

## Article

# Virtual Reality Research: Design Virtual Education System for Epidemic (COVID-19) Knowledge to Public

Yongkang Xing<sup>1</sup>, Zhanti Liang<sup>2</sup>, Conor Fahy<sup>3</sup>, Jethro Shell<sup>3,\*</sup>, Kexin Guan<sup>4</sup>, Yuxi Liu<sup>5</sup> and Qian Zhang<sup>2</sup>

<sup>1</sup> Center of Experimental Teaching, Guangdong University of Finance, Guangzhou 510521, China; 70-173@gduf.edu.cn

<sup>2</sup> Department of Art Design & Creative Industry, Nanfang College, Guangzhou 510970, China; liangzht174104@stu.nfu.edu.cn (Z.L.); zhangq@nfu.edu.cn (Q.Z.)

<sup>3</sup> Institute of Artificial Intelligence, De Montfort University, Leicester LE1 9BH, UK; conor.fahy@dmu.ac.uk

<sup>4</sup> Canway Technology Consult Co., Ltd., Guangzhou 510630, China; 18402445@life.hkbu.edu.hk

<sup>5</sup> School of Internet Finance and Information Engineering, Guangdong University of Finance, Guangzhou 510521, China; 20-060@gduf.edu.cn

\* Correspondence: jethros@dmu.ac.uk

**Abstract:** Advances in information and communication technologies have created a range of new products and services for the well-being of society. Virtual Reality (VR) technology has shown enormous potential in educational, commercial, and medical fields. The recent COVID-19 outbreak highlights a poor global performance in communicating epidemic knowledge to the public. Considering the potential of VR, the research starts from analyzing how to use VR technology to improve public education in COVID-19. The research uses Virtual Storytelling Technology (VST) to promote enthusiasm in user participation. A Plot-based VR education system is proposed in order to provide an immersive, explorative, educational experiences. The system includes three primary modules: the Tutorial Module, the Preparation Module, and the Investigation Module. To remove any potential confusion in the user, the research aims to avoid extremely complicated medical professional content and uses interactive, entertainment methods to improve user participation. In order to evaluate the performance efficiency of the system, we conducted performance evaluations and a user study with 80 participants. Compared with traditional education, the experimental results show that the VR education system can be used as an effective educational tool for epidemic (COVID-19) fundamental knowledge. The VR technology can assist government agencies and public organizations to increase public understanding of the spread of the epidemic (COVID-19).

**Keywords:** virtual reality; COVID-19; education; interactive design; storyline; user interface; Virtual Storytelling Technology (VST)



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## 1. Introduction

Virtual Reality (VR) technology is an innovative technology developed in the 20th century. The scale of VR consumers continues to increase. In 2018, CCS-Insight reported that the value of VR devices sold will increase from US\$1.5 billion in 2017 to US\$9.1 billion by 2021 [1,2]. The VR technologies provide innovative Information and Communication Technologies (ICTs) to improve the user experience in interacting with the environment [1,2]. It generates immersive customer experiences with the combination of virtual-physical touchpoints [2]. VR has three primary characteristics: 360-degree, real-time and interactive [3].

1. **360-degree:** Speicher concludes that a 360-degree experience is the key feature of VR [2,4]. 360-degree experiences do not merely reflect the number of degrees, it means that the VR device can provide an immersive virtual environment (VE) to users [2]. Furthermore, users will be largely immersed in the VE in visualization and motion [2].
2. **Real-time:** Each behavior of the 3D entities will run in real-time [4]. The users will feel in a 'realistic' environment in a pseudo-natural manner [2,3].

3. **Interactive:** The system will provide the functionalities for users to act on the behavior in VE such as movement and manipulating [2,3].

Due to the characteristics, VR technology opens a new horizon in the traditional game industry. It shows enormous potential in the educational, commercial, and medical fields [2]. VR can use its immersive characteristics to improve communication efficiency [3]. Moreover, VR technologies lead users to interact with the virtual environment (VE) to become active participants [4,5]. The interactive environment can train users' reflection ability. VR and its derivative technologies have the following application advantages in the application process in the educational field. At first, users can use VR equipment to self-learn these teaching resources anytime and anywhere [3,6]. Educators do not need to spend a long time explaining detailed knowledge by traditional education mode [7,8]. Secondly, VR technology can enable users to obtain a more realistic learning experience. In some courses, the teaching content displays in a 3D layout. Users wear VR devices to view this content from different perspectives in a virtualized environment [1,9]. The learning becomes immersive. Thirdly, VR and its derivative technologies can stimulate students' interest in learning. Using Augment Reality (AR) and VR technology, users' senses such as vision, touch, and hearing can be integrated to get a real situational experience and feel the immersive experience. The educational content becomes perceptible, interactive and even touchable. It effectively getting rid of the boring learning atmosphere in the past [8,9].

Considered the VR advantages in the educational field, Kirkley built up the VR education conceptual framework in 2005 and illustrated the possible views in the future VR industry [5]. She put forward two key elements in VR education: learning environments and training technologies [5]. Learning environments focus on how to build the VE [5]. Training technologies pay more attention to the interaction between virtual and reality [5]. Based on Kirkley's framework, Garrett developed the virtual training system in the mining industry in 2012 [6]. Besides, Santoso designed the AR application to assist students' spatial cognitive ability in 2012 [7]. Our research shows that more and more organizations use VR technology to improve their training and education system [2].

From 2020, the COVID-19 outbreak has brought severe adverse effects globally [10–12]. World Meter shows that it has spread to 223 countries and regions with 215,477,242 cases and 4,488,570 deaths till 27th August 2021 [13]. Many medical scientists start to analyze how the global society has poor performance in stopping the COVID-19 outbreak. In Ethiopia, Negera analyzed the Ethiopian population structure and extensive group investigation [10]. The result shows that the Ethiopians in the countryside do not have sufficient knowledge and oppose quarantine policy due to their poor economic circumstances [10]. At the same time, the urban population has independent knowledge level predictors. They support the government policy so that the urban performance is much better than the countryside [10]. Negera highly recommends that the government fill the knowledge gap and persuade people to follow the preventive measures [10]. The COVID-19 knowledge gap does not only appear in developing countries. Developed counties also have similar circumstances. Geldsetzer started an investigation to assess public knowledge and perceptions about COVID-19 in the United States (USA) and United Kingdom (UK) at 2020 [14]. The report shows that the public has a better education background than developing countries. They also generally know the primary mode of disease transmission and common symptoms [14]. However, many people still have many misconceptions about COVID-19. For instance, there are only 40% USA and 32% UK people believe that a face mask can protect you from getting infected with COVID-19 [14]. Geldsetzer believes that the government needs to correct public misconceptions and provide relevant knowledge to the public [14]. Considering the above data, it is evident that government agencies and public organizations should provide adequate COVID-19 knowledge and information to the public so that it could assist society in facing the outbreak. Therefore, how to improve emergency preparedness and response capabilities becomes a concern of the global public health community.

The traditional epidemic education to the public mainly relies on national science and health documents. For instance, the USA CDC standard healthy courses include reading (book/online re-sources/poster) and Poisoned Picnic [15]. It is significant that reading plays an important role in the courses. There is only one interactive session which is Poisoned Picnic. The session let the student join as an active participant to join the practice. However, the session cannot run without teachers and enough participants. Therefore, there are significant time and participants limitations for traditional education. It is challenging to attract the youth and countryside population. The youth requires interactive elements while the countryside population has location limitations. The medical education simulation software developed using VR technology is a new educational methodology [12]. The VR technology can provide more entertainment and interactive elements to attract them. The VR application does not have a location limitation. It can run anytime and anywhere.

In this paper, the research aims to design a VR education system that can apply to government agencies and education organizations with the aim of furthering public understanding of the Epidemic (COVID-19). The proposed tool is based on entertainment interaction while there is no time or location limitation (Figure 1). The characteristics are as follows:

- The VR education system uses the Virtual Storytelling Technology (VST) to build the system structure and provide users with active exploratory experiences.
- The system balances the entertainment and education elements. The research covers the fundamental Epidemic (COVID-19) knowledge from various medical articles. Meanwhile, entertainment interactions are integrated with the exploring process to enhance the user's immersive experience.
- The system uses Unreal 4 as the development platform. By writing blueprint scripts, it can efficiently design VR/desktop interactions by adopting various platforms criteria.



**Figure 1.** The VR education System: (a) 3D Environment; (b) Interaction with tools.

Our research has released some position outcomes. In the 4th International Conference on Control and Computer Vision (ICCCV 2021), the research presented how to design the 3D environment and UI to adapt to the VR education system [9]. Compared to the previous article, the research moves much further. The research has built up the system structure with VST and organized the user test experiment. In the following sections, the research discusses the research methodologies, system overview and experiments.

## 2. Related Work

Our educational system is related to interactive design and COVID-19 knowledge. In order to design the system to convey COVID-19 knowledge to the public, our research should design an educational system with an immersive experience and professional knowledge. Therefore, we briefly discuss how to design the user experience design and investigate the related medical knowledge in this section.

### 2.1. User Experience Design

User experience design is the process of creating products that provide meaningful and impressive experiences to users [16]. Hassenzahl points out that a good user experience product should be helpful, usable and fashionable [17,18]. In order to achieve the successful target, the interactive method in the system should be easy and effective [17]. Therefore, designing the system with more accessible and effective interaction becomes the key challenge to solve.

At first, the research focus on designing the overall exploring process in the system. Our target is providing the entertainment experiences and knowledgeable education. Danilicheva put forward to use VST to provide a VR educational process [16]. VST focuses on delivering the exploring process with interactive storytelling, narrative or drama [16]. It can enable the users to participate in the system's story. By exploring the VE with the narrative process, the user can easily influence and become active participants [16]. In order to enhance to storytelling, the system should include different characters such as player(user) and non-player characters [19]. Besides, the storytelling has two major driven modes which is plot-based and character-based storytelling [16]. Plot-based has a limitation that the user should follow the storyline. In contrast, character-based have more rights to explore in the open sandbox [16]. Our research will use the plot-based because our target is assisting the public to receive the COVID-19 knowledge in a short time. The users cannot spend hundreds of hours in the system as an open sandbox video game. Therefore, plot-based is our system's storytelling mode.

Secondly, the research should balance the entertainment and education in the system. The VR educational system has many similar points with video games, including graphics technology, developing process and interactive devices [16]. It is a big challenge to balance entertainment and education [20]. The system should have more educational elements than entertainment.

The research designs the overall storyline based on medical knowledge so that the overall experience will tend to education. The research plans to refer from the medical journals to design an interactive COVID-19 epidemic prevention storyline. In the storyline, the user will play as a medical staff to go through every medical step of solving COVID-19. However, some professional sections may be boring to the user. The research will optimize the process with some interesting interactive methodologies. Consequently, the user will like to explore, similar to playing a video game with less resistance. The user will understand the related COVID-19 knowledge and decrease misconceptions with government agencies and medical organizations.

### 2.2. COVID-19 Knowledge Storyline

In order to design the storyline with adequate COVID-19 knowledge, it is necessary to investigate medical articles about the COVID-19 epidemic prevention process. Controlling the COVID-19 outbreak has two major sections: treatment for patients and protection from infection [21]. The treatment process contains much professional medical knowledge that cannot educate the public quickly. Therefore, the research focus on protecting from infection. Infection protection includes isolation measures, aerosol generating procedures and environmental cleaning and laboratory biosafety [22]. The research designs the storyline to cover the above aspects.

Figure 2 displays the system's storyline. The research designs the user to play as the medical staff. The user will go through the COVID-19 infection protection procedure. The figure illustrates the several steps include new case response, personal preparation, onsite investigation and case submission. New case response section assists the user in knowing about the COVID-19 case information. The personal preparation section contains equipment preparation and individual protection. Both procedures can help the user to understand the isolation for preventing transmission of COVID-19. For instance, the user can learn how important to wear eye and face protection in COVID-19 outbreak. Onsite investigation section allows the user to investigate and test the close contact, environment

cleaning and environmental sample collection. The final section is the animation to show how the case submit to the Centers for Disease Control and Prevention (CDC). The overall storyline covers the knowledge of the infection protection field. The plot-based storyline can let the user explore medical knowledge with interactive experiences. In the following section, the article displays the system details.

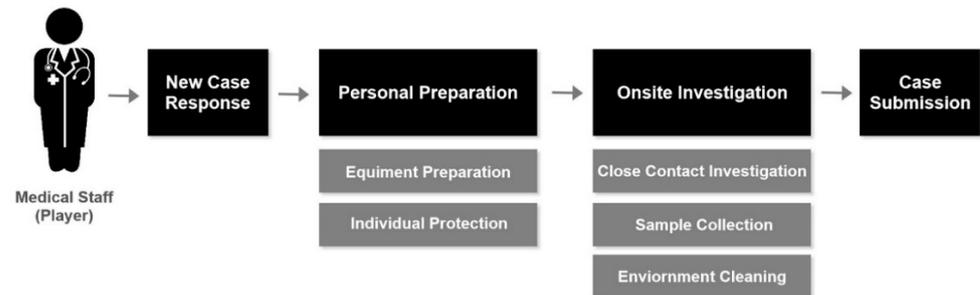


Figure 2. COVID-19 Education System Storyline.

### 3. System Overview

By analyzing the public needs and the main framework of the VTS, the logical architecture of the proposed system is shown in Figure 3. The structure refers from the storyline design. Firstly, there are five major sections: menu, tutorial, personal preparation, onsite investigation and case submission. Secondly, different sections are using different scenes. Menu and case submission section are in the traditional 2D panel. Tutorial, personal preparation and onsite investigation is in VE. Thirdly, there are two major scenes: medical center and case environment. The scene simulates a standard medical center with a meeting room, equipment room, front desk and ambulance section.

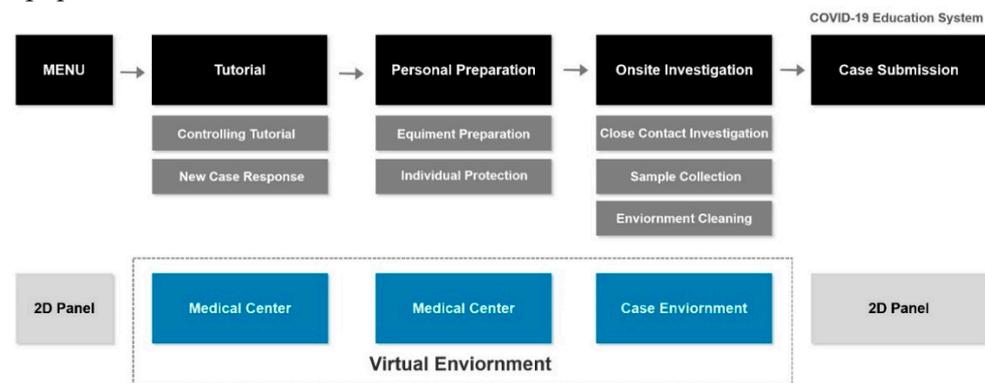


Figure 3. COVID-19 Education System Structure.

The system is a VR application system based on desktops, which provide COVID-19 knowledge to users in exploring the VE. Thus, it can provide users with an immersive experience by combining VR interactive technology. Unreal 4 has strong compatibility in supporting various VR and desktop video games. Therefore, the VR educational system uses Unreal 4 Engine to develop. The sub-sections cover the system details include the interactive mode and function modules.

#### 3.1. Interactive Mode

The interactive mode of this system can be divided into the operation mode and user interface.

##### 3.1.1. Operation Mode

The system’s primary interactive methodology is based on VR technologies. Across the world, although XR devices receive high sales, it still occupies a low percentage compared to desktop and mobile phones [1,9,23]. Stream reports that XR devices only achieve 2.13%

in Stream 2021 global users [9,23]. If the system only supports the VR platform, it cannot complete the primary target of popularizing virtual simulation education. Therefore, the system also provides the traditional keyboard/mouse operation mode to extend the user range. Table 1 shows the operation input instructions of the computer and VR. The system uses Oculus Touch as the sample VR controlling instruction. The desktop controlling mode can achieve the same interactive result as VR controllers by keyboard/mouse.

**Table 1.** Operation Guideline [9].

Desktop Control Mode	VR Control Mode (Oculus Touch)	Interactive Result
Mouse X, Y, Z axis	User Head Movement	Camera Direction Movement
Mouse Right Click	Right Hand Controller First Trigger	Right Hand Grasp
Mouse Left Click	Left Hand Controller First Trigger	Right Left Grasp
Keyboard W/A/S/D button	Controller Movement	User Movement
Keyboard Left Shift button & Mouse Movement	Left Hand Controller Thumb stick	Left Hand Movement
Keyboard Left Alt button & Mouse Movement	Right Hand Controller Thumb stick	Right Hand Movement
Keyboard ESC button	Reserved Button	Pause System
Keyboard F button	Button.One	Turn on Selected Medical Tool
Keyboard Q button	Button.Two	Wear Protection Grass
Keyboard Tab button	Button.Three	Check Medical back package

The system provides various interaction methodologies. Figure 4 illustrates the primary interactive samples. Figure 4a displays how to interact with the medical package [9]. At first, the system allows the user to pick up the medical tools by VR controller first trigger. The users can press the controller Button One to turn on the selected tool [9]. Figure 4b shows how to use a thermometer to measure the close contact's temperature. When the right hand controlling aims the thermometer to the head of the close contact and clicks the right-hand trigger button, the user can successfully measure the body temperature and start the storyline conversation to the contact.



(a)



(b)

**Figure 4.** Interactive Methodologies: (a) How to interactive will medical package [9]; (b) How to use medical tool in on-site investigation [9].

### 3.1.2. User Interface

User Interface (UI) is the medium between the user control and the system [1]. The UI experience is a standard that reflects a good user experience [24]. Considered the characteristic of VR device input, it is necessary to provide a significant and straightforward UI to guide the user in exploring the system [1]. The UI section covers three primary aspects: menu page, head-up display, environmental indication.

Figure 5 displays the menu page UI. Figure 5a illustrates the loading page and Figure 5b is the paused menu page. The research develops the shape, size and color

of the UI controls with the flat design. The UI style is clear and easy to guide the user to move to the exploring process.



**Figure 5.** Menu UI: (a) Loading Page [9]; (b) Paused Menu Page.

Figure 6 displays the gaming UI. Figure 6a shows the user measures the close contact's temperature by wearing the complete protective equipment. The mask and eye protection icon display on the right bottom side. When the user takes off the equipment, the icons will disappear and warn the user. Figure 6b displays the tool icon. When the user takes the medical package, the medical tool icons appear on the left side to let the user check the tool list and select the correct tool to use or wear. The icons list with a slight angle rotation to generate the depth perspective. Besides the UI icon indication, the system uses the 3D object in the scene to indicate the user to move the target position (Figure 6b). Both 2D and 3D UI can assist the user to avoid lost in the VE and guide them to complete the tasks.



**Figure 6.** Gaming UI: (a) HUD UI with using medical tool [9]; (b) HUD UI with carrying medical package and 3D indication [9].

### 3.2. Function Modules

This section focuses on the main modules of the system which scene is in the VE. The main modules are the essential section to use VR technology to convey the COVID-19 knowledge to the user. The main modules of this system can be divided into the Tutorial Module, Preparation Module and Investigation Module. The details of the main modules are shown in Figure 7.

The Tutorial Module aims to assist the user to understand the basic interaction and use the storyline to attract the user as an active participant. The Preparation Module educates the user in individual protection and related medical protection knowledge. The Investigate Module explores the investigation process. The user can learn how the medical staff deal with the diseases. It is beneficial for the user to cooperate with medical staff in daily life. Furthermore, the module educates environmental cleaning knowledge.

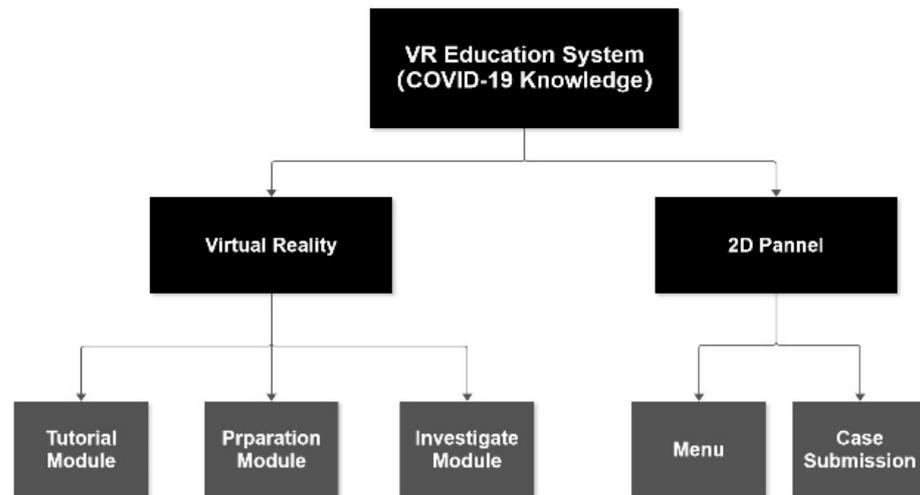


Figure 7. System Function Modules.

### 3.2.1. Tutorial Module

In order to assist the user in understanding the movement and interaction in the system, it is necessary to build the tutorial module as the first VR module in the system. The module has three sections: Controlling Tutorial, Pick up Phone Call and New Case Response. The controlling tutorial is at the front desk in the medical center. Furthermore, the research uses the plot-based methodology to guide the user to move to the next section. Notifying to pick up the front desk phone call, it moves to the new case response section. It provides the story background to help the user enter into the storyline as an active participant. Figure 8 displays the exploring flow of the tutorial module.

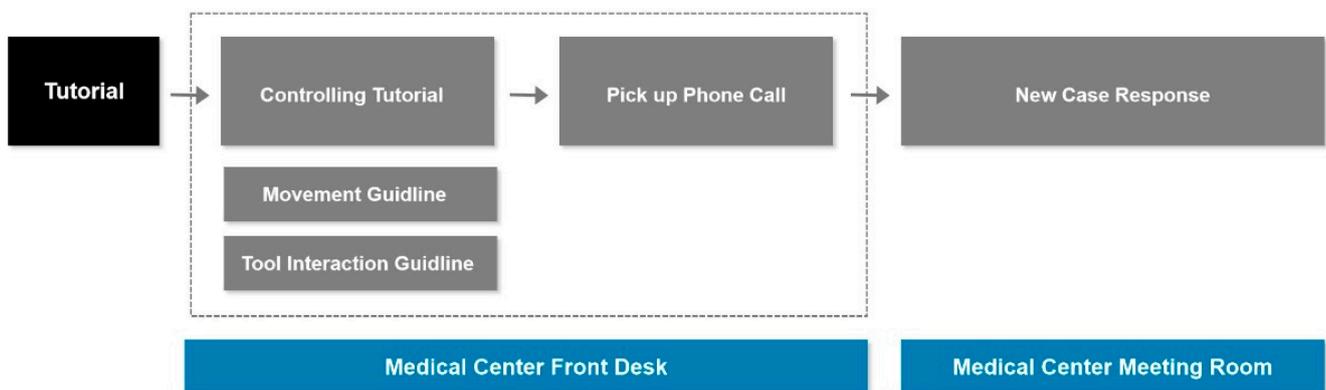


Figure 8. Tutorial Module Exploring Flow.

Figure 9a shows the rendering image of the movement tutorial. The system will display the text notification to guide the user. When the user completes the current movement and the interaction instruction, it will move to the next interaction notification till the tutorial completed. The front desk phone will ring after the user finish the controlling tutorial (Figure 9b). The phone section leads the user to trigger the plot. The trigger point can enhance the user participant and the storyline can smoothly move. Figure 9c displays the new case response section in the meeting room. This section is an animation to introduce the new case information. After playing the animation, the user moves to the preparation module.

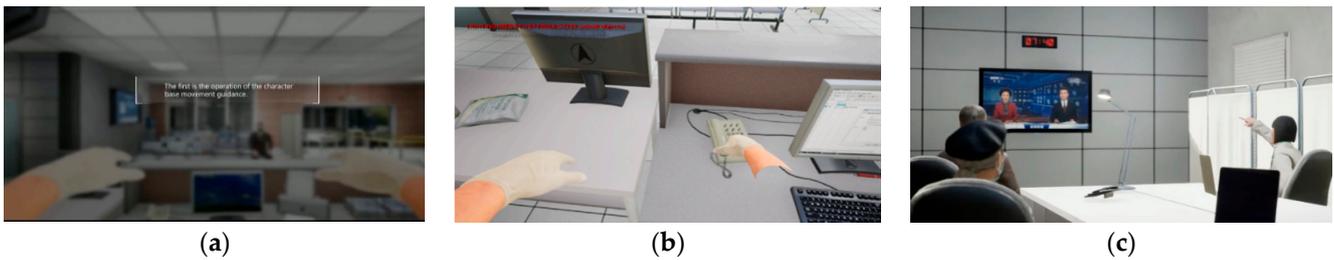


Figure 9. Tutorial Module Implementation: (a) Movement Tutorial [9]; (b) Tool Interaction Tutorial [9]; (c) New Case Response [9].

### 3.2.2. Preparation Module

The preparation module is the second VR module in the system. The module aims to educate the user about medical equipment and individual protection knowledge. Figure 10 displays the exploring flow of the preparation module. After the tutorial module, the user needs to move to the equipment room. At first, the user collects the equipment in the room. Secondly, the user wears personal protection includes goggles, mask, face shield, gloves and gown. The system provides the 3D UI panel as Figure 11b. The user cannot leave the room without completing the wearing section. After the wearing section, the user receives the notification and moves to the back door. The departure animation transfers the user to the investigation module.

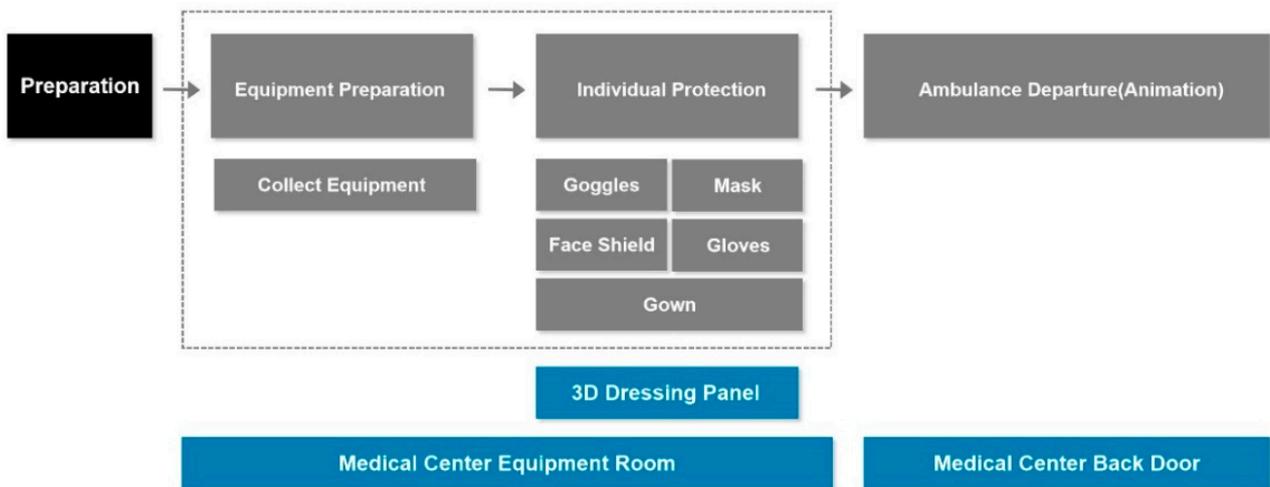


Figure 10. Preparation Module Exploring Flow.

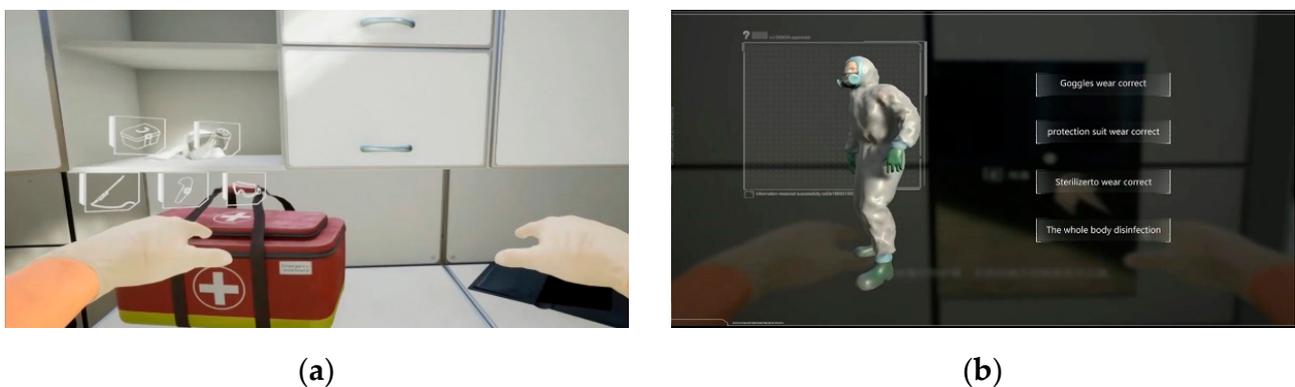


Figure 11. Preparation Module Implementation: (a) Equipment Preparation [9]; (b) Individual Protection Dressing 3D UI Panel [9].

Compared to the tutorial module, the preparation module has more interactive elements. Figure 11a shows how to collect the related materials in the equipment room. The research

uses the highlight color to simplify the collecting process. When the user enters the equipment room, the system indicates the user to interact with the medical package. The system notifies the user to collect the suitable material from the warehouse to the medical package. The system highlights the tools to help the user to find. Besides, the 3D wearing section refers to the game character dressing. After completing the collection, the system indicates to start the individual protection section. Figure 11a shows the 3D wearing panel. The user needs to move the equipment to the correct corresponding position. After the section completed, the equipment room door opens and the user can move to the back door to trigger the storyline. Both two sections use interactive game methods to improve the user experience.

### 3.2.3. Investigation Module

The investigation module is the third VR module in the system. The module aims to educate the user about close contact and environment cleaning knowledge. Figure 12 displays the exploring flow of the investigation module. The user moves to the close contact room after the ambulance departure animation. The contact is in the bedroom. The first step is communicating with contact and measuring his temperature. After the investigation, the contact leaves the room and moves to the health facility. The user continues the investigation in the room. The system indicates the user collects the sample in the bedroom and bathroom. After the collection, the user starts the environment cleaning. The user can use the disinfection spray to clean the room under the instruction. When the investigation completed, the animation drives the user to the case submission module.

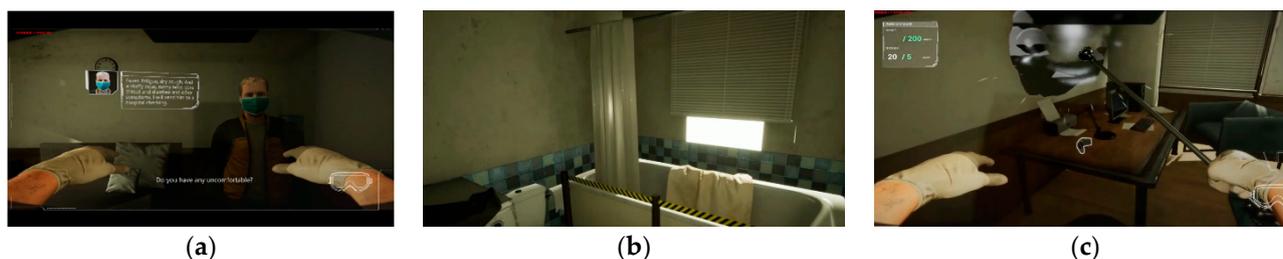


**Figure 12.** Investigation Module Exploring Flow.

The module has three major interactive sections, which are contact investigation, sample collection and environment cleaning. The research refers to VTS and designs simple and attractive interactive methods to improve the user experience in the sections. The module reduces many unnecessary procedure contents and reserves the core and fundamental knowledge to the user.

Figure 13a the communication with close contact. The user can select different questions to ask the contact. The game branch dialogue can enhance the participant for the user. Measure temperature is a small interactive game. The user needs to use the thermometer to aim at the contact's forehead (Figure 4b). The thermometer cannot display the correct temperature if the user cannot aim at the correct target. The section educates the user on how to use the thermometer correctly.

After the contact leaves the room, the user starts collecting the environment sample in the bathroom and bedroom (Figure 13b). The system highlights the vital furniture. When the user closes the furniture and uses the tool to collect the sample, the system displays the correct collection notification. The cleaning section is the next step. The system notifies the user to gear the disinfection spray and clean the environment. The research designs the unclean part as the black sphere in Figure 13c. The user should spray disinfections to the target for a while till the sphere disappear. The section uses the "capture and destroys" as the general game flow. It can attract the user to finish the cleaning target. The section assists the user in knowing how to use the disinfection spray and cleaning the environment.



**Figure 13.** Investigation Module Implementation: (a) Close Contact Investigation [9]; (b) Sample Collection in bathroom [9]; (c) Environment Cleaning [9].

#### 4. Evaluation

The evaluation runs a contrast experiment. The experiment aims to testify the VR education system can have better performance efficiency than traditional education such as books or newspapers. 80 students in Nanfang College of Guangzhou and Guangdong University of Finance were chosen for the system evaluation. The users participate in a task with limited time and receive an online questionnaire utilized for data collection. The experiment has three primary analysis points:

- Measure the effectiveness of educating COVID-19 knowledge (all media).
- Compare the effectiveness of digital and traditional education.
- Compare the effectiveness of VR devices and desktops.

##### 4.1. Participant

The research randomly chooses 80 participants from the Nanfang College of Guangzhou and Guangdong University of Finance in the evaluation section. All participants are bachelor students. Forty students are studying Computer Science (same class) in Guangdong University Finance. Other students are studying the Digital Technology (same class) at Nanfang College of Guangzhou. Each student has the same educational background. Participants are divided equally into four groups named Group A/B/C/D, as shown in Table 2. Each group contains 20 students. The experiment uses different media to explore the COVID-19 content as the contrasted condition in each group.

**Table 2.** Demographics of the Participants.

	Group A	Group B	Group C	Group D
Participant	20	20	20	20
Media (Condition)	HTC Vive	Desktop	Brochure	NO
Background	Bachelor Student	Bachelor Student	Bachelor Student	Bachelor Student

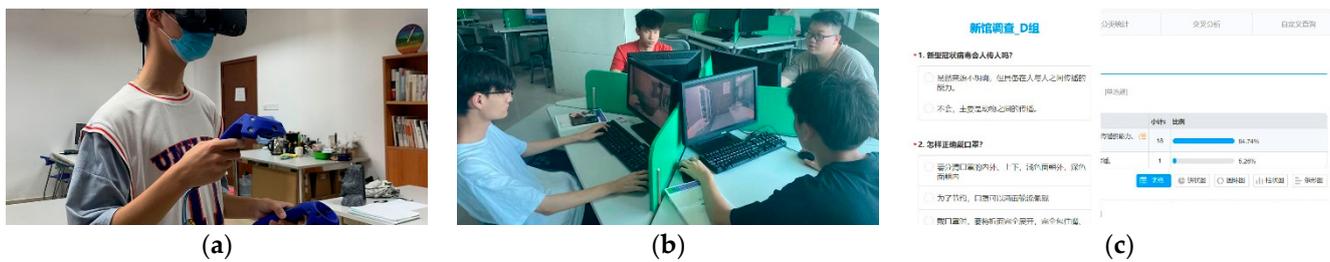
Group A/B/C are the experimental group. Group D is the control group without any media. Group A/B use the education system but they use different media (condition). Group A uses VR devices (HTV Vive) and Group B uses the desktop. Group C is the traditional education group. They watch the education brochure which has the same medical knowledge as the VR system. After the exploring process, Group A/B/C receives a short online questionnaire related to COVID-19 knowledge. Group D runs the questionnaire process without experiment.

##### 4.2. Tasks

The experiment's focus is mainly on the participants' performance on two tasks: interactive experiment and questionnaire. Both tasks' content use simplified Chinese due to users' regional. Group A/B/C participate in both task while Group D only take part in questionnaire session.

### 4.2.1. Interactive Experiment

Group A/B/C participants take part in the interactive experiment. Figure 14a shows that the participants use HTC Vive to interact with the system. Group B participants use the desktop to explore the system (Figure 14b). Group A/B has 20 min time limitation to play. Group C has the same time in reading the brochure. The brochure contains the same knowledge with images and texts as the VR system. The study collects the participants' failure data and marks the failure reasons.



**Figure 14.** User Experiment: (a) Group A User Test; (b) Group B User Test; (c) Online Questionnaires (WJX.cn Platform, accessed on 22 September 2021).

### 4.2.2. Questionnaire

Group A/B/C/D participants need to complete the open-end questionnaire online in five minutes (Figure 14c). The online questionnaire section includes four single choices, four multiple choices and three judgment questions in the questionnaire. The questionnaire covers the COVID-19 knowledge in the system. Preparation and Investigation module has more medical content, so they have higher ratio in the questionnaire than the Tutorial module (Table 3). The public does not need to master professional medical knowledge. Therefore, the questionnaire avoids exact numbers and asks the abstract knowledge in medical flows and procedures. For instance, a question is selecting the correct disinfectant in environmental cleaning COVID-19.

**Table 3.** Questionnaire Content Distribution.

	Single Choices	Multiple Choices	Judgment Question
Tutorial Module	1	1	1
Preparation Module	2	1	1
Investigation Module	1	2	1

Each single choice or judgment question has 1 point. The multiple choices are 2 points. If the user selects the correct selection but less than the right number in the multiple choices, he can get 1 point. The total score is 15 points. After the students completed the questionnaire, the correct rate of user experience is calculated. For example, fourteen people get 10 points, and six people get 9 points. Considering that the max score is 15 and that there were 20 people in total, the average correct rate is computed as  $(14 \times 10 + 6 \times 9) / (20 \times 15) \approx 65.33\%$ .

### 4.3. Result and Analysis

The research collects the user score in four groups from questionnaire data. Figure 15 displays the user score distribution in each group. The research runs the one-way MANOVA (Multivariate Analysis of Variance) in Excel software to analyze the difference between each group's score (Table 4). The *p*-values data is shown as follows:

- The *p*-values of the user score for Group A and D is 0.0068. The *p*-values for Group B and D is 0.0014. The *p*-values for Group C and D is 0.0148. The data indicates that the difference in the user score between the experimental groups and the control group is significant.
- The *p*-values of the user score for Group A and B is 0.865. The data indicates that the difference in the user score between Group A and Group B is insignificant.

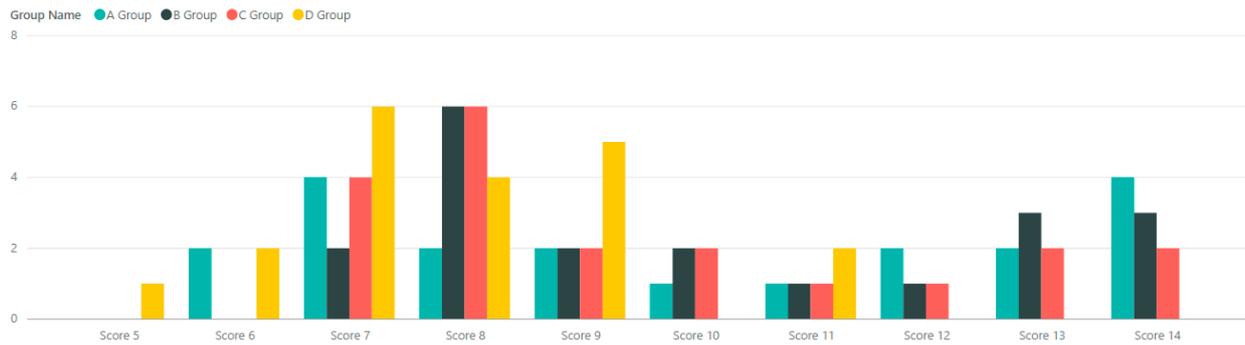


Figure 15. User Score Distribution.

Table 4. One-way MANOVA Analysis Between Different Groups in Excel Software.

Compared Group			Group A and Group D		
SS	df	MS	F	p-value	F crit
46.225	1	46.225	8.17	0.0068	4.0981
Compared Group			Group B and Group D		
SS	df	MS	F	p-value	F crit
52.9	1	52.9	11.75	0.0014	4.0981
Compared Group			Group C and Group D		
SS	df	MS	F	p-value	F crit
27.225	1	27.225	6.51	0.0148	4.0981
Compared Group			Group A and Group B		
SS	df	MS	F	p-value	F crit
0.225	1	0.225	0.029	0.865	4.0981

The data shows that the experimental groups have significant differences to the control group. Group A has a low difference from Group B. To study the data more deeply, the research calculates the average correct rate. Considering the failure possibility of completing the exploration, the study also collects Group A and B’s completed rate and failure reason. Furthermore, the research calculates the average completed rate within the completed units as showed in Table 5. For the VR education system, five trends are obtained as follows:

- It is encouraging that Group A/B/C has better performance in average correct rate than Group D (Control Group). Both digital and traditional media can improve the knowledge level efficiently.
- Group A/B (Digital Media) has higher number than Group C (Traditional Media). Interactive technologies can enhance the education experience and result in increasing the correct rate.
- Group A uses VR devices with interactive hardware characteristic, but its correct rate is 1% less than Group B (Desktop).
- Compared to Group A with four failure samples, Group B has a high completion rate that only one user can not complete the exploration.
- Group A has the best performance if the study filters the failure sample from data. The correct rate is 73.75%, which is higher than the Group B number (69.12%) within the completed sample.

**Table 5.** Experiment Data.

	Group A	Group B	Group C	Group D
Average Correct Rate (%)	67%	68%	63.66%	52.98%
Completed Rate	80%	95%	100%	/
Average Correct Rate (Completed Units)	73.75%	69.12%	/	/

In order to analyze the performance in Group A/B, the study collected the failure reasons (Table 6). The Group B user fails to complete the exploration on time. Two Group A users have the same reason. Both three users stop at Investigation and cannot complete it before the deadline. Another two Group A users reflect that the system is hard to control with VR devices and stop at Preparation Module.

**Table 6.** Failure User Data Collection.

Failure User	User Group	Fail Reason	Ending Module
Users 1	Group B	Not enough Time	Investigation Module
Users 2	Group A	Not enough Time	Investigation Module
Users 3	Group A	Not enough Time	Investigation Module
Users 4	Group A	Hard to control	Preparation Module
Users 5	Group A	Hard to control	Preparation Module

Considered the above data, the education system can significantly improve the performance efficiency especially the completed user in Group A. It can conclude that the immersive user experience can bring positive effects in education. However, there are some existing issues. The education system receives a low completion rate in the VR device platform. The system should consider the difference between desktops and VR devices. The users may spend more time in exploring than desktops. Future research should optimize the VR flow. Furthermore, the controlling difficulty is another challenge for the users not familiar with VR games. Therefore, the system should provide more tutorial elements to decrease the difficulty. The study will consider the above data carefully and put forward the optimizing solution. The system will continue to be optimized and contribute to the VR education field.

## 5. Conclusions and Future Work

In order to provide adequate COVID-19 knowledge and information to the public, the research develops the VR system related to COVID-19 knowledge education. The system uses the VST method to design the exploring flow. Users can enjoy the educated process with the plot-based storyline. The system supports both desktop and VR devices to extended as much as possible user market. There are three primary modules: Tutorial Module, Preparation Module and Investigation Module. Both modules follow the plot-based design to provide a smooth transition and immersive interactive experiences. The research runs a comparative user test with 80 participants. The result shows that the system is more attractive and efficient than the traditional education media. Based on these evaluations, we believe that the proposed system can assist the public to improve their COVID-19 knowledge and provide the VR education sample to society. The proposed system can contribute to VR in the fields of education. In short, the research supports that the VR education system can be efficient in education. The VST can enhance the user participant enthusiasm.

Our research contains the VR educational field and considered using VR technology to improve the future interactive design. Future work will continue to discuss more VST and its approaches combined with industrial criteria. We will use various statistical analysis methodologies such as mixed-ANOVA to measure the user experience after using the system with pre-test and post-test.

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