Design of Virtual Reality Simulation-based Safety Training Workshop

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Abstract - Safety training is essential to high danger jobs. It is normally conducted in the traditional ways of classroom teaching or physical training at the workspace. In classroom teaching, safety procedures are theoretically described, the trainees cannot physically feel or see the machines or tools. Whereby safety training in the real-life workspace for high risk and high danger jobs often poses a risk by directly exposing the trainee to the danger area. In this project, a quiz-based interactive Virtual Reality (VR) simulated workshop was developed which allows training to be carried out in a realistic yet harmless environment, with the aims to improve the effectiveness of safety training and to reduce the incidents in the workshop. Studies were done to compare both the traditional classes and the VR system. Results show that the VR system is more effective, the trainees who took the VR training scored higher in the test compared to trainees who attended the normal classes.

Keywords—Virtual Reality; Safety training; VR headset.

I. INTRODUCTION

Safety training is an important process when it comes to introducing new trainees to high danger jobs, especially jobs which involve the use of potentially harmful machinery and tools. Safety education aids by introducing trainees the safety regulations of operating machinery, this will in turn significantly reduce the likelihood of safety-related accidents to happen in the workplace [1]. Safety training also benefits the company as it reduces the extra cost that will incur if an accident happens (i.e. medical fees, insurance, compensations, etc.) [2].

Safety training is important for trainees who use power tools such as drills, saws, and grinders at their workplace. Safety training today can be as simple as a lecture with the assistance of PowerPoint slides with the lack of hands-on experience. Trainees may not fully understand the correct method of operating a power tool which poses a higher risk of accidents. Furthermore, safety training programs are often costly, as it involves travel expenditure to transport the trainees to the training venue.

When a university sends students to robotics competition where participants are required to build their own custom robots, the students would need to go through the safety trainings. These custom robots are usually made of materials such as wood and metal that require the use of power tools to assist in cutting, drilling, grinding etc. These processes can be dangerous if the student is unfamiliar with the operation of the tools. The university needs to provide safety training sessions for students who are involved with these projects. As a solution, an interactive environment using VR technology can be used, which allows trainees to interact with virtual objects without touching it physically.

This project aims to improve the safety training programs where students can effectively learn about the safety procedures that should be practiced in their workspace through a Virtual Reality (VR) workshop. The VR workshop simulates the environment of the real-life workspace where the students can learn the safety features of machines and tools by operating the machines and reading the guidelines provided. A

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quiz-based gaming mechanism was incorporated into the VR workshop to make the learning more fun. The VR workshop allows students to familiarize themselves with the tools and eliminates the risk of accidents that could happen in a real-life workspace.

II. LITERATURE REVIEW

Benefits of Virtual Reality

Virtual Reality (VR) is defined as a computer-generated visual "reality" which can be used to explore and interact with the generated environments ("reality") [3]. This process typically involves a VR headset as well as positional tracking devices to realistically display and allow the user to navigate the virtual environment as they do in real life. This allows trainees to experience different kinds of working environments regardless of time and geographical location. Using VR technology for safety education allows trainees to be risk-free while learning in the generated workplace environment [4], this essential factor can be applied to a variety of risky jobs (i.e. medical training for surgery, training to handle factory tools, etc.). Furthermore, VR safety training can be conducted remotely [4], it does not require trainees to be physically present at the training facility. This will in turn aid in the reduction of travel costs, as well as save time.

Effectiveness of Learning through Virtual Reality

In 2014, a study was conducted to assess the learning efficiency of the trainees when taught using different methods - learning on lecture with slides, learning with a lecture in a laboratory, and learning in a 3D game. Trainees who were taught using the 3D game that involved manipulatable machines (i.e. grinder) were able to interact with the machines only by using mouse and keyboard without being exposed to danger [5]. The assessment score is measured based on how well the trainees understand the usage and safety precautions of a grinder before handling it [5]. The study concluded that from a sample size of 20 trainees who were taught using 3D technology had achieved the highest mean score of 86.11% in the assessment, while trainees learning with lecture in laboratory and lecture with slides had the mean score of 68.06% and 47.72% respectively [5].

Another study in 2017 used VR as a tool in mechatronics education, whereby users can pick a tool/appliance in the VR to interact with [6]. The project allows users to choose an activity and component they want to learn, then a VR simulation for learning is stimulated to showcase the construction of the device, the parts of the device, and how it works. After the interaction, within a sample size of 20 trainees, most of the users reported giving high ratings on the technology and would want it to be implemented in the class [6].

In 2018, trainees of the National Taiwan University wanted to test the efficiency of studying with VR by implementing it in class studies. A portion of the study's 105 trainees (participants) were provided with 3D VR simulations of chemical reaction experiments and the human anatomy experiments to interact with, while another portion was taught using the traditional way using lecture. Before the test was conducted, a pre-test was held to determine the trainee's initial performance in materials science. A post-test was then conducted to analyze the efficiency of VR in education. It was demonstrated that trainees taught with VR achieved a better average result of 75% and 84% compared to trainees who were taught in the traditional way who achieved an average result of 67% [7].

Comparison of Different Types of Virtual Reality Headsets

VR headsets are generally categorized into 3 groups - low-end VR headset (i.e. Google Cardboard), mid-range VR headset (i.e. Samsung's Gear VR), and high-end VR headsets (i.e. Oculus Rift, HTC Vive). Regarding the technical requirements and suitability for this form of VR education, a high-end headset was an ideal option due to its ability to provide positional tracking, high-resolution graphics and smooth movement requirements needed for proper education, and these options cannot be provided by low-end and mid-range VR headsets. Furthermore, both Oculus Rift and HTC (high-end VR headsets) provides users with compatible controllers to allow for the interaction with a virtual object within the VR world, an option and is not provided by any low-end or mid-range VR headsets [8]. However, the downside of such efficiency is that the technology

does not provide users with portability as it is required to powered by external computers or game consoles to run smoothly (i.e. external camera/laser for tracking systems, computer with graphics card, etc.) [8]. It is also, unfortunately, the most expensive options, with average prices ranging from $599 - $799 [8]. In conclusion, high-end VR headsets although expensive, fulfils the requirements for the efficiency of studying and provides the most real-time immersive experience to users making it the most suitable option [8].

Comparison of Different Game Engine for Virtual Reality Application Development

According to Unity [9], a game engine is defined as a framework which supports game development in areas including import assets from other software, create scene using assets, apply visual effects and game logic into the application. The game engine plays an important role in software development as it provides many features and pre-written codes which makes software development much more efficient and quicker. In this experiment, the three main game engine comparisons we've made were: Unity, Unreal Engine 4, and CryEngine. Unity is considered as an engine which is optimum in terms of cost and quality [10]. Furthermore, it has a relatively low system requirement. To develop in Unity, the system requirements are Operating System greater than Windows 7 SP1+, or Mac OS X 10.9+, CPU with SSE2 (Streaming SIMD Extensions 2), and a graphics card with DirectX 10 capabilities [11]. However, a more complex scene would have a higher system requirement [10]. The main advantage of Unity technologies is the ease of use [12] because the tools and component of the engine are easy to understand. Unity allows scripting in C# and has a big community which is ready to help in the forums [12]. Besides, Unity is also the most widely used game engine in comparison to Unreal Engine 4 and CryEngine, beginner can easily find help from the tutorials or forums when they face any problem during development. Unity also includes an asset store, containing a lot of useful tools that can be purchased and downloaded as add-on for use in the game engine [12]. One disadvantage of Unity is the lower graphics quality (less realistic) compared to Unreal Engine 4, and CryEngine [12]. Generally, the Unity game engine is ideal for this purpose compared to unreal engine 4 and CryEngine, as it has a simpler framework for beginners to understand compared to the other two options. Unity does not specify the minimum requirement of the processor, but it indicated that it should have support for SSE2, while Unreal engine and CryEngine both have a minimum requirement of multiple-core processors. Unity also can support DirectX 10 while Unreal Engine and CryEngine requires DirectX 11 [13][14]. This means that Unity can run on lower-spec hardware. In terms of help and support, Unity has a larger community and could provide better help compared to Unreal Engine and CryEngine. Therefore, Unity is the better option for beginners as it is user friendly and well supported by the huge community.

III. DEVELOPMENT TOOLS

This project was developed using the following software development tools:

Blender – An open-source 3D computer graphics software that is used to create and edit 3D models necessary for this project.

Unity - A game engine that is used to create the 3D environment, this is used to create and manage the UI and the algorithms for the game objects.

Visual Studio 2017 – An integrated development environment to create and edit C# code used for game logic.

Steam VR plugin (in Unity) – The plugin used to set up the HTC Vive. It came with assets that are needed for VR development

IV. APPLICATION OVERVIEW

The aim of this project is to simulate a virtual workshop which contains power tools that trainees need to get familiarized with. The virtual workshop allows trainees to move around and learn about the safety guidelines of the workshop by reading the instructions that are attached to the "walls" of the virtual workshop. They can interact with the tools which are in the virtual environment. Each trainee is required to play the quiz game by answering the quiz questions during the training. The purpose of this method is to ensure that all users are familiarized with the power tools before using it in real life. Trainees can familiarize themselves with the power tools easily as they are able to interact with the power

tools virtually. They can learn the method to turn on and off the machine and the ways to cut the material. They are also taught about the hazards that can cause unwanted injuries. Trainees can also play the instructions audio if they have problem reading the instructions.

The VR workshop has three major components. The first component is an interactive 3D virtual world that simulates the workshop environment. This component is the main component in this project, it is built using Blender and Unity 3D. The workshop setup mimics the real workspace, virtual tools and furniture are placed in the workshop as shown in Fig. 1.

Fig. 1 Virtual workshop

The users will be prompted to put on the safety glasses and glove when they first enter the virtual workshop as shown in Fig. 2. The glasses and glove can be put on by clicking the button using the VR controller.

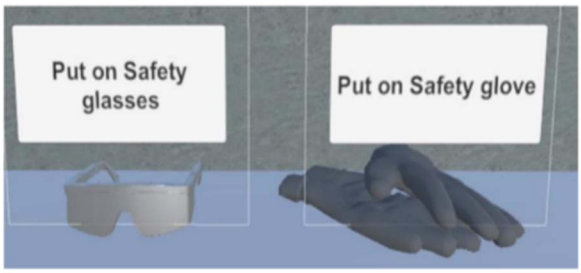
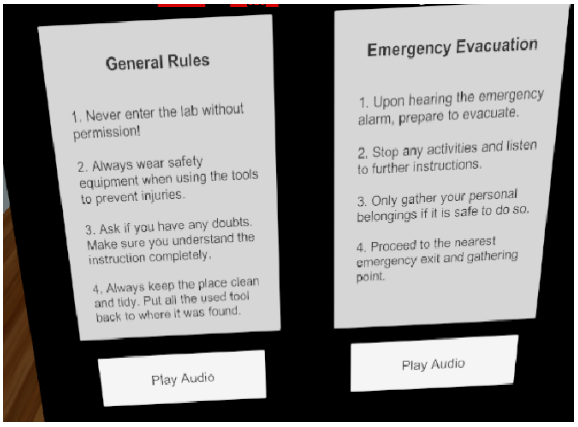


Fig. 2. Button to put on or put off safety glasses

The second component is the safety instructions. The safety instructions comprise of workshop rules and regulations, safety procedure and guidelines on how to operate the tools. These safety instructions and guidelines are added to the wall of the virtual workshop (Fig. 3 and Fig. 4).



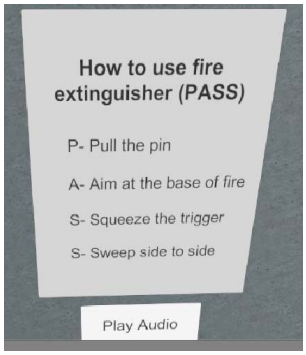


Fig. 3. Safety instructions

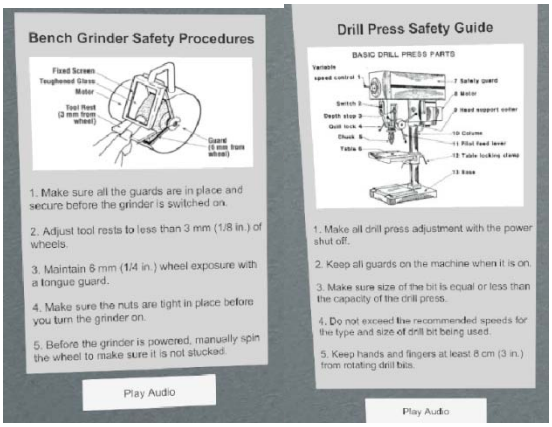


Fig. 4. Bench grinder safety procedure & drill press safety guide

The third component is the quiz-based gaming component. The quiz panels are placed next to each machines or tools as shown in Fig. 5.

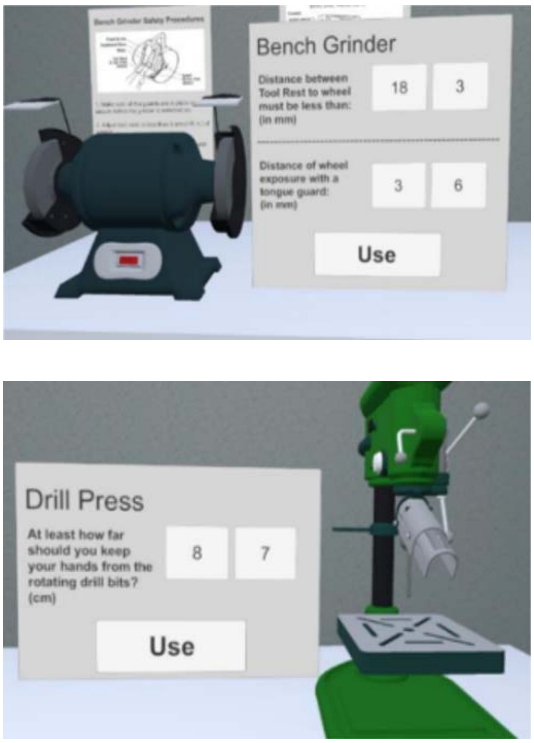


Fig. 5. Quiz panels

After reading the operation instruction, the users are required to answer the quizzes before start using the tools. To make the learning experience more fun, a live count is added to the simulation, when a user chooses the wrong answer, one life count will be deducted. When users have completed all questions, they will be greeted with a "Congratulations" screen. When users have no lives left, a "game over" screen will be shown.

V. RESULTS DISCUSSION

A study had been carried out with 10 students from Sunway University, by first letting them train through the VR workshop and follow up with a test and survey. The participants are split into two groups. First group of users attended the safety training through simple classroom lecture using PowerPoint slides, while the other group of participants attended the safety training through the VR workshop.

After the training, the users were tested with a set of 35 questions on the things they have learnt. This is to evaluate their performance as well as the effectiveness of the training. Results show that the VR system is more effective, the participants who took the VR training score higher in the test with an average score of 71.4% while participants who attended the normal classes only achieve an average score of 40%.

A survey questionnaire consists of 5 questions as listed in TABLE I is given to the participants to obtain their feedbacks on the user experience and opinions regarding the simulation. Five-point Likert scale is used in the survey, with 1 as 'Strongly Disagree and 5 as 'Strongly Agree.

TABLE I. SURVEY QUESTIONS

1	The virtual workshop experience is good.
2	The virtual workshop is useful to learn about the tools.
3	I feel safe using the tools in virtual workshop
4	I think Virtual Reality technologies is good for safety education.
5	Overall, how would you rate this virtual workshop?

The result from the evaluation shows that majority of the participants agree that VR is good for workshop training. Majority of the participants think it is good for training because the virtual workshop provides a more interactive environment when compared to PowerPoint slides which only includes one-way communication from the lecturer to the trainee.

VI. CONCLUSION

Virtual reality has been proven to be effective for educational use. This project has successfully demonstrated the developing of a virtual reality simulated-based safety training workshop. Virtual reality is implemented into safety training and it is found to be useful for trainees to understand the safety rules of their workplace through an interactive way of learning as it is more interactive compared to the traditional methods of trainings. Future work can be done to implement the idea into bigger scale of training sessions covering more types of rules, scenarios and tools which would be beneficial to everyone.

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