive ones and how to allow the use of them without supervision. These concerns, as well as considerations of maintenance and further development of resources, made the teachers stress the necessity of having the necessary support from the IT department of the educational institution.

5 Discussion

Through the development and testing of the VR game based on 360°-videos and -images, insight has been gained regarding some aspects for use of games and simulations in education. The overarching question was about how to use games and simulations for learning.

A key aspect of the prototype presented in this paper is the depiction of a realistic context. By allowing the students to experience and get to know their future work placement environments, they could potentially be better prepared and have an easier transition. The results of the study indicate that this approach is considered to be valuable, also for other procedures beyond phlebotomy. By implementing eye-tracking and analyzing the viewing patterns of students, teachers believed they could gain useful insights into what students focus on when they are inexperienced and compare it to experienced practitioners, potentially helping guide the students in what they should focus on.

Students and teachers expressed an interest in having various types of interaction depending on the type of task. For the phlebotomy itself, a closer approximation of the real task, with 3D elements, was desired, even if the 3D objects would not appear to be realistic parts of the environment. How to best combine realistic and abstract environmental details needs further investigation, and can have a big impact on the development process of 360°-based games and simulations. The importance of spatiality in the learning of procedures is also an important aspect. Are there concepts for which learning is heavily dependent on performing the tasks within a 3D space, or is learning in a 2D environment sufficient?

In the process of introducing a game in an educational setting, there is a multitude of persons of different roles involved, such as teachers, students, developers, IT support, and economists. The complexity of the whole process was mentioned as a particular obstacle of concern by the teachers. How to initiate the development of an idea and engage all the necessary persons at the correct time, and manage these tasks while involved in regular tasks such as teaching, was considered a key challenge. Further investigation could help teachers bring many unfulfilled ideas to life, and have the possibility of managing them over time as well.

The manner in which scoring is done in the application could be reconsidered. Currently, the player earns one point for each correct answer, both in the quizzes and the interactive trolley round. A better approach could be to more heavily weight important aspects, or allow for scaled scoring dependent on how well the player performed, and less dichotomous answers. Also, as suggested by test participants, visualizing the consequences of their mistakes could be highly beneficial in a VR game because of its immersive properties.

A key challenge for using realistic visuals in VR is performance. One of the reasons desktop VR was used in the testing for this paper was to ensure high and stable framerates to enhance the users feeling of presence and to reduce the risk of cybersickness. As the users position is fixed in 360-VR, the potential benefits of standalone HMDs were considered less important. With the general hardware capabilities of current HMD solutions, the performance of 360-VR can be a big advantage. However, the rapid development both in graphical rendering capabilities and in VR technology, makes it increasingly feasible to also achieve good performance in realistic virtual environments based on 3D objects. If a point is reached where performance is not as big of an issue, 360-VR could still be preferable when replicating real locations, depending on time and resources constraints.

6 Conclusions

This paper has presented an immersive VR serious game for work placement preparation for students, with biomedical laboratory science (BLS) education as an initial use case. The proposed game is based on 360° images and -videos and allows students to enter visually realistic depictions of real laboratories and work environments, where they can get familiar with the facilities and the associated workflows, and learn procedures and skills. The application has been tested in two user studies with BLS teachers and students.

Testing revealed a positive attitude towards the proposed solution. Students and teachers were willing to use the game as part of their education. Several testers noted that having verbal guidance integrated into the game would be valuable. Additional difficulty levels, learning illustrations, and an in-game tutorial were also mentioned as potential improvements.

The project has highlighted several areas which should be further studied. First, what type of interactions to use at different areas in the application can have a big impact on the engagement and learning of the students and should be studied in more detail. Additionally, there is a need for a systematic evaluation of user experiences for all roles involved in the development process and practical use, and for how the involved persons, such as teachers, can manage it on top of their regular tasks. It could also be valuable to perform a comparison of environments where areas are added, removed, or swapped out, and their impact on learning and engagement.

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