Virtual Reality Training for Fire Safety Education Integrated with the Oculus Rift

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ABSTRACT

A 3D user interface that allows users to conduct activities and feel the results is known as Virtual Reality (VR). Instead of being a linear animation with predetermined camera movement, VR can be thought of as a multidimensional real-time simulation. VR users can walk around freely in a virtual area, which is impossible with pre-rendered visuals of a 3D scene. VR training for fire safety education has been designed to help people learn certain information and prepare themselves for a fire accident. This app has gained crucial exposure to fire safety and fire exercises. Every department should provide fire training to everyone. However, fire drills usually take a lot of expense and time. Eventually, fire drills were implemented in an abbreviated period in which most people only watched the demos from the firefighters and usually, it was held once a year. During fire training sessions, not everyone can physically use the fire extinguishers, resulting in the objectives of briefings by firefighters not being achieved, and most people still lack awareness of using fire extinguishers. Thus, the virtual reality fire drill application with Oculus Rift integration can provide safety education in a more practical and attractive form.

Keywords: Fire Drill Training, Virtual Reality, Fire Safety Education, Immersive Technology, Oculus Rift

INTRODUCTION

Most schools and institutions conduct fire drills to test the capacity of the students and the staff. To learn more and practice using a fire extinguisher in a fire mishap. Some organizations need to carry out fire drills every two months. Conventionally, not everyone will have the chance to operate a fire extinguisher in fire drills. Interactive technology such as Virtual Reality (VR) can convey any training in an immersive and gratifying way. Live exercises also require trained personnel, space, equipment, consumables, and risk controls. An immersive simulation offers a complementary environment in which a learner can repeat procedures, make decisions, and observe consequences without exposure to heat, smoke, or flame.

With the growth of technology in the universal and immersive virtual world (Metaverse), everyone with a portable computer device (i.e., smartphone) or VR head-mounted device can immerse in the world [1,2]. People are more drawn to immersive ways to learn things since users feel just as immersed as they usually feel in consensus reality. This work presents a design and development to create a VR fire drills application where the user would put out a fire in a mishap using a fire extinguisher collaboratively guided by structured instructions. The VR training is evaluated in two types of tests: (i) Functional Test and (ii) User Acceptance Test, and achieved a good result.

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Types of Virtual Reality

Virtual reality can be described along a continuum of immersion. Non-immersive VR presents a three-dimensional environment on a desktop monitor and is normally controlled through a keyboard, mouse, or game controller. Semi-immersive systems use large displays, projection walls, or cave automatic virtual environments (CAVEs) to increase visual enclosure. Fully immersive VR uses a head-mounted display (HMD), stereoscopic images, spatial tracking, and hand controllers to place the learner inside a computer-generated environment. The present application adopts fully immersive VR because fire-extinguisher training depends on first person observation, object manipulation, spatial orientation, and procedural action.

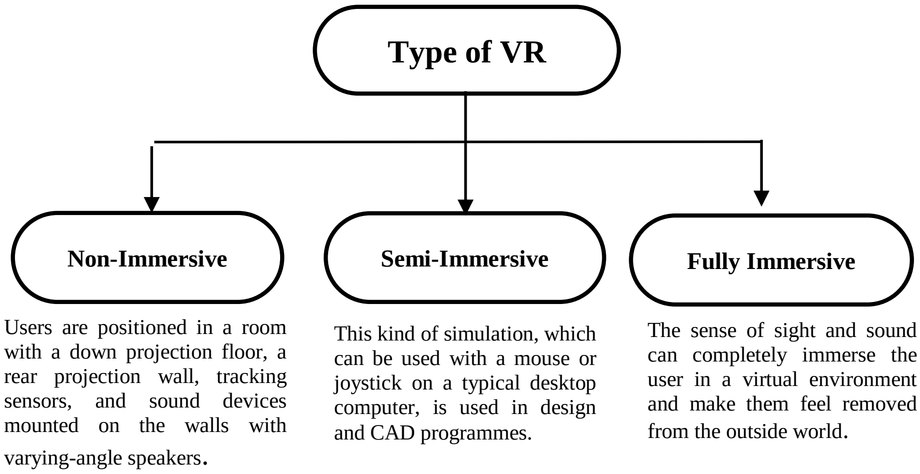

Figure 1. Types of Virtual Reality

Head-Mounted Displays and Oculus Rift S

An HMD presents separate images to each eye and updates the scene according to the user's head position and orientation. Tracked controllers extend interaction by allowing the learner to point, select, grasp, and manipulate virtual objects. The Oculus Rift S was introduced as a PC-connected headset with inside-out tracking, improved optics, Passthrough+, and handheld Touch controllers [3]. In this study, the headset provides the visual viewpoint and the controllers are represented as virtual hands.

Figure 2: Oculus Rift S

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RELATED WORKS

The Oculus Rift S prototype formed part of an earlier local development sequence. A 2020 predecessor, Virtual Reality for Fire Drill Version 2.0, used a smartphone, VR Box viewer, and game controller to teach extinguisher types, selection, and operating steps across multiple fire scenarios [4]. Its documented limitations included controller difficulty, absent warning and completion messages, and the need for clearer instructions and additional environments. These findings provide a design baseline for understanding why the later project adopted tracked Oculus controllers and a more immersive PC platform.

More recent fire safety applications broaden the context. Wong and So reported high satisfaction with a hospital fire management and evacuation simulation for nursing students, with expert review incorporated into scenario development [110]. Fu et al. found positive perceptions and engagement among primary-school pupils while noting practical implementation challenges [11]. Keya et al. used design-science methods to examine how VR fire-evacuation training could be integrated into school and university practices, emphasizing instructional support and alignment with drills [12]. Table 1 shows others related work in this study.

Table 1. Related works about the use of immersive technology in fire safety education.

Ref	Author (s)	Context and method	Contribution relevant to this study
[5]	Grabowski (2021)	HMD and CAVE fire training with cadets/firefighters	HMD condition achieved stronger presence, usability, and acceptance.
[6]	Seo et al. (2021)	Oculus Rift industrial safety system	Stakeholder-derived risks and scenarios strengthened content authenticity.
[7]	Hong et al. (2023)	VR fire escape; 173 secondary students	Presence and self-efficacy supported learning; frustration was detrimental.
[8]	Stefan et al. (2023)	Systematic review of 136 safety-training studies	Behavior and real-world result measures remained uncommon.
[9]	Scorgie et al. (2024)	Systematic review and meta-analysis	VR supported acquisition and retention, although results were heterogeneous.
[10]	Wong & So (2024)	Hospital fire evacuation; nursing students	Expert-reviewed scenarios and satisfaction evidence supported feasibility.
[11]	Fu et al. (2024)	Qualitative study; 25 primary pupils	Positive engagement accompanied practical integration challenges.
[12]	Keya et al. (2025)	School implementation; design-science studies	VR should complement drills and needs instructional/technical support.
[13]	Ibrahim et al. (2026)	VR versus lecture; 130 nursing students	VR produced larger immediate knowledge gains and high usability.
[14]	Lovreglio et al. (2021)	VR versus video extinguisher training	VR improved knowledge acquisition and maintained self-efficacy.
[15]	Chen & Chien (2022)	High-rise evacuation serious game	Scenario-based play supported evacuation and behavioral-skills training.
[16]	Saklangic & Mertoglu (2023)	VR fire training and individual awareness	VR-supported instruction increased fire-safety awareness.
[17]	Russell et al. (2024)	Residential-fire decisions; 159 participants	Immersion and perceived risk influenced simulated decisions.
[18]	Domgue K et al. (2025)	AR compared with VR and video	VR remained strongest overall for extinguisher training outcomes.

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[19]	Ussenov et al. (2025)	Apartment-fire VR versus video; 20 participants	VR achieved higher knowledge and presence scores.
[20]	Muffato et al. (2026)	Active VR versus video-slide learning	VR improved procedural scores and execution time; stress impaired performance.

The research gap is therefore not the absence of VR fire-safety prototypes. It is the need to document how an existing prototype is integrated into an instructional sequence and distinguish technical acceptance from educational effectiveness. This study addresses those needs while identifying performance, retention, stress, and hardware portability measures required for stronger evaluation.

MATERIALS AND METHODS

The Virtual Reality for Fire Drill is a project aimed at replacing conventional fire drills and briefing on fire safety. This initiative is intended to allow students and staff to learn about fire safety well. The traditional approach of providing the fire drill to students and staff is ineffective because they get annoyed with the material as if they prefer the same thing replicated by a firefighter demonstration. Students and workers are not given the details because they like it, so most students and staff are unaware of it. VR technology is one of the technologies that has evolved to produce recent technology. When designing for experience in virtual reality, there are a few principles that need to take into consideration.

Experiment with the VR Environment

In order to get experience with the VR environment and understand the fire drill training, developers and experts have to try a lot of different scenarios and applications. It should not be overlooked that there is still a proportion of employees that do experience sickness. Improvements should be made through the Alpha and Beta Testing and keep upgrading the features offered in the application. Therefore, in this study, developers start with the 1st version that only integrates with low-cost HMD. Then upgrade to the new environment (2nd version). After improving some features (3rd version) that align with the current technology, the VR app is now integrated with the oculus rift to get real experiences.

Immersive Authoring Tools

Unity served as the central immersive authoring environment. It was used to assemble scenes, import three-dimensional models and two-dimensional graphics, animate objects, configure controller input, enable VR support, and build the Windows application. Oculus software supported communication between the PC, Rift S headset, and controllers. Blender supported the preparation or modification of three-dimensional assets. Adobe Photoshop and Canva were used for instructional graphics, posters, textures, and interface materials.

Table 2. Development tools and their functions

Tool/component	Description
Unity	Scene authoring, media integration, interaction scripting, animation, controller configuration, and Windows build.
Android SDK Tools	Android software development toolkits
Blender, Cinema 4D, 3Ds MAx	Creation or modification of 3D objects and environment assets.
Adobe Photoshop / Canva	Posters, textures, interface graphics, instructional panels, and other 2D media.
Oculus software	Runtime support for the Oculus Rift S HMD and tracked controllers.
Audacity	Digital audio editor and recorder
PC workstation	Windows 10, at least 8 GB RAM, and graphics capability at or above the stated GTX 1050 project requirement.

Figure 3: Immersive Authoring Tools in Unity Editor XR

Modelling and Rendering

The virtual environments were constructed from reusable three-dimensional assets representing rooms, industrial spaces, vehicles, extinguishers, fire sources, and surrounding objects. Two-dimensional instructional materials were imported as sprites or textures. Within Unity, models were positioned, scaled, textured, lit, and assigned collision and interaction behaviours.

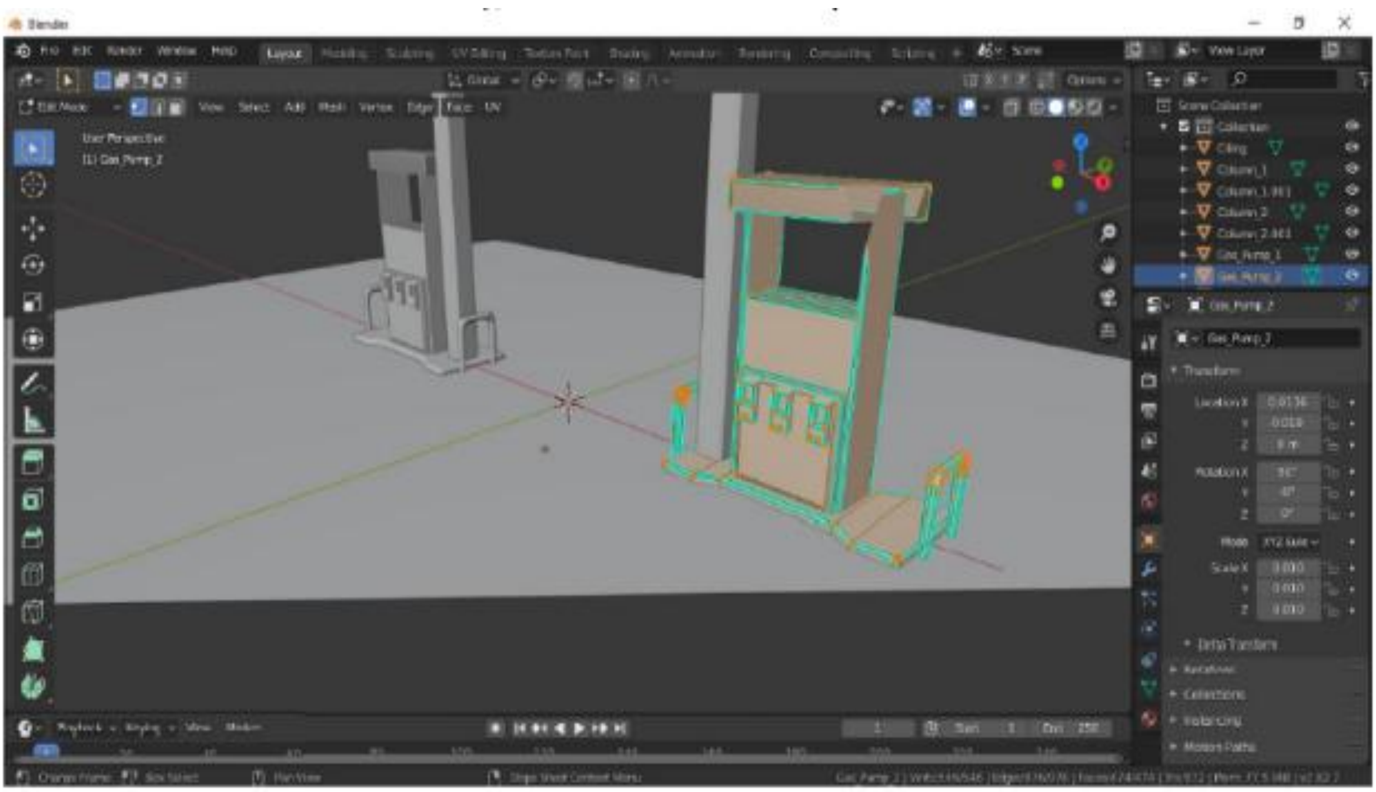

Figure 4: Modelling and Rendering Software with Blender

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Design Considerations

To get experience with the VR environment and understand the fire drill training, developers and experts have to try a lot of different scenarios and applications. It should not be overlooked that there is still a proportion of employees that do experience sickness. Improvements should be made through the Alpha and Beta Testing and keep upgrading the features offered in the application. Therefore, in this study, developers start with the 1st version that only integrates with low-cost HMD. Then upgrade to the new environment (2nd version). After improving some features (3rd version) that align with the current technology, the VR app is now integrated with the oculus rift to get real experiences.

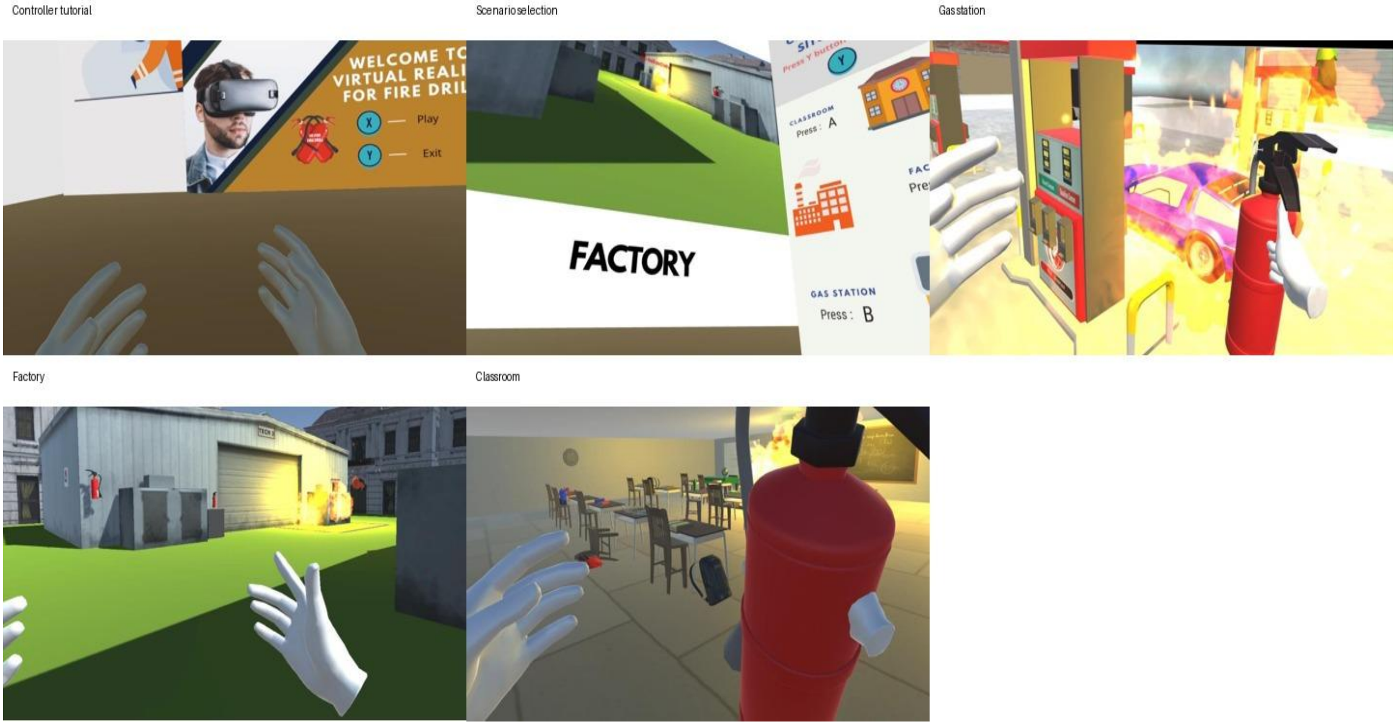

Figure 5. VR Environments

Fire-Safety Training Content Development

The content was organized as a short instructional pathway. The learner first receives an introduction to the VR controls and the purpose of the application. Fire and extinguisher information is then presented before the learner selects an environment. In the practice scene, the learner locates the extinguisher, approaches the fire, manipulates the object using virtual hands, and attempts to extinguish the fire. The prototype therefore focuses on extinguisher awareness and procedural rehearsal rather than full-building evacuation or incident command.

Table 3. Training content and intended learning function

Stage	Training content	Intended function
Orientation	Headset/controller guide and menu navigation	Reduce operational uncertainty for novice VR users.
Knowledge preparation	Fire and extinguisher information, posters, and instructional media	Introduce hazard awareness and equipment concepts.
Scenario selection	Classroom, factory, or gas-station environment	Provide contextual variety and support repeated practice.
Procedural practice	Locate, grasp, aim, and operate a virtual extinguisher	Rehearse the sequence of an initial response to a small fire.
Feedback	Visual change in the fire; completion feedback was limited	Indicate the outcome; this component requires improvement.

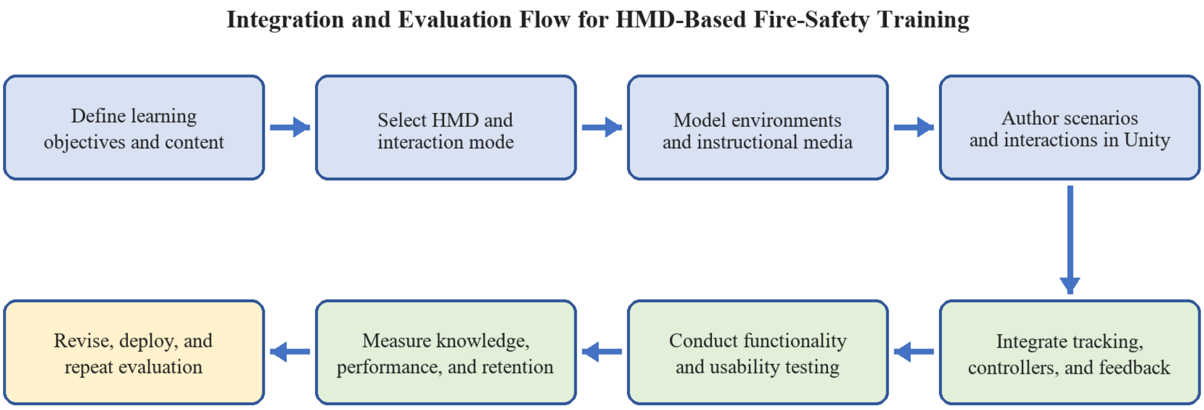

Figure 6. Development and evaluation flow for integrating HMD-based virtual reality into fire-safety education.

Evaluation Procedure

The evaluation used functionality testing followed by user acceptance testing. Two expert reviewers assessed instructions, relevance, environmental suitability, multimedia elements, content flow, readability, and ease of use on a five-point agreement scale. The user acceptance test involved 20 respondents: 18 students, one private-company employee, and one sales associate. Their ages were 14-18 years (n=1), 19-23 years (n=8), and 24-28 years (n=11); 12 were male and eight were female.

RESULTS AND DISCUSSION

This part focuses on the phase of implementation, where the developer tests the prototype. This stage is dedicated to developing and testing Fire Drill Virtual Reality. All the testing and development that will take place throughout this process are recorded so that they can be used as a reference in the distant future. All the software and hardware necessary for this program to work properly are needed for this process to be carried out.

The implementation phase is an important part of the design process since it is at this phase that the designs for each module are executed. Additionally, during the implementation phase, documentation and the tool used will be established so that educated decisions can be made about how to install a software or mobile application properly and safely. It will build the best development techniques early in the development cycle to discover and eliminate any safety risks.

The completed prototype provided an immersive main menu, controller orientation, fire-extinguisher information, scenario selection, and three virtual practice environments. Users could move within the environment, view virtual hands, approach an extinguisher, and interact with the training scene. The modular structure also permitted later revisions to scenes, assets, instructions, and interaction scripts.

Compared with the Version 2.0 predecessor, the Rift S implementation replaced smartphone viewing and a conventional controller with a six-degrees-of-freedom HMD and tracked hand controllers. The earlier system nevertheless established the instructional foundation: extinguisher information, multiple environments, scenario-based suppression practice, and simple interactions [4]. The integration therefore represents a hardware and interaction upgrade within a continuing fire-safety training design rather than an unrelated application.

Functionality Testing

Interface evaluation, evaluation setting, schedule check, and technique research are part of the test procedure. The research plan explains and describes the test trial, including a detailed overview of the test design process. This document outlines the specifications, attributes, appropriate test environment, goals to be met, and other experiments. The developer and designer must determine the appropriate tests to enable the intended product to take off. The product testing criteria must be recorded and mentioned in the evaluation schedule, the product that will be assessed, the testing schedule, and the individuals evaluating the product.

Both the key elements of the test, such as the test atmosphere and location, must be determined for the testing to be done properly. The test technique should be used to ensure the testing goes smoothly. Choosing a consumer to test the product is critical because their comments will be invaluable in improving and upgrading the project (Figure 6).

The test user identifies who was involved in each stage of the testing process. Two target users are chosen to test the application: (i) The fire department and (ii) The public. Three firefighters from Selangor participate in the alpha testing as fire extinguishers and fire safety specialists/ Subject Matter Expert. Meanwhile, random target users who test the programme are employees from a specified company and random people for beta testing. A total of ten people are chosen to test the application.

A multimedia expert will test the functionality. They will evaluate usability-focused implementations such as the project interface, interaction, layout, multimedia integration, and content agreement. Before moving on to the next stage, the goal is to determine which error or problem must be fixed. The professional will review the application and react to a developer's questionnaire.

Table 4. Expert functionality testing results (n=2)

Dimension	Item	Mean / 5
Learnability	Instructions are easy to understand	4.5
Learnability	Content is easy to understand	4.5
Learnability	Content is relevant	5
Learnability	Environment is suitable	5
Usefulness	Media elements aid understanding	5
Usefulness	Content flow is effective	5
Usefulness	Poster delivers correct information	4.5
Usefulness	Music, sound, and graphics are suitable	4.5
Usefulness	3D models are suitable	5
Ease of use	Text and fonts are readable	5
Ease of use	System is easy and user-friendly	5
Ease of use	Instructions are clear enough for tasks	4.5

Figure 6: Testing with Oculus Rift

User Acceptance Testing

For User Acceptance testing, the goal of user acceptability testing is to see how well this system works and how well the project's target user understands it. Those who responded should receive the code to test the tools' operation. After they have completed the exam, they must fill out a questionnaire about the project's effectiveness and content. Feedback from the experts, there are some difficulties in giving instructions. Some people may become clueless or not know what to do next. In addition, there are no pop-up messages on this virtual reality application. If the player extinguishes the fire, there will be no pop-up message informing them that they succeed.

A total of 20 participants responded to the user acceptance testing. The genuine target user performs beta testing in a real-time situation, where it will be presented once it is completely functional. User acceptance testing is conducted to get feedback from real customers to lessen the risk of product loss and improve the product's general consistency. This is the final check before the end customer provides the real object.

The interaction uses a virtual hand for the beginning button and can grab the object. Being programmed in this Virtual Reality application is simple and easy to understand. Because this is an application designed to teach the user how to use a fire extinguisher, the interactions in it are designed to be simple so that the user can quickly learn and practice using a fire extinguisher. This VR application was created with more than two environments, each with its own set of contents. This is due to the numerous sources of fire that might occur at any moment and in any location. As a result, this application does not focus on a single environment with a single type of fire source but instead includes multiple habitats with various fire sources. As a result, users will be taught how to put out fires in various circumstances by utilizing the proper sort of fire extinguisher.

During the testing, VR Hardware is provided focused on virtual reality where users experience themselves being in a virtual world putting out the fire. Users will be able to put out fires in this application since they will be immersed in a virtual developed environment through it.Table 5 shows the findings for beta testing using Oculus. Most respondents agree that the Fire Drill application instructions are easy to understand (95%). The environment design is also attractive and suitable for fire safety education (100%). Figure 9 shows the acceptance test results.

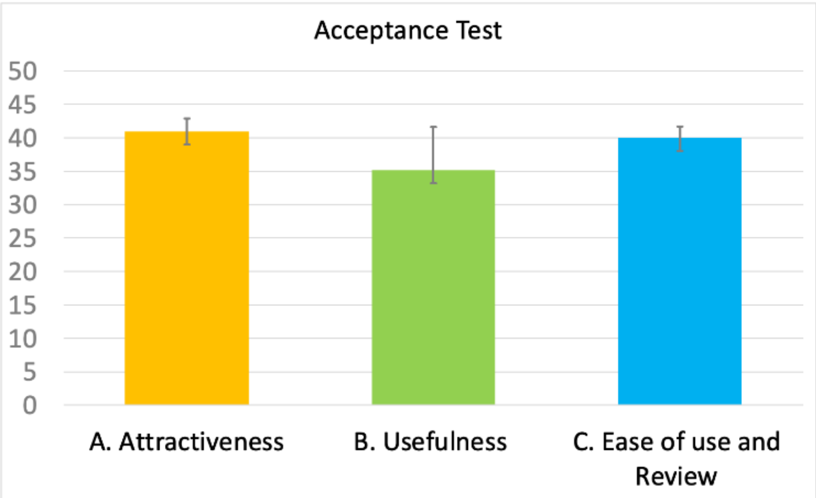

Figure 9: Results for Acceptance Test

Table 5: Findings for Beta Testing

Item	Percentage				
	1	2	3	4	5
The instructions are easy to understand.	0	0	5	45	50
The environment design is attractive and suitable for fire safety.	0	0	0	45	55
A good system to learn about fire extinguisher safety.	0	0	0	50	50

The application's use of sounds effect helps the user understand more easily.	0	0	15	30	55
Media elements such as fire, smoke, 3D models and other graphics are suitable.	0	0	0	30	70
Knowing more about fire extinguisher types and their uses is very useful.	0	0	5	35	60
The poster delivers useful information.	0	5	5	45	45
The system is easy to use	0	0	0	45	55
The fonts and texts used are readable and can quickly be understood.	0	0	5	40	55
The instructions are clear enough for the users to carry out tasks.	0	0	5	45	50
The instructions are clear enough for the users to carry out tasks.	0	0	5	45	50
Simulation provides good information.	0	0	5	45	50
The simulation enhances teaching and learning for fire safety education.	0	0	0	45	55

DISCUSSION

The developmental comparison also reveals continuity in user feedback. The Version 2.0 UAT involved 14 respondents and produced favorable agreement-item means of 4.3-4.8, while all respondents endorsed its awareness, new-information, teaching-and-learning, and perceived-effectiveness questions [9]. Respondents nevertheless requested clearer or audio instructions and more environments, and the report recommended warning and completion messages. Similar requests in the later Oculus evaluation indicate that improved hardware alone did not resolve instructional-feedback needs.

LIMITATIONS

Modern technology provides creative approaches, particularly for academic study. A virtual environment or virtual learning can also increase opportunities for interactions and learning experiences. Making VR learning games is still difficult, in any case. Educators need financing to create massively multiplayer VR games that blend conventional computer gaming with VR. Several limitations on this project have directed us to make changes to get rid of the limitations and, at the same time, bring more functionality and effectiveness to this project. Every project needs improvement in terms of functions, modules, controls and so on so that this project maintains its sustainability throughout the days and in future. But the purpose of fire drills is not just to get ready for flames. Employees are instructed to leave the office as soon as a crisis or life-safety issue arises.

CONCLUSION

This study described how an Oculus Rift S-based immersive application can be integrated into fire safety education. All employees' training should include a major component in evacuation techniques. More environment needs to be added to this Virtual Reality Application for future improvements. This application can be more functional with a pop-up alert or message informing players that they succeed or what to do next. This will make players more alert to their tasks. Also, create proper instructions so that the player knows what to do and what they need to complete in the system. By having proper instructions, they will complete the task efficiently.

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