

First aid training using virtual reality

Burapa Phatichon and Chantana Chantrapornchai*

Faculty of Engineering, Kasetsart University, Bangkok 10900, Thailand

ABSTRACT

***Corresponding author:**
Chantana Chantrapornchai
fengcnc@ku.ac.th

Received: 8 June 2023
Revised: 1 October 2023
Accepted: 31 January 2024
Published: 23 July 2024

Citation:
Phatichon, B., and
Chantrapornchai, C. (2024).
First aid training using virtual
reality. *Science, Engineering
and Health Studies*, 18,
24020001.

This work considers the use of virtual reality (VR) technology to self-teach first aid training. It is known that VR provides realistic experiences to train individuals. We created interactable first aid lessons using the Unity engine and a VR interaction framework, and provided hands-on experience, with tests based on practical exercises. The VR application materials, with the first aid knowledge gathered from many government and hospital websites, consisted of 10 lessons and 7 tests. The lessons were appraised by 14 learners, resulting in a total average satisfaction score of 9.1. The post training first aid knowledge test scores increased by 35% from pre-course level. All learners reported having greater confidence, with their practical test scores improving by an average of 22% after multiple tests, demonstrating that the application could be effectively used for learning and practice purposes.

Keywords: virtual reality; training; first aid; unity; VR; Oculus Quest 2

1. INTRODUCTION

Accidents are the leading cause of death worldwide. However, many of the fatalities resulting from accidents did not occur at the scene but during transportation to or at the hospital. In many cases, the victims did not have severe injuries, but lacked appropriate first aid, leading to worsening conditions and ultimately death (WHO, 2016). A common issue was that people did not know what to do in an emergency situation.

Proper first aid can prevent complications and disabilities resulting from injuries. It can alleviate pain and delay the onset of more severe symptoms, as well as assisting the patient's body to quickly return to its normal state. Examples of basic first aid include wound cleaning, controlling bleeding, and managing severe injuries that could lead to death (Brouhard, 2023).

Virtual reality (VR) technology is a computer-generated simulation that is displayed on a three-dimensional device, allowing users to see and interact with the simulated environment as if they were actually present in it (Mérienne, 2017). VR technology is widely used to provide users with immersive experiences that are difficult to replicate in real life, including educational

and training applications, such as first aid training simulations (Donovan, 2018; Johnson-Glenberg, 2018).

Various studies have shown the effectiveness of using VR training. For example, in medical training, where the actual equipment is not readily available, orthopedic training using VR can be conducted (Clark, 2021), with the results suggesting that the skills learned by using VR could be transferable to actual surgery. Radianti et al. (2020) researched the usage aspects of VR in higher education. The important components in using VR are basic interaction, realistic surroundings, intermediate feedback, and instructions. In the engineering field, most learning content is procedural; hence, it induces basic interactions that are suited to VR training. VR is mostly used for educational learning and industrial skill training. Oculus and Unity 3D are popular devices that can provide a developed framework (Checa and Bustillo, 2020). Interactive experiences are the key to learning, with user satisfaction and indicators to real experiences being commonly measured (Checa and Bustillo, 2020).

With VR technology, realistic simulations and training for first aid are possible. By creating a simulated environment that creates various scenarios and locations, the learning experience can be made more engaging and

interactive. The graphics used in the training can be designed to be interesting and visually appealing, with users interacting with the content to gain hands-on experience. Role-playing scenarios can be diverse and do not require the presence of physical models or other individuals. Furthermore, the training can be conducted anywhere, at any time, and can be customized to offer a variety of challenges and experiences.

The current study provided a prototype VR application for first-aid training lessons, with Unity 3D and Oculus Quest 2 being the target framework and device, respectively. The application was designed with several module elements (interactive capability, user performance measurement, and scenario creation), with many lessons and exercises included. The application can be used to teach first-aid training via in-school teaching through role-playing scenarios.

2. MATERIALS AND METHODS

2.1 System analysis

In developing a VR application, there are design challenges associated with the user experience, visuals, sound, physical system, dealing with hardware limitations and user physical conditions.

The goal of the current work was to provide users with learning opportunities related to symptoms, causes, dangers, first aid techniques, and decision-making in various situations. Criteria included that the application should be interesting and easy to understand, with sufficient and accurate content, and with physical interaction that could simulate different first aid scenarios. In addition, the application should enable users to have fun while developing their relevant first aid skills (Oyelere et al., 2020; Lan et al., 2018).

To achieve this, the application must provide users with actionable results based on various test scenarios with random variables to encounter different experiences each time it is used. To ensure long-term content variety, the website allows users to create and share their own events.

Additionally, the application is designed to cater to a broad range of users with different ages, preferences, skills, physical conditions, and basic knowledge. It has a small file size, uses minimal processing power, includes no delicate content and utilizes clear graphics, simple controls, and minimal motion, as well as supporting various languages, playing styles, and body postures (Ioannou et al., 2021).

The training information was gathered from articles, lessons, e-books, quizzes, infographics, and demonstration videos from trusted sources on the internet. People's expectations about doing an offline first-aid course and VR training was also studied and applied what was learnt from their teaching techniques.

2.2 Content design

Existing VR applications used for first aid training were explored and it was noticed that many of them were primarily centered around teaching cardiopulmonary

resuscitation (CPR). Most of these were commercial platforms using a web interface (PIXO, 2023; JBHXR, 2023). Others necessitated users attending in-person first aid courses that were either charged for or free, which might involve additional equipment and instruction (JBHXR, 2023).

Our application considered a different approach, concentrating on providing a broader range of first aid content beyond CPR. Our application was designed to be a self-contained, interactive, challenging, and customizable learning tool, eliminating the need for physical equipment or in-person instruction.

The application contains a comprehensive range of educational content, including lessons and examination scenarios that are designed to instruct users on recognizing symptoms, assessing risks, and executing appropriate first aid procedures for a total of 12 common injuries. These injuries encompass a spectrum of everyday occurrences: bruises, cuts, punctures, choking incidents, fractures, burns, insect bites, animal bites, bee stings, snake bites, fainting episodes, and seizures. These occurrences are not only prevalent but also highly probable in daily life situations (Ellis & Associates, 2023; Ministry of Health & Family Welfare Government of India, 2021).

The information needed for the application was carefully selected and organized. Multiple forms of content, including articles, instructional lessons, e-books, quizzes, informative infographics, and demonstrative videos, were drawn from authoritative and reputable sources available on the internet (Ellis & Associates, 2023; Ministry of Health & Family Welfare Government of India, 2021; St John WA, 2023). This careful selection was made to ensure the accuracy and reliability of the information incorporated into the application. In addition, high school teachers and a university lecturer were consulted regarding the content and examination options.

Furthermore, the content development process was created using a holistic approach, which involved an analysis of the expectations and requirements of individuals participating in traditional offline first-aid courses. Insights were gathered from studying VR training modules across various domains, thereby garnering inspiration from diverse pedagogical techniques and methodologies. This comprehensive exploration of teaching methodologies and user expectations served as a guiding framework for structuring and presenting the instructional content within the application, enhancing its educational effectiveness (Lan et al., 2018).

2.3 System design and tools

The system structure is presented in Figure 1. The VR application was built using the Unity engine with the VR interaction framework (Bearded Ninja Games) as the project development tool. The target device was the Oculus Quest 2. The scenario customization website was developed using Flutter. NodeJS and ExpressJS were used backend to create the application programming interfaces (API)s that were connected with the database server (MySQL).

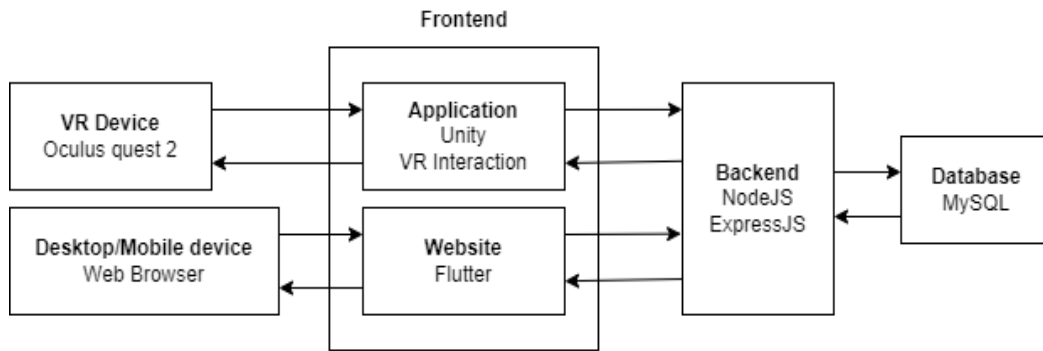


Figure 1. Overall system structure

Next, the important system elements in our VR application are described, consisting of the capability of users and the mechanics of teaching, testing and evaluating user actions.

2.3.1 Interaction system

The main interactive items are described below:

1. User interface (UI) button press — The user points the right controller towards the UI to display a ray pointing to the desired location, and then presses the trigger to interact with the UI.
2. Movement — The user can move or change position within the scene by pointing the right controller to a designated teleport point and pressing the trigger to move to the selected teleport location.
3. Object grabbing — Objects can be grabbed by bringing the controller within the designated grabbing range or position. When the grip button is pressed, the object will be held. Releasing the grip button will release the object.
4. Faucet on/off — To turn on/off a faucet, the user grabs the designated location and rotates their wrist a certain angle.
5. Pouring — During the grabbing of objects that can be poured, tilting the object at a certain level will result in the object being poured, such as pouring water from a bottle or wound wash bottle.
6. Pinching/Gripping — This is used to grab objects by either pinching or gripping. If the end of the object that can be pinched is brought to an object that can be gripped and the trigger button is pressed, it will result in gripping the object. Releasing the trigger button will release the object.
7. Wiping — Moving an object across a surface that can be wiped will result in wiping. The detection is based on the amount of motion detected within a certain timeframe on the surface that can be wiped.
8. Compressing — When placing an object on a designated area for compressing and holding it, it will result in compressing.
9. Tape sticking — To stick tape, the user holds the tape and then places it at a designated point where it can stick. Pressing the trigger button will attach the tape to the designated point.
10. Bandaging — This can be done by holding the object to be tied close to a designated point where tying is possible. Pressing the trigger button will record the starting point of the tying. If the object is moved to the

edge of the tying area, a suitable model will be created to hold the object. Releasing the trigger button will cancel the tying.

11. Pose detection — The user's hands and head are placed in the correct position based on previously recorded data. Then, the system recalculates the user's height and arm span using data obtained from the position and angle of the controller and the VR headset compared to the height and position of the user's center of gravity.
12. Patient positioning — The user can grab any part of an unconscious or semi-conscious patient to reposition them.
13. Heart pumping — When the user places their hand on the designated area for pumping and applies positive pressure, it will be considered a pump. The system detects the continuous rhythm and consistency of the applied force by finding the peak points of the applied force and the timing of the changes in direction of the applied force.

2.3.2 Event system

Figure 2 shows the event flow diagram. Every single event that happens in the scene is called an event. The event system controls what happens in the scene and what appears in a sequence, based on the event conditions which may vary depending on the user's actions (Matthew, 2018).

A scene may contain 20–100 events that can be broadly categorized into two types: actors and waiters. Actors perform their action and move on to the next event immediately, while waiters wait for a condition to be met before moving on to the next event.

In reality, there can be events that can perform both functions. The list of event types includes the following:

1. Dialogue event
This event orders the dialogue displayer to display pre-set dialogue in sequence. It can be set to wait for the dialogue to finish or move on to the next event immediately.
2. Activate event
This event activates or deactivates a game object or a set of objects in the scene and moves on to the next event immediately.
3. Animation event
This event orders the animator to play a pre-set animation and moves on to the next event immediately.

4. Turn event

This event rotates a game object or an object in the scene to a certain direction or angle using a pre-set time and moves on to the next event immediately.

5. Move event

This event moves a game object or an object in the scene to a certain position or direction and distance using a pre-set time and moves on to the next event immediately.

6. Walk event

This event orders a walkable object to move to a position or move in a direction at a specified speed, and to go to the next event immediately after the movement starts.

7. Jump event

This event jumps to another event, and the user can choose to jump relatively by specifying the number of events to jump from the current event or jump absolutely to the event with the specified number.

8. Wait event

This event waits, with there being two types of wait: delay wait and wait until. Delay wait will wait for a

specified amount of time and then play the next event, while wait until will wait until it receives an interrupt code that is specified beforehand, and then go to the next event.

9. Check event

This event waits until it receives an interrupt code, with receiving more than one interrupt code possible. Each interrupt code can be set to either skip to a specified event or call a specific method through a unity event.

10. Choice event

This event orders the dialogue displayer to show choices for the user to select and waits until the user makes a choice. Each choice can be set to either skip to a specified event or call a specific method through a unity event.

11. Custom event

This event calls a specific method through a unity event, allowing for more flexibility and customization in creating in-scene procedures.

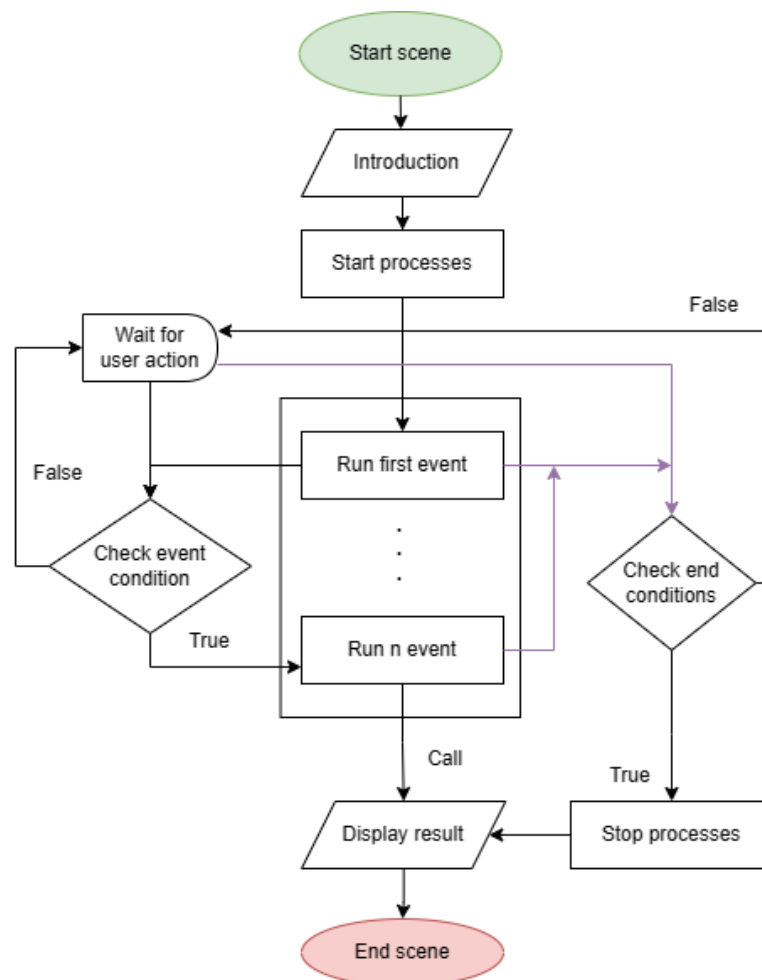


Figure 2. Scene event diagram

2.3.3 Patient and injury

A patient refers to a character created to represent a human in the scene. Within the scene, the patient can have a limited number of injuries at any given time. The

patient has initial variables that can be used to influence subsequent calculations, such as age, pain tolerance, and emotional resilience. The patients are given different appearances and names, and have important status

values including emotional state, physical condition, and mental state, which are affected by injuries and have consequences for medical outcomes.

An injury refers to the part of the body that has been affected and has consequences for the patient's status. Injuries can be treated, have scores and different variable values depending on the type of injury. Injuries can be divided into two types:

1. Body-part injuries

Specific injuries occur in common areas when randomized. For example, the hand or elbow can be shown in a graphic display in teaching mode. There are detection sensors used in medical care, such as touch or collision detection. When an interaction occurs, the detection sensor will send a value back to the injury. The injury will then show the graphic display and calculate the effects on the patient's status at that time. Some injuries may have animations that change the patient's appearance.

2. Whole-body injuries

Whole-body injuries do not have clear graphic displays, but instead have effects on animation and physics, such as seizures or being knocked over.

2.3.4 Teaching system

The main teaching components are divided into three parts: teaching control, teaching knowledge content, and teaching first aid techniques.

1. Teaching control

Teaching control is provided wherever the user may not know how to control a particular feature or when a new device is introduced. Animations are used to teach the basic controls of the device, including the buttons and the actions performed. Mini-games are provided for practicing basic interactions before using the features in other contexts.

2. Teaching knowledge content

In most scenes, a small robot nurse called "EggMan" will provide users with information and advice in a text and voice format to help them understand and feel relaxed during the learning process.

Detailed information about first aid, injuries, and medical care are displayed on a small UI window embedded in the learning screen. The information is organized into steps to prevent it from being too lengthy.

3. Teaching how to administer first aid

First aid techniques are taught using tasks or things that must be done. This includes the steps involved in first aid techniques, and users must read the detailed information on the UI window to learn what to do, what not to do, and the precautions to take. During first aid interactions, gauges are displayed to indicate the progress of the actions and how close they are to completion. The mental and health gauges of the injured patient are also displayed to show the severity of the injury and the outcome of the first aid actions taken by the user (Sun, 2022; Tanawat, 2021).

2.3.5 Examination system

Each scene of the examination system has different learning contents, so the format of the examination may differ. There are approximately 3–5 examinations per scene as follows:

1. Control examination

This examination tests the user's agility in controlling equipment or interacting with items related to the contents of first aid, such as grasping, bandaging, using gauze, and administering medicine. Typically, this examination will be the first examination carried out to help the user to prepare physically and to be mentally alert and agile. The examination has a few factors that are randomized, so each round of testing is not repeated. The method of measuring the results of this examination is the time taken to complete the task.

2. Injury knowledge examination

This examination is available in every scene of the examination system and is in the form of answering five questions with four answer choices per question provided. Users must press the button on the table to select the answer they think is correct. The questions test for knowledge related to injuries, such as the characteristics of injuries, causes, dangers, and first aid methods. The questions are randomly selected and the answer choices are randomly shuffled. The method of measuring the results of this examination is the score for correctness.

3. First aid examination

This examination requires the user to handle real-life first aid situations by providing all the necessary equipment (which may include unnecessary equipment) and treating a patient with an injury chosen randomly. The appearance of the patient is randomized, including age, pain tolerance, emotional resistance, and initial physical and mental conditions. The user must follow the steps to provide first aid to keep the patient in the best condition. The method of measuring the results of this examination is the physical and mental condition of the patient, the condition of the injury, and the score for correctness in providing first aid.

4. Image assessment examination

This examination is a special format only available in the basic first aid scene. It is in the form of answering questions with image prompts, asking whether the place in the image is safe or not. The user has two buttons to select from. The method of measuring the results of this examination is the score of correctness.

5. Assistance order examination

This examination is a special format only available in the basic first aid scene. It involves displaying 3D models of patients with four randomly chosen injuries. The user must observe the characteristics of all four patients and determine the order of assistance. The user must pick up the number laid out and place it in front of the patient to indicate the order of assistance. The method of measuring the results of this examination is the score of correctness (Polnok, 2005).

6. Memory examination

This examination is a special format only available in the emergency first aid scene. It involves showing items that are different from each other and the user must answer what each item is. There will be choices in the form of 3D models. The examination is designed to measure observation and memory skills. The method of measuring the results of this examination is the score of correctness.

7. Emergency call examination

This examination is a special format only available in the emergency first aid scene. It involves displaying a simulated emergency situation and allowing the user to dial the correct number with their mobile phone and report the emergency according to what they see in the image. The method of measuring the results of this examination is the score of correctness.

2.3.6 Performance evaluation system

The performance evaluation system consists of three main components, each with a weight percentage assigned based on the scene:

1. Time

The time component is based on how quickly the user completes the training or exam. The faster the time, the higher the score. However, the weighting for the time depends on the other performance components.

2. Objectives

Objectives are mandatory tasks that must be completed to pass a scene. In training scenes, objectives are achieved during the task, while in exam scenes, objectives are achieved by obtaining a score above the pass threshold. Failure to meet the objectives or to activate the end condition means the user does not pass.

3. Bonus

Bonuses are additional points awarded for exceptional performance. Penalties can also be applied to reflect poor user performance.

In each interaction, the checker sends the results to the scorekeeper, which evaluates the user's performance based on the scene's objectives and bonuses. In lesson scenes, the medical outcome is also a component of the score; however, passing depends on following the instructions.

2.3.7 Custom scenario system

The custom scenario system allows users to create and share custom simulation scenarios, as shown in Figure 3. The custom scenario is created through the website and saved to the database. It can be accessed through the application. The scenario creation process contains six steps:

1. Naming the scenario, providing a description, and setting the difficulty level.
2. Selecting a location, which is a pre-configured scene for the user to build on.
3. Defining patient characteristics by specifying up to three of the patient's symptoms (age, appearance, pain tolerance, emotional resistance, physical condition, psychological condition, location in the scene, and onset time of symptoms).
4. Selecting which medical equipment and assistance tools are available.
5. Defining the objectives, bonuses, end conditions, and badges for the scenario.
6. Adding instructions, welcome messages, and cover images.

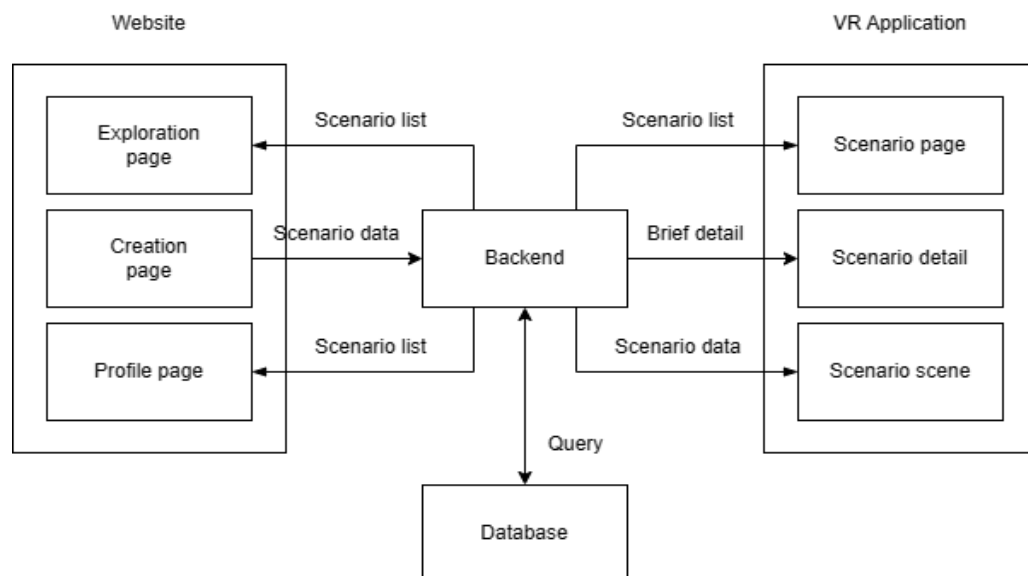


Figure 3. Custom scenario saving and loading diagram

2.3.8 Additional systems

1. Localization system

The localization system reads a CSV file with keys for different sentences and columns for different languages (either Thai or English). When called, the system reads the file and displays the appropriate language each time a scene is loaded or the language is changed.

2. Voiceover system

The system reads audio files from a resource folder, which can be specified by key and language code to work with the language switch system. It supports character voices in scenes as well as simulating user speech when selecting options in response to questions. Users can also choose their own voice profile.

3. Calibration system

Oculus or VR headsets in general have built-in sensors to detect the user's position. By measuring the height from the floor and adding the average height from the eyes to the top of the head, the system can calculate the user's true height. Measuring arm range can be done by having the user extend both arms and measuring the maximum distance reached during the measurement.

3. RESULTS AND DISCUSSION

3.1 Development result

The results are presented in the following aspects: interface, interaction, lesson scene, exam scene, and customization window. Additionally, to be able to

understand the feel of the 3D scene and interactions, a video (<https://www.youtube.com/watch?v=WfaAuAhhf3k>) shows a sample scene.

3.1.1 Main user interface

Most of the user interfaces are in form of a futuristic transparent screen in front of the user, with the user interacting with the screen using a laser pointer from the controller. The interface is simple, consisting of tutorial, lesson, scenario, profile, and setting pages, as shown in Figure 4 and Figure 5. The menu is described in Thai language.

3.1.2 Interactions

As described in Section 2.2.1, Figures 6–8 show the corresponding interactions for gripping, pouring, and pumping, respectively.

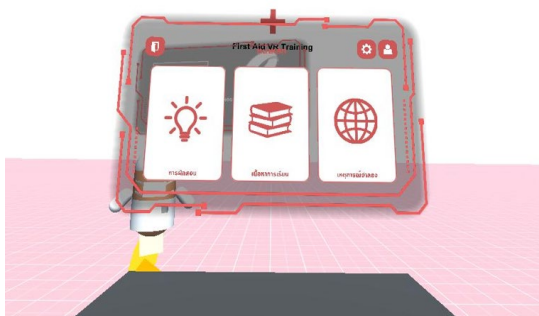


Figure 4. Example of main user interface



Figure 5. Example of content preview window



Figure 6. Example of gripping interaction



Figure 7. Example of pouring interaction

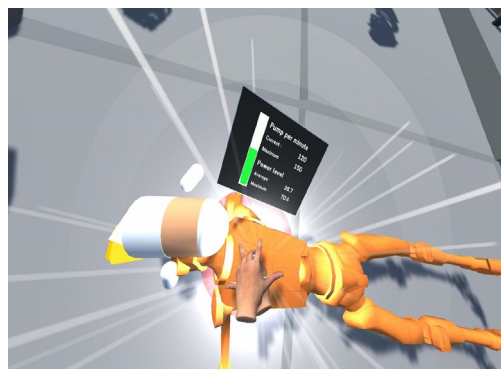


Figure 8. Example of heart pumping interaction

3.1.3 Lesson scenes

As described in Section 2.2.4, Figures 9–11 show the look and the feel of lesson scenes. Figure 9 shows a scenario that the user has to solve, with the necessary steps shown in Figure 10. Figure 11 shows the guidance graphics to let the user know what to do.

3.1.4 Exam scene

As described in Section 2.2.5, Figures 12–13 show the look and the feel of examination scenes. The pointed finger is used to push the button for answering multiple

questions, as in Figure 12. In Figure 13, the user needs to give proper first aid to the patient using the given tools, with the menu graphic on the right side of the screen showing the patient's emotion, happiness, and health status levels.

3.1.5 Custom scenario

As described in Section 2.2.8, Figure 14 shows the scenario customization window. In this example, a scenario involving 3 injured patients was created. They were all adults with normal conditions (in red selections).



Figure 9. Assessment exercise scene where user can walk around to observe patients



Figure 10. Helper tablet where user can read explanations and 'how to do' steps



Figure 11. Example of injured patient in burns and scalds lesson scene



Figure 12. Quiz example scene



Figure 13. First aid examination scene

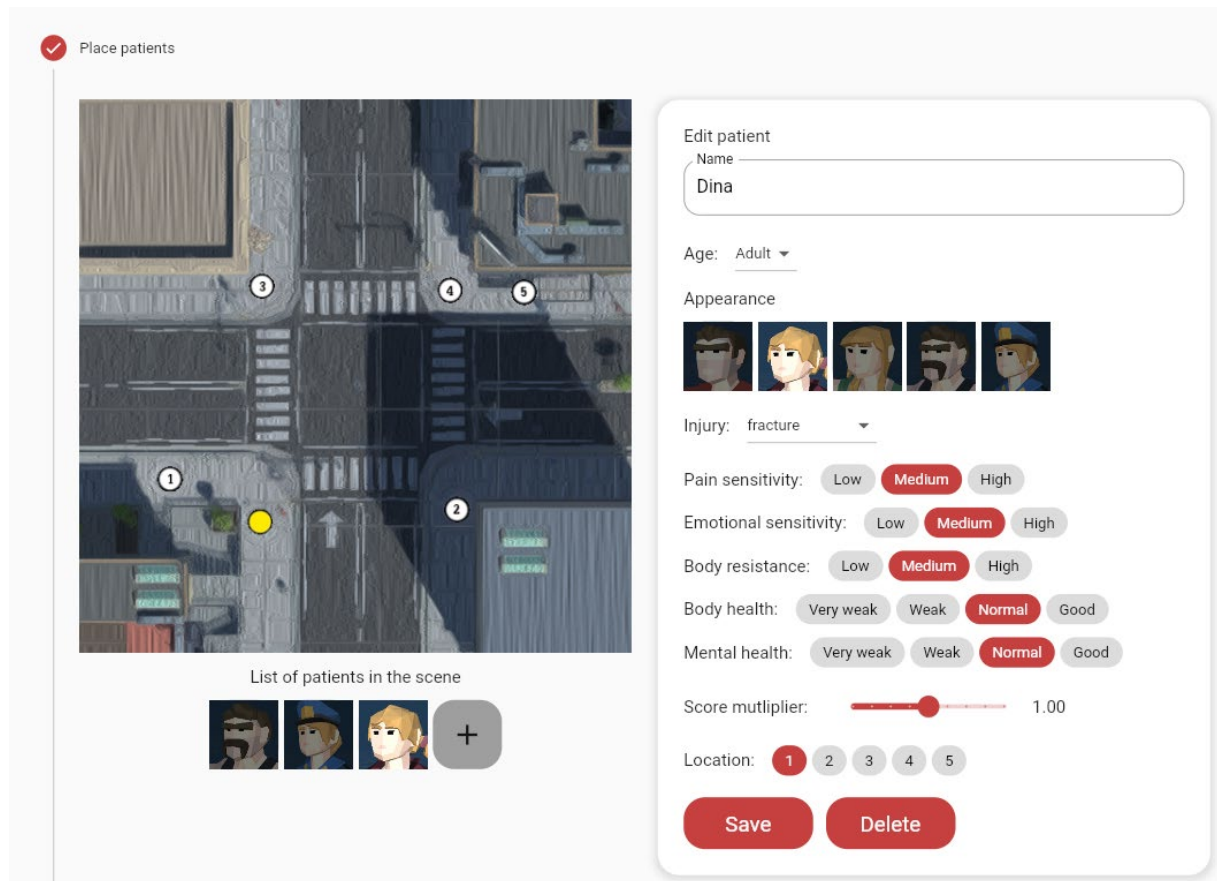


Figure 14. Example of scenario customization window

3.2 User testing results

Usability testing of the application was achieved with university students from various faculties who were interested in VR technology and basic first aid knowledge. Pre-test and post-test assessments were conducted with 12 questions before and after using the application. In total, 14 users participated in the testing, aged 18–23 years. Figure 15 shows the participants' prior knowledge sources before the training, while their levels of confidence in first aid knowledge are shown in Figure 16.

Pre-test and post-test assessments were conducted using 12 first aid questions before and after using the application. The testing covered using the control teaching scene, the main interface, 1–3 teaching scenes, and 1–3 examination scenes (depending on the time the user was willing to participate). All participants were required to make two attempts for at least one examination scene,

ensuring that they both retained and compared their recorded scores from both attempts. Following the training, participants were asked to provide feedback on how they felt to assess any change in their confidence levels. The results depicting the increase in confidence levels are presented in Figure 17. The comparison between the participants' pre-test and post-test scores is displayed in Figure 18. The average score on the pre-test was 7.07, while the average score on the post-test was 9.57. Using the efficiency formula, there was a 35.3% improvement in scores.

Figure 19 illustrates the results for the participants' examination scores on the second attempt compared to their scores on the first attempt. The average score for the first attempt among participants was 1,305, while on the second attempt, it had increased to an average of 1,596, reflecting an improvement of 22.3%.

On first aid training using virtual reality

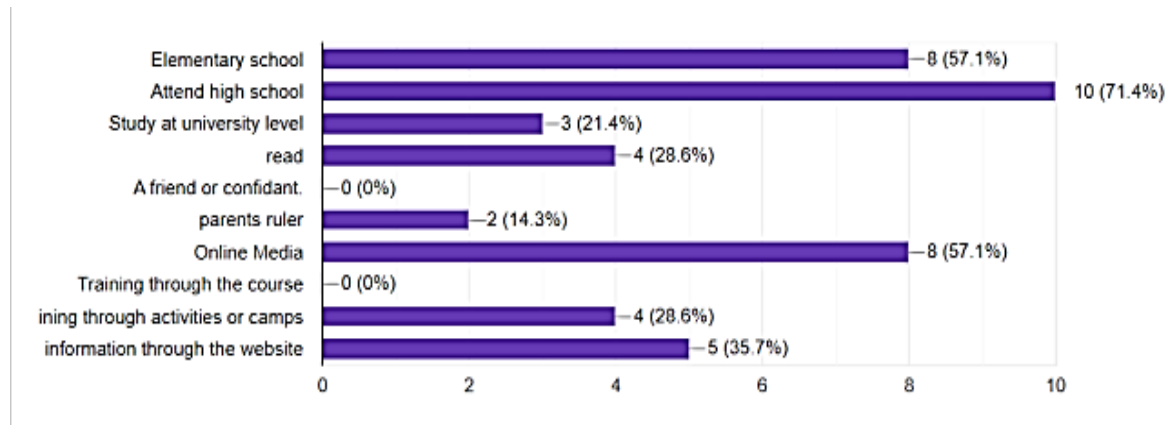


Figure 15. Participants' prior knowledge sources before training

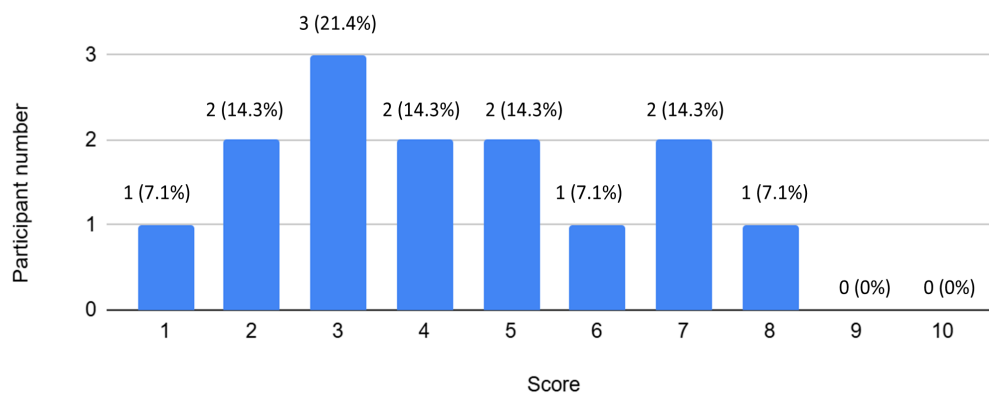


Figure 16. Level of participant confidence in first aid knowledge

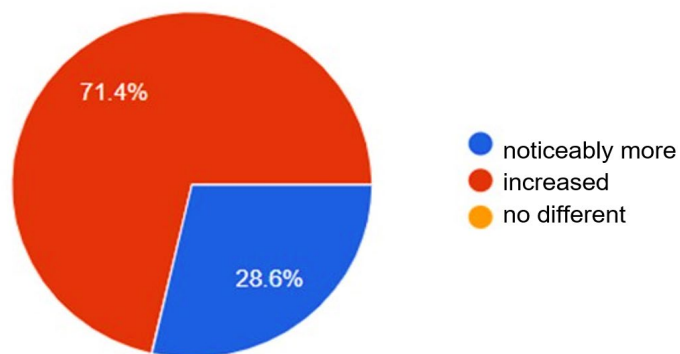


Figure 17. Level of confidence after training

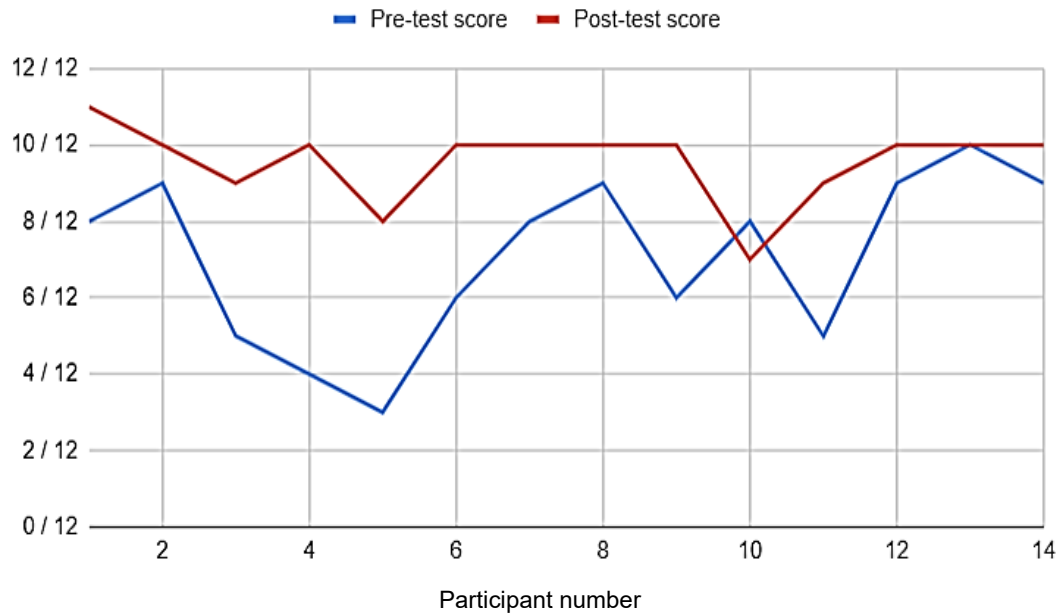


Figure 18. Pre-test and post-test score comparison of participants

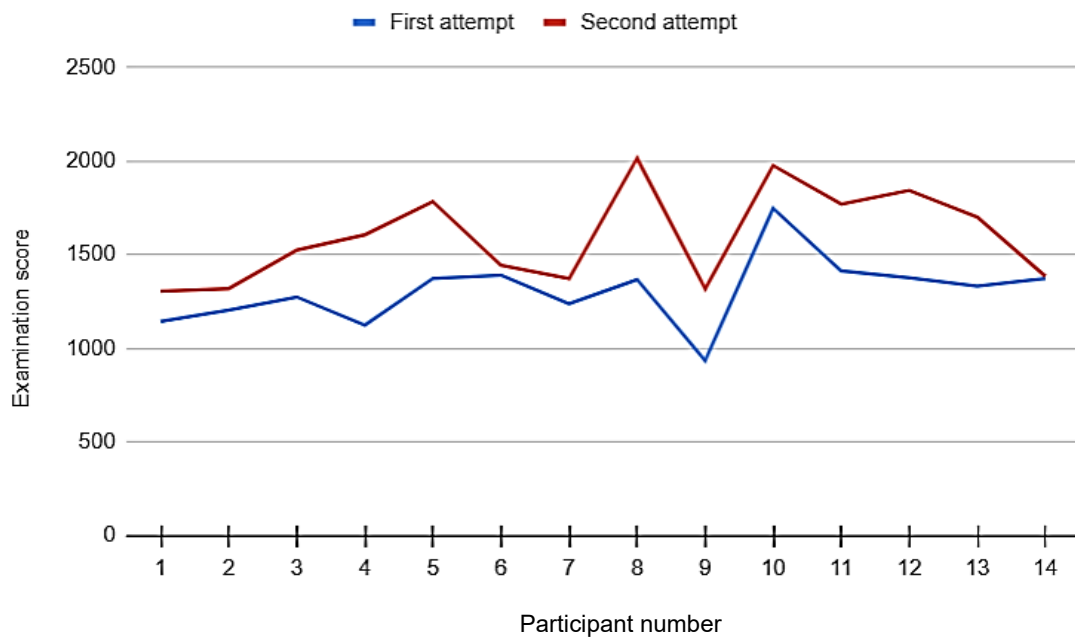


Figure 19. Participant scores of multiple examination attempts

The results of testing in terms of participant impression, overall system satisfaction, and lesson content satisfaction are shown in Figures 20–22, respectively. The average score for impression was

9.2, for overall system satisfaction was 8.9, and for lesson content satisfaction was 9.2, with the overall average for total satisfaction being a score of 9.1 out of 10.

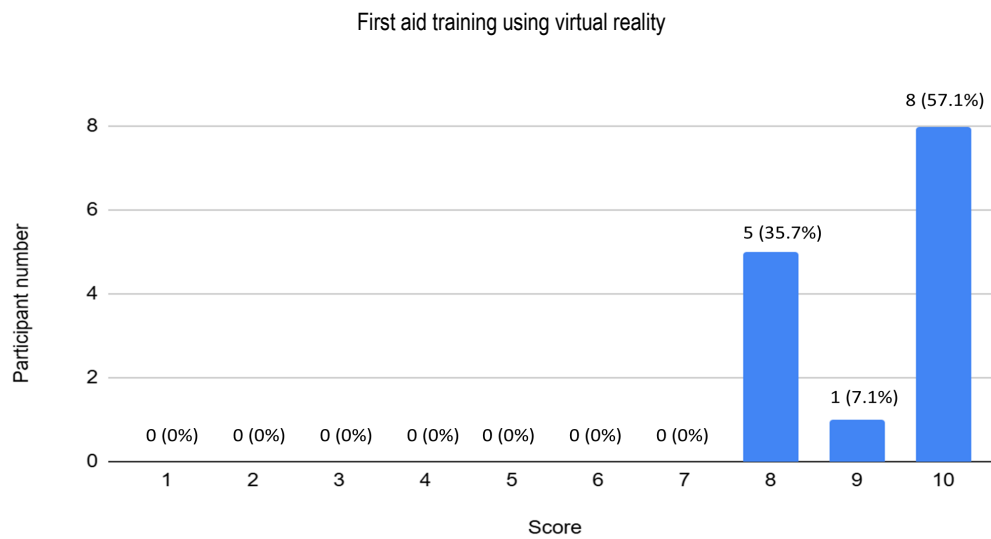


Figure 20. Participants' level of impression

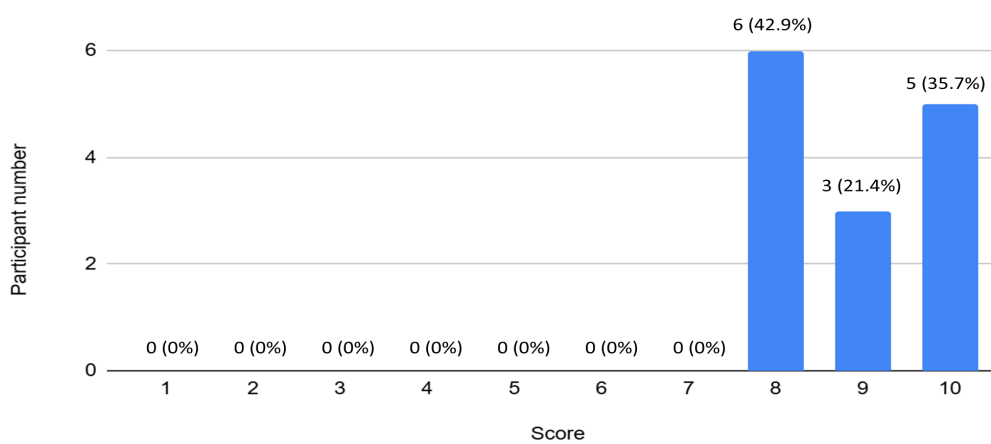


Figure 21. Level of overall satisfaction of participants

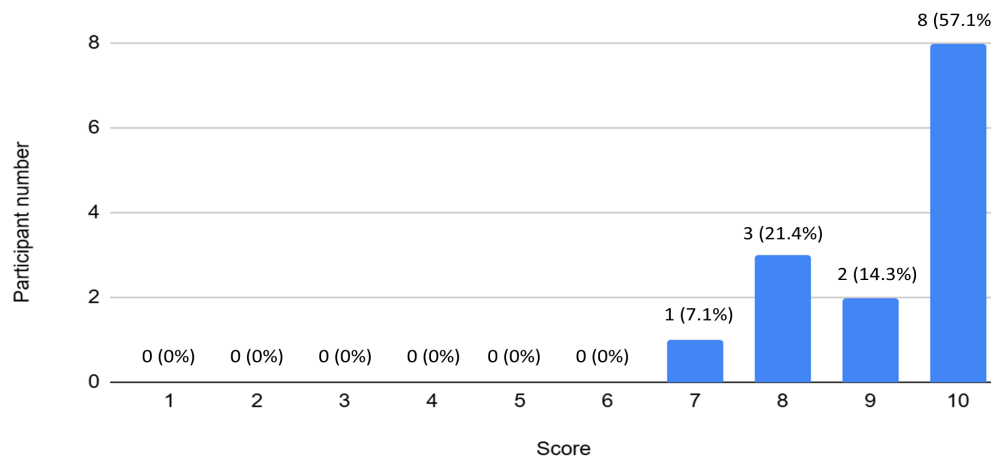


Figure 22. Participant level of satisfaction with teaching methods and knowledge content

4. CONCLUSION

This study presented a VR application for first aid content in everyday life situations which has the following features.

1. Teaching and examination scenes that demonstrate the symptoms, dangers, and correct first aid procedures for 12 common injuries (bruises, cuts, punctures, choking, fractures, burns, insect bites, animal bites, bee stings, snake bites, fainting, and seizures).

2. Physical-based interaction system involving button pressing, movement, object grabbing, faucet opening and closing, liquid pouring, squeezing/pressing, wiping, compressing/soaking, taping, positioning, and heart pumping.
3. A teaching aid system that includes mini-games for control training, dialogue options, realistic images, injury status display, graphical wound presentation, step-by-step instructions via mobile devices, and results display and score calculation.
4. A simulation system that allows users to create their own simulated scenarios or use those created by others, with the ability to select locations, starting positions, scene conditions, patient, and first aid equipment status.

When the game was tested with a group of users who had background knowledge of first aid training, the results showed that they were highly impressed and satisfied, with a total average score of 9.1 out of 10. There was an increase of 35% between the pre-and-post first aid knowledge test scores of participants. All test participants reported greater confidence in using the application after the test, and the practical test scores improved by an average of 22% after multiple tests, demonstrating that the realistic first aid training project could be effectively used for learning and practice purposes. Further study could test the application using a sample group that has no background first aid knowledge.

Future added features to the game could include broader content (covering more injuries), lesson creation, advance user performance analytics, and interaction improvement.

REFERENCES

- 4 Help VR. (2023). *Training program - First aid in virtual reality*. [Online URL: <https://4helpvr.com/en/home-en/>] accessed 1 October, 2023.
- Brouhard, R. (2023). *First aid instructions for 10 medical emergencies*. Verywellhealth. [Online URL: <https://www.verywellhealth.com/basic-first-aid-procedures-1298578>] accessed on October 1, 2023.
- Checa, D., and Bustillo, A. (2020). A review of immersive virtual reality serious games to enhance learning and training. *Multimedia Tools and Applications*, 79, 5501–5527.
- Clarke, E. (2021). Virtual reality simulation-the future of orthopaedic training? A systematic review and narrative analysis. *Advances in Simulation*, 6, 2.
- Donovan, D. (2018). *[10 Case studies] Virtual reality increases training effectiveness*. Interplay Learning. [Online URL: <https://www.interplaylearning.com/blog/virtual-reality-increases-training-effectiveness-10-case-studies/>] accessed on August 30, 2022.
- Ellis & Associates. (2023). *Standard first aid I*. Library of Congress Cataloging. [Online URL: https://jeffellismanagement.com/sites/default/files/pdfs/web/First_Aid_Ellis_SH.pdf] accessed on October 1, 2023.
- First Aid Training Bangkok. (2023). *First aid training in Bangkok and throughout Thailand*. [Online URL: <https://www.firstaidtrainingbangkok.com/>] accessed on October 1, 2023.
- Ioannou, A., Bhagat, K. K., and Johnson-Glenberg, M. C. (2021). Learning experience design: Embodiment, gesture, and interactivity in XR. *Educational Technology & Society*, 24(2), 73–76.
- JBHXR. (2023). *VR first aid training*. [Online URL: <https://www.jbhxr.io/vr-first-aid-training/>] accessed on October 1, 2023.
- Johnson-Glenberg, M. C. (2018). Immersive VR and education: Embodied design principles that include gesture and hand controls. *Hypothesis and Theory*, 5, 81.
- Lan, K. Y., Hsiao, I., and Shih, M.-F. (2018). Effective learning design of game-based 3D virtual language learning environments for special education students. *Educational Technology & Society*, 21(3), 213–227.
- Matthew, R. (2018). *Implementing event systems in games and using the preprocessor*. LinkedIn. [Online URL: <https://www.linkedin.com/pulse/students-take-implementing-event-systems-games-using-matthew-rosen/>] accessed on October 2, 2022.
- Mérienne, F. (2017). Virtual reality: Principles and applications. In *Encyclopedia of Computer Science and Technology*, pp. 1–11. Oxfordshire, UK: Taylor and Francis.
- Ministry of Health & Family Welfare Government of India. (2021). *Training Manual on Management of Common Emergencies, Burns and Trauma for ASHA at Ayushman Bharat-Health and Wellness Centres*. National Health Systems Resource Centre. [Online URL: https://nhsrcindia.org/sites/default/files/2022-05/Emergency%20Module%20for%20ASHA_Inside_23%20March%202022.pdf] accessed on October 1, 2023.
- Oyelere, S. S., Bouali, N., Kaliisa, R., Obaido, G., Yunusa, A. A., and Jimoh, E. R. (2020). Exploring the trends of educational virtual reality games: A systematic review of empirical studies. *Smart Learning Environments*, 7, 31.
- PIXO. (2023). *First aid*. PIXOVR. [Online URL: <https://pixovr.com/vr-training-content/first-aid/>] accessed on October 1, 2023.
- Polnok, S. (2005). *First aid and resuscitation operations*. Faculty of Nursing, Naresuan University. [Online URL: <http://www.nurse.nu.ac.th/web11/E-learning/FirstAid/cai/index.html>] accessed on August 5, 2022. [in Thai]
- Radianti, J., Majchrzak, T. A., Fromm, J., and Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, 147, 103778.
- St John WA. (2023, October 1). *A first look into the St John Skills VR game | First Aid Skills | St John WA* [Video]. YouTube. <https://youtu.be/DaDrWWbGbuA>
- Sun, S. (2022). *Basic First aid principles*. Promotions.co.th. [Online URL: <https://promotions.co.th/บทความ/basic-first-aid-principles.html>] accessed on August 5, 2022. [in Thai]
- Tanawat. (2021). *First aid to safe life*. DSA|SU. [Online URL: <https://dsa.su.ac.th/ksu/?p=11077>] accessed on August 5, 2022. [in Thai]
- WHO. (2016). *Post-crash response: Supporting those affected by road traffic crashes*. [Online URL: <https://www.who.int/publications/i/item/post-crash-response-supporting-those-affected-by-road-traffic-crashes>] accessed on May 27, 2023.

