Virtual Reality Based Application for Safety Training at Shipyards

S I Wahidi*, T W Pribadi, W S Rajasa, M S Arif
Departement of Naval Architecture, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember
Jl. Arief Rahman Hakim, Surabaya 60111 Indonesia

*Corresponding author, e-mail: sufian@its.ac.id,

Abstract. The implementation of safety training is conducted to provide knowledge on the importance of safety for its employees. However, the implementation of safety training requires many consumable things such as a lot of Portable Fire Extinguishers (PFE) that increase the operational cost and trigger the environmental pollution. This research aims to design a safety simulation based on VR (virtual reality) to provide an immersive experience for safety training and reduce the training costs. It was obtained that the application of VR technology requires two main devices namely HMD (Head-Mounted Display) and controller. Observations were conducted in the training of conventional safety and health at shipyards and training institutes. This research only simulates training on the use of PFE, fire drill, and risk observation on confined space from the ten topics of safety training based on observations that have been undertaken. Software such as Inventor, Microsoft Visual Studio, and Unity were used. After safety simulations was conducted, the result showed that safety training used VR can improve the work safety theory knowledge by 14.05%. Total cost of investment required for the development and equipment was IDR 24,043,667. The reduced cost of the safety training using VR was about IDR 193,889,154.88 or 68.13%.

1. INTRODUCTION

SHIYARDS are business entity that has a high risk of workplace accidents. Manpower Social Security Administering Agency of Indonesia records the number of occupational accidents in Indonesia tends to continue to increase. A total of 123,000 cases of occupational accidents were recorded throughout 2017. This amount increased by 20 percent from 2016. The majority of causes of occupational accidents occur because of unsafe actions (unsafe action) of workers. Unsafe action that workers often do, causing 80% of the work accident is not obedient in the use of PPE, the lack of understanding the work SOP, the unkind work, and disparage the dangers of the environment[1].

To reduce the number of occupational accidents in shipyards and increase worker knowledge of the risk of hazards faced, the shipyard conducts in-house occupational safety training such as Basic Fire Fighting, Fire Drill, operational tool lift and transport, work permits etc. But unfortunately, it is ineffective because the workers have never felt the accident until the accident happened. Moreover, the
implementation of occupational safety training requires inexpensive equipment and potentially cause environmental pollution and air pollution such as fire use in fire fighting training.

In order to answer these problems, the main objective of this research is developing a safety simulation based on VR (virtual reality) to provide an immersive experience for safety training and reduce the training costs, it takes a simulation of occupational safety and health, which is based on virtual reality technology. It is conducted to provide an immersive experience in training and cut training costs. Simulating a virtual reality-based computer programming will provide an experience directly to workers in cases of work accidents that are very common in the shipyard. The procurement of this simulation tool in the shipyard is expected to reduce the working accident rate and reduce air pollution and pollution caused by occupational safety training.

The novel components of this research are twofold. Firstly, VR has never been used to model a safety training for ship production and ship repair and maintenance in shipyard. Secondly, this research provide research analysis based on cost and technical aspect on using virtual reality for safety training in shipyard.

2. LITERATURE STUDIES

2.1 Virtual Reality Technology

Virtual reality technology is a technology that allows users to interact with a computer-simulated environment in both the real world and the imaginary world[2]. Virtual reality is a partial or complete representation of a tangible or fictionalized electronic environment. Such representations may include a three-dimensional image or an image that has an interactive nature and allows the user to be in the environment in an immersive manner[3].

2.1.1. Virtual Reality Hardware and Supporting Software

The adoption of virtual reality technology requires Head-Mounted Display hardware assistance and a controller to allow users to experience immersive and interactive experiences. The current virtual reality devices are as follows:
- Oculus Rift, Oculus Quest, Oculus Go
- HTC Vive
- Lenovo Daydream
- Google Cardboard, etc.

Software used in the design of applications that can be run using virtual reality technology is Microsoft Visual Studio, Blender, and Unity Game Engine[4].

2.1.1.1. Microsoft Visual Studio

Microsoft Visual Studio includes a compiler, SDK, Integrated Development, Environment (IDE), and an MSDN Library documentation. The compilers that are incorporated into Visual Studio include Visual C++, Visual C#, Visual Basic, Visual Basic NET, Visual InterDev, Visual J++, Visual J#, Visual FoxPro, and Visual SourceSafe[5].

2.1.1.2. Blender

Blender is a 3D software used to create visual effects, 3D prints models, interactive 3D applications, and video games. Blender has several features including 3D modeling, texturing, bitmap image editing, and rendering[6].

2.1.1.3. Unity Game Engine

Game Engine Unity is a three-dimensional game authoring tool for MAC and personal computers. Game engine is the core of every video game. From translating to displaying graphics on screen, integrating controls and devices for games, and game engines will make the next decision that will happen. Modern three-dimensional Game engine full of written code[7].
2.1.1.4. Training using Virtual Reality

Training using virtual reality technology can be divided into three categories. The first category is training from fields that require a virtual environment similar to a real job situation. The training included training in driving vehicles, trials, maintenance simulators, and medical and military procedures. The second category of training presents aspects that cannot be brought to the real world to support learning. Examples of this category include prehistoric site visualization, nuclear industry, and fire extinguisher. The third category presents activities that are not purely training situations, but involve cognitive activities requiring a number of implicit learning actions[8].

Currently, some occupational safety training uses virtual reality technology as one of the entire teaching equipment. Such as the Warsaw-based VRSENSE Training Institute and training organized by government agencies such as the British Safety Council which provides a wide range of certification for one of the safety and health certifications Work.

VRSENSE's occupational safety and health training focuses on virtual reality-based training. This agency sells virtual reality simulated application products in the form of compact disks and virtual reality appliances supporting simulated applications that they develop.

1. General Fire Safety
2. Pharmaceutical Fire Safety
3. General Safety Hazards
4. Construction Safety Hazards

The work safety and health training simulation application developed by VRSENSE can only be run on HTC Vive hardware.

British Safety Council also developed several virtual reality-based certifications, one of which is occupational safety and health certification. In addition to the cyber reality-based occupational safety certifications the British Safety Council also organizes online certifications and classes. Occupational safety and health certifications with virtual reality devices are as follows.

1. Risk Management Certification by IOSH
2. National General Occupational Safety and Health Certification by NEBOSH

The certification organized by the British Safety Council uses Oculus Go hardware as a certification teaching device.

2.2. Shipyard Safety and Health Training

Occupational Safety and Health training is distinguished by its organizational level. The training is provided for management, supervisory personnel, and worker levels. Work safety training for workers is done at inhouse before being allowed to start work. Shipyards must ensure that no worker is assigned to do high-risk work unless already given the necessary training[9].

The in-house workplace safety training topic that the shipyard needs to do is as follows.
- General problems of occupational safety and health, policies, rules and regulations.
- Identification of hazards and risk assessments.
- Safe working procedures including during emergencies.
- Permit to work, isolation, gas free, enter confined space, emergency response.
- Company-specific methods and procedures such as the use of safe workshop machines.
- General topics such as self-protection, scaffold, slip, fall from altitude.
- Briefing before carrying out the task to highlight the dangers and methods to deal with it.
- Demonstration of certain tasks.
- Development of surveillance skills.
- Exercises and training.

3. RESEARCH METHODS

Procedure for conducting this research is illustrated in Figure 1.
3.1. Literature and Field Studies

Literary studies were a stage of the search for literature or theories related to the problems and methods that will be addressed in this study. The literature studies conducted include:

- Occupational Safety and health
- Occupational safety and health training
- Virtual reality technology
- Virtual reality technology hardware
- Virtual reality programming engine Game
- Occupational safety training using cyber-reality technology

Field visit used by observing and learning directly the training of safety and work health contained in the
company as well as the collection of data related to this research, including:
- Occupational Safety Training syllabus
- Work safety training activities at the shipyard
- Training cost of occupational safety in shipyards

3.2. Application Development
Application development began after the simulation concept was obtained based on the results of data processing. Then simulated occupational safety using virtual reality designed computer-based programming.

   Here were the stages of application creation.
   - Three-dimensional environment creation
   - Application Script Creation
   - Application development using game Engine software

3.3. Application Validation
Application validation needed to be conducted to find out if the developed application can be used by the user properly. Application validation was performed by observing the movements performed by the user with the reaction displayed on the Head-Mounted Display (HMD) used by the user. Application validation was conducted against the controller's movement input and user head movement against the view in HMD.

3.4. Analysis and Discussion
Technical analysis conducted in this study included a comparison of user experience in occupational safety training using VR to conventional occupational safety training. Other technical analysis was to compare pre-Test and post-test results in writing to trainees before and after the use of job safety simulations using VR to determine the effect of safety training work of participant safety theory knowledge.

   At this stage, an economic analysis of the application design simulation of the virtual reality-based work safety training was conducted. Economic analysis conducted in the form of estimation of investment costs in application development and comparison of conventional employment safety training costs with work safety training using virtual reality devices.

4. CURRENT WORKPLACE SAFETY TRAINING

According to ministerial Regulation No. 26 of 2014 on assessment of implementation of occupational safety and health management system of the company who employ at least one hundred workers and have a high level of potential danger the company was obliged implementing occupational safety and health management systems.

   One of the systems was to provide training in the form of inhouse training. Inhouse training was given periodically every month once and every new project that has a certain risk of security was also mandatory inhouse training. Besides inhouse training, it was also done toolbox meeting every morning before doing the job. Occupational safety and health training in shipyards was coordinated and performed by the Health Safety and Environment division [10].

4.1. Implementation of Occupational Safety Training
In the implementation of occupational safety and health training, each class session consisted of 30 participants and the material will be delivered by one teacher and one teaching assistant for lecture activities, class discussions, and questions and answers.
Table 1. Monthly Schedule of Safety Meeting 2019

| No  | Topic Discussion               | January | February | March | April | May | June |
|-----|--------------------------------|---------|----------|-------|-------|-----|------|
| 1   | Fire Prevention and Protection | Week 1  | Week 2   | Week 3 | Week 4 | Week 1 | Week 2 | Week 3 | Week 4 |
| 2   | APD                            |         |          |       |       |     |      |
| 3   | Permit to Work                 |         |          |       |       |     |      |
| 4   | Tool and Equipment             |         |          |       |       |     |      |
| 5   | Crane and Lifting              |         |          |       |       |     |      |
| 6   | Power and Electrical           |         |          |       |       |     |      |

| No  | Topic Discussion               | July    | August   | September | October | November | December |
|-----|--------------------------------|---------|----------|-----------|---------|----------|----------|
| 7   | House Keeping/5R                | Week 1  | Week 2   | Week 3   | Week 4  | Week 1   | Week 2   | Week 3   | Week 4  |
| 8   | Fire Prevention and Protection  |         |          |           |         |          |          |           |         |
| 9   | APD                            |         |          |           |         |          |          |           |         |
| 10  | Permit to Work                 |         |          |           |         |          |          |           |         |
| 11  | Tool and Equipment             |         |          |           |         |          |          |           |         |
| 12  | Power and Electrical           |         |          |           |         |          |          |           |         |

(Source: PT.PAL, 2019)

Table 1 explained about the work safety training materials conducted in the shipyard PT. PAL Indonesia was performed routinely every month.

4.2. Occupational Safety Training Courses

4.2.1. Personal Protective Equipment

Potential work accidents that can be minimized when using personal protective equipment including sharp objects, falling objects, sparks, and splashes of harmful chemicals. Certain occupations have their own risks, so it was necessary to use special personal protective equipment.

4.2.2 Basic Fire Fighting

Early prevention and response to fire hazards was required to prevent fire incidents and reduce the impact. In extinguishing the fire, the substance used must be precisely according to the class of the fire due to different flame characteristics[11]. Substances that correspond to the fire class can be seen in Table 2 below.

| PFE Type   | Principle of Use | Aim For          | Description                        |
|------------|------------------|------------------|------------------------------------|
| Water      | Removing heat sources | Class A | Not for Fire class B, C, D, and K   |
| Foam       | Isolating oxygen fuel from | Class A | Not for fire class C and D        |
| Dry Powder | Isolating oxygen fuel from | Class A |                                      |
Table 2 showed the appropriate fire extinguisher was used for its fire class according to the National Fire Prevention Association.

### 4.2.3. Response to Emergencies

Emergencies were a condition, abnormal conditions or events where these circumstances occurred suddenly and can be transformed into disasters resulting in many casualties and damages. The step in the evacuation was as follows.

- a. Keep calm and do not panic.
- b. Use the emergency ladder.
- c. Regular walk and do not run.
- d. It does not carry large items and complicate evacuation.
- e. Tell colleagues around the room to evacuate with others.
- f. When stuck with fire smoke, stick to the emergency stairs by taking a short breath, try to crawl or crawl to avoid smoke, and do not turn around because it will collide with the person behind.
- g. If you are forced to break through the smoke then breathe and fast to the emergency exit.

### 4.2.4. Risk Observation

The risk observation training aimed to find or know the risks that may arise in activities undertaken by companies or individuals. In the prototype developed this time, the user will observe the risks in the confined space. Ordinances for entering confined spaces were as follows.

- a. All channels, including disposal channels connected with limited space, must be inspected in accordance with the possibility of danger. Make sure that the entire drain is closed or isolated.
- b. Only secured portable lamps or chandeliers that do not cause power jumps that can be worn in confined space areas. Ordinary incandescent lamps are very dangerous to use because of sparks from the switch or the exposure of hot filament from the lamp against flammable materials then it will be able to ignite and explode.
- c. Each worker must read the ordinance of entering the confined space and ask for the supervisor's permission and must wear all necessary personal protective equipment.
- d. Before opening the manhole cover, the surrounding air condition should be monitored to ensure that the oxygen content in the safe level is 19.5%-23.5% and flammable gases should not exceed the safe exposure for health.
- e. All areas of confined space must be increased by the concentration of toxic gases, oxygen levels, and explosive potential by experienced operators in testing equipment before they are allowed.
- f. Supervisors must ensure that limited space is safe to enter.
- g. Any worker who will enter the confined space must receive an explanation near the confined space called the Tailboard Briefing.
5. SAFETY TRAINING PROTOTYPE DEVELOPMENT

Workplace safety training simulations using cyber-reality technology were designed to be able to provide simulated work safety training based on work in the shipyard. Due to limited cost and timing of authors, the prototype developed in this study only simulates training on the use of PPE, fire drill, and observation of risk in confined spaces. These three trainings were also based on categories compiled under the journals of Virtual Reality for Training and Lifelong Learning. The category was a simulated tutorial in the training of the use of the fire extinguishers, a simulated emergency response in the simulation of Firedrill, and the observation of the risk that took the case of work in confined spaces. This VR-based training also came with material about general occupational safety such as the introduction of personal protective equipment, Basic Fire Fighting, Emergency response Plan, and Risk Observation in the form of video.

5.1. Safety Training Simulation Category

5.1.1 Tutorial
In the simulation, the tutorial will be designed to accommodate the training of the use of light fire extinguishers.

5.1.2 Response to Emergencies
A hazard response was designed to provide participant experienced in a fire hazard and provided an interaction room for participants’ response in the danger of immortality.

5.1.3 Risk Observation
While the observation training risk provided knowledge in observing the risk of danger in confined spaces.

5.2. Devices Uses for Occupational Safety Training
In this research, the VR hardware used was Oculus Go with the following specifications.

| Table 3. Oculus Go VR Device Specifications |
|------------------------------------------------|
| **Processor** | Qualcomm Snapdragon 821 |
| **SoC** | Qualcomm Snapdragon 821 |
| **RAM** | 3GB |
| **Audio** | Internal speakers, 3.5mm headphone jack |
| **Display** | 5.5-inch LCD Display (2560x1440) |
| **Sensors** | 3DoF Gyroscope, Accelerometer, Magnetometer |
| **Controller** | 3DoF Controller |
| **Bluetooth** | Bluetooth 4.1 |
| **Wireless** | Wi-Fi 802.11 ac/n |

Table 3 explained that Oculus Go has sufficient specifications to provide a simulation with the help of HMD and its default controllers. Although there was a deficiency in his freedom degree thus it cannot be simulated the movement of walking and bent.

5.3. Development of Safety Training Application
Prototype Work safety training simulation using virtual reality consists of the preparation stage of teaching materials, application development, and test stage applications[12]. The plot of prototype work safety training simulation in this study can be seen in Figure 2.
Explanation of the development flow of safety simulation prototype is explained as below.

5.3.1. **Determining Teaching Materials**
In this study, the teaching materials to be taught with cyber-reality technology was the safety of work on shipyards. The materials to be taught in this application are tutorials in the use of fire extinguishers, response in danger of fires, and observation of hazard risk in confined spaces.

5.3.2. **Determining Which Content Can Be Simulated**
From the material, the matrix was created to determine the training process that can be simulated with VR. The process of determination was based on the action during training that can be simulated with VR with media controller and HMD as a device of interaction with the virtual world.

5.3.3. **Defining the Sub step of any Material**
The creation of a sub step of each training material was useful to create an application programming framework to be developed. The sub step of each training material covers the conditions of the virtual environment in the training, the equipment to be used in training, the mechanical interaction of equipment in the training, and the orders that can be done in the training.

5.3.4 **Defines VR Devices**
The VR device used in this study was Oculus Go with the Android platform to run the application.

5.3.5. **Creating Virtual Environments**
The initial stage of creating a safety simulation prototype using VR was the creation of an environment or virtual environment that visualized the real environment in each training simulation category.

5.3.6. **Script Writing**
Application script writing was created for any object objects in the virtual environment in order to interact with the desired form of interaction. Application script writing was created using Microsoft Visual Studio software.

5.3.7. **Application Development**
At this stage, all the objects that have been created were put together with a script containing an interaction command using an engine game software called Unity. This stage was an important process in the development of a simulator software, if at the time of the execution of the object cannot be manipulated according to the instructed then it is likely there is an error in the script/code that has been created.

5.3.8. **Application Testing**
Application testing was performed to see if there is any use in application. At this stage, a user interface response validation test and a command function in the simulation of the controller and HMD movements when using the user. The invention of the problem in this stage will be done improvements to the Unity software. After that, the
verification test was conducted with the questionnaire method to find out if the prototype developed in this study deserved use by the user.

5.4. Safety Training Simulation User Interfaces

The user interface on the virtual reality-based work safety simulation consisted of home menus and training categories such as the use of extinguishers, fire drill, and observation of risk in confined spaces.

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Figure 3 was a user interface of home menu simulation training. User can choose freely the type of work safety training that is desired in this section.

The User interface in work safety training can be seen in Figure 4.

Figure 4 was the user interface of one of the trainings that is fire drill. In the training session, the user has begun to calculate the training and assessment time and at the end of the simulation, the training was displayed as it has been done and what should be done.

6. ANALYSIS AND DISCUSSION

6.1. Technical Analysis

Technical analysis conducted in this study included a comparison of user experience in occupational safety training using VR to conventional occupational safety training. Other technical analysis is to do comparisons of pre-test results and pro-test trainees before and after the use of simulated work safety using VR.

| Variable   | Conventional Training     | Training with VR                           |
|------------|---------------------------|-------------------------------------------|
| Space      | Involving the original environment to suit the training needs | Training can be done in a not too wide place |
| Variable       | Conventional Training                                                                 | Training with VR                                                                 |
|---------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Safety        | Involving a genuine environment that has a high risk of accidents                       | Training is conducted in an environment with a high level of safety               |
| Environmental Impacts | Involving fires that cause smoke and fire extinguishing substances that cause environmental pollution | Training does not cause pollution and pollution                                    |
| Time          | Involving time for preparation                                                         | Training does not take a long time to prepare and can be done repeatedly          |
| Equipment     | Involving equipment that materials                                                     | Training involves virtual reality devices                                         |
| Simulation    | Conventional training has limited media to visualize occupational safety and health material | Training has a high level of engagement                                             |
| Assessment    | Done manually                                                                          | Done automatically                                                                |

Table 4 is a comparison of the two training processes based on seven variables: space, safety, environmental impact, time, equipment, simulation, and assessment.

The results of pre-test and post-test have been done by the five respondents in writing, obtained the average result of the correct answer from pre-test is 21.8 of 30 questions. Post-test that was completed by the five respondents were obtained the average result of the correct answer from post-test is 25.4 of 30 questions. Thus, an average increase of 14.05% was obtained. It can be said that VR-based occupational safety training can improve participants’ occupational safety theory knowledge by as much as 14.05%.

6.2. Economic Analysis

Economic analysis was conducted to see the cost comparison between conventional occupational safety training and VR-based occupational safety training [13]. The stage that will be calculated is the investment cost of a set of VRS based safety training simulator tools, operational cost of occupational safety training using VR, and the comparison of conventional job safety training costs to Work-based safety training.

6.3 Equipment’s Investment Cost

3D Artist with 64 hours’ worth of IDR 2,453,333.33 and Application Developer with 140 hours’ worth of IDR 9,095,333.33 to total application of Rp. 11,548,666.67 and investment cost of a set of training equipment of Rp 12,496,000. The details of the prototype development costs in this study can be seen in Table 5.

| Table 5. Cost of investment equipment training |
|-----------------------------------------------|
| Applications | Cost          |
|---------------|---------------|
| Application Development | Rp 11,548,667 |
| Equipment     | Rp 12,495,000 |
| Total         | Rp 24,043,667 |

6.4 Comparison of Conventional Training Costs with Virtual Reality Based Training

There are several differences in the equipment used in both training. The materials used in conventional
occupational safety training are personal protective equipment, extinguishers, and fire pits [14]. While for VR-based work safety training requires the cost of application designing, VR equipment, and electricity. The details of the cost comparison can be seen in Table 6.

| Materials                  | Conventional Training (Rp) | Training with VR (Rp) | Cost Reduction (Rp) |
|----------------------------|-----------------------------|-----------------------|---------------------|
| Personal Protective Equipment | 24,165,000                  | 24,165,000            | -                   |
| Fire extinguishers         | 180,060,000                 | 180,060,000           | -                   |
| Fire Pit                   | 75,206,700                  | 75,206,700            | -                   |
| Application Development    | 11,548,666                  | -11,548,666           | -                   |
| Simulation Equipment       | 74,970,000                  | -74,970,000           | -                   |
| Electricity                | 8,253                       | -8,253                | -                   |
| Labor                      | 5,140,625                   | 4,156,250             | 984,375             |
| Total                      | 193,889,154                 |                       |                     |

Table 6 indicates that there is a reduction after the use of VR devices for occupational safety training of IDR 193,889,154.00. It can be concluded that occupational safety training using VR can reduce costs by 68.13% of conventional training.

6.4.1.1 Prototype Validation Testing

The application validation test in this study needs to be done to find out if a work safety training simulation application is developed can be used properly. Thus, validation is the direction of view and controller gestures to match the movement of view direction and controller in the virtual environment. In the validation phase, this application is done by comparing the display of HMD and controller with the movements performed by the user, while for movement in the virtual environment cannot be performed validation because of movement in the environment Virtual was conducted with a touch on the trackpad by the user, plus in this training simulation the user does not make migrations in the real world. Validation was conducted using simulation view of fire drill training because there is an evacuation route that has an angle 90 ° and to match it with user movement used 360 coordinates ° thus this validation can be done Accurate. The simulation view of fire drill can be seen in Figure 5.

![Figure 5. Fire drill simulation look from above.](image-url)
User will move HMD by looking towards the bottom, top, front, left, and right. During the move make sure that the display in the application corresponds to the user's head movement. The second validation is performed with the user directing the controller towards the bottom, top, front, left, and right. During the move make sure that the display in the application corresponds to the direction of the user controller.

6.4.1.2 Prototype Verification Testing

This study used the questionnaire method to verify the Work Safety training simulation application in this study using the questionnaire method. The questionnaire aimed to provide an assessment of the feasibility of the application that has been developed. The respondents were workers in shipyards because the application was developed to be implemented in shipyards. Questionnaires consisted of several questions about developed applications. Respondents first conducted a training simulation using developed applications and then carried out the filling questionnaire. Questions in the questionnaire used the Likert-interval scale one for the lowest and four values for the highest score.

Based on the results of a processed questionnaire, the highest average percentage is gained on the fourth question, means that simulated occupational safety training using virtual reality devices is more environmentally friendly than Work safety training conventionally with an average percentage of 90% which means 90% of respondents strongly agree that developed applications are assessed more environmentally friendly. Meanwhile, the fifth question, which is a practical safety training simulation is used to get the lowest percentage of 70% but still in the third interval, which means 70% of the respondents agreed that the developed open is practical to use. From total percentage, the average obtained value of 83% entered at the fourth interval which means that the average respondent strongly agrees with the developed application safety training simulation in this research.

7 CONCLUSION/SUMMARY

After the experiment and research the conclusion of the study is as follows:

1) The process of supply of occupational safety and Health to the shipyard is currently carried out in-house and external training or training that requires outside parties. In-house safety training includes general recognition of occupational safety, hazard observation and risk assessment, supervision skills development, work procedures, work permit, isolation, gas free, entering confined spaces, of emergency response, use of safe equipment, scaffolding, work at height, demonstrations such as fire suppression and the use of personal protective equipment and exercises as well as training such as fire drill, earthquake drill, and tsunami drill. The implementation of occupational safety training in shipyards has high levels of danger such as fire involvement and scaffold use in altitude.

2) Designing a virtual reality-based work safety simulation application on a shipyard requires two supporting devices namely the Head-Mounted Display and a controller. The design of a work safety simulation application based on cyber reality technology is done through several processes that define teaching materials, determine materials that can be simulated with VR devices, determine the substeps of any material, determine which VR devices to use, create virtual environments, application script writing, app development, and app testing. The study only simulates training on the use of extinguishers, fire drill, and observation of risk on the limited space of ten occupational safety training topics in shipyards.

3) A comparison of conventional occupational safety training with work-based safety training in virtual reality technology is seen from the seven variables in the training process: space, safety, environment, time, equipment, simulation, and assessment. VR-based work safety simulation simulations can improve the theoretical knowledge of occupational safety trainees as much as 14.05% based on written pre-test and post-test results. The cost required to design a work safety simulation application based on virtual reality technology is divided into the cost of making applications and equipment costs amounting to Rp 24,043,667. The reduced cost in occupational safety training using VR against conventional occupational safety training is Rp 193,889,154.88. Job safety training using VR can reduce occupational safety training costs by 68.13% of conventional job safety training.

The limitations of this research is simulated only on the utilization of fire extinguisher, fire drills, and risk observation in confined spaces from the ten topics of in-house work safety training in shipyards. Therefore, the future work, other in-house safety training topics can be simulated. In addition, this research applies virtual reality
technology, for further research, mixed reality or augmented reality can be applied.

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