Design and Development of Training Simulation for Fire Evacuation based on Mixed-reality

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Abstract

The purpose of this study is to present a case of designing a fire evacuation training for elementary students through Mixed-reality (MR). The simulation is developed using Microsoft HoloLens 2. The simulation applied gamification (e.g. learning goals, points, timers), and Goal-Based Scenario (GBS). The task involves dealing with the science laboratory and evacuation. Learners must extinguish a small fire, evacuate quickly in case of a big fire, and report it after evacuation. Learners earn points based on speed and accuracy. When learners perform missions, in the mixed-reality environment, they use real objects such as fire extinguishers and a handkerchief.

The developed simulation conducted a usability test. 10 participants answered the questionnaire after watching the demonstration video. The questionnaires of the usability test contained 3 items with a 5-point Likert scale. As a result, participant positively evaluate the simulation (Learning easiness = 4.5, Aesthetics = 4.84, Operability = 4.20). This mixed-reality simulation can provide an immersive learning experience and a safe training environment for children learners. We will conduct a follow-up study to add the scenarios and provide more diverse interaction.

Keywords: fire evacuation simulation, mixed-reality, gamification, goal-based scenario

Introduction

Over the past five years (2015-2019), the total number of fire disasters in educational research facilities has been 956, of which 235 (24.68%) were found to occur in elementary schools, showing a high frequency of fire (Kim, 2021). In addition, elementary school students are less interested in the safety of school facilities and facilities (Kim, 2002). Since they are also in the developmental period of promoting safety habits, safety education for elementary school students is highly required. However, existing child safety and disaster safety education is limited to audio-visual lectures or one-time training. Therefore, it is required to develop practical fire evacuation training suitable for the characteristics of elementary school students.

Mixed-reality (MR) can offer the interaction of real objects and virtual objects and increase the sense of reality in a disaster situation. In the context of safety education, MR-based simulation offers more realistic training since it

is premised on the real world (Jeong, 2018). Therefore, MR-based fire evacuation training simulation will give learners immersion and realism. The purposes of this study are as follows:

1. To design and develop an MR-based fire evacuation training simulation.
2. To check the direction of improvement through usability evaluation.

In addition, this simulation aims to strengthen the ability to react swiftly in case of fire by applying the principle of gamification and goal-based scenario. Also, this simulation took the characteristics of elementary students into consideration.

Method

Design and Development of Simulation

According to the demand analysis, we designed an MR-based simulation for fire evacuation training. The simulation was targeted at elementary students who are insensitive to safety and had basic knowledge. In addition, the device used for the simulation is Microsoft's HoloLens 2.

The simulation applied a Goal-Based Scenario (GBS) and gamification to promote the learners' interest. First, by applying GBS, this simulation provides learners with a meaningful goal of fire evacuation and a scenario with immersive and practical contextuality. Schank (2013)'s GBS includes the following: Learning goals, Mission, Cover story, Role, Scenario operations, Resources, and Feedback. Learners enter the fire training simulation after learning how to suppress a small fire and evacuate with a learning card. The overall scenario content is that learners respond when fire incidents appear in science laboratories. The learner is required to extinguish a small fire caused by an alcohol lamp in the science laboratory. However, since the fire extinguisher is not working, learners have to find alternative products. After the small fire was extinguished with an alternative product, a bigger fire breaks out next to it and the learner must evacuate. It is at this time that a learner gets a real handkerchief to cover their mouth. Then they evacuated and reported the fire situation according to the learned procedure. For a sense of reality, fire extinguishers and handkerchiefs are carried out with a real tool.

Second, we applied the gamification principle and implemented missions, scores, leaderboards, and time-limiting functions. The learner scores each time he or she performs the mission successfully or gets the quiz right. Since it is disaster safety, a time limit has been set for speed.

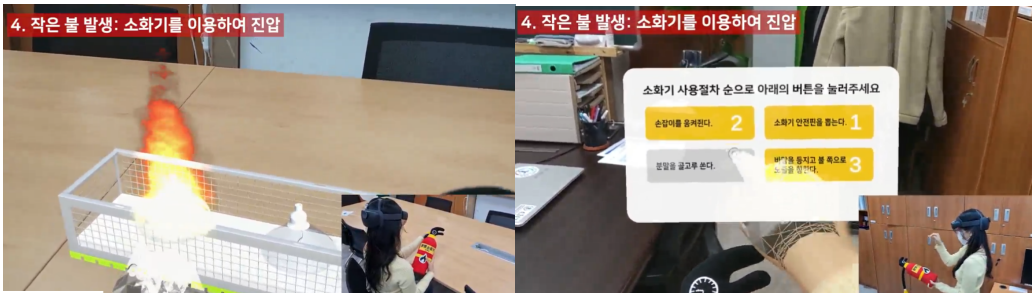

Figure 1 Extinguish a small fire in the simulation

Content development was divided into physical learning materials and simulation content development. The physical learning materials consist of learning card and models that look like a real fire extinguisher and handkerchief. By using a learning card, the learner can learn how to evacuate in the event of a fire and how to cope with each fire

type, how to use a fire extinguisher, and how to notify it. In addition, using the models in simulation helps the interaction between real and virtual objects in the simulation. MR content was developed based on HoloLens 2. Simulations were developed using Unity 3D, and virtual objects were developed by SketchUp, a 3D design software.

Figure 2 Pre-learning using study cards

Usability Test

A usability test was conducted to see if it was appropriate to use in practice and if there was anything more to supplement. Graduate students and college students answered a questionnaire after seeing a demonstration video. 10 participants responded to 13 items. The questions used in the study of Ding, Jang, and Yun (2018), as well as that of Jeon, Kim, and Ko (2020) were revised and applied. The questionnaire consists of three subscales, Learning easiness (1~5), Aesthetic (6~10), and Operability (11~13), with a 5-point Likert scale. In addition to the results of this usability evaluation, by referring to the participants' additional opinions, the follow-up study will be conducted later.

Results

Table 1
The result of the usability test

No.	Items	M(SD)	No.	Items	M(SD)
1	This simulation would be useful for fire disaster response training.	4.44 (0.68)	8	Icon's meaning in this simulation is obvious	4.8 (0.6)
2	The simulation consists of core contents.	4.6 (0.49)	9	The simulation didn't include unnecessary information.	4.9 (0.3)
3	It would offer specific information for learners.	4.6 (0.8)	10	Color, arrangement, and expression in the simulation are consistent.	5 (0)
4	The amount of learning was adequate to achieve the intended objective.	4.7 (0.46)	11	The interaction between learner and virtual material looks natural.	4.3 (1)
5	Content is appropriately for 5, 6th-grade elementary school student's developmental period	4(1)	12	It seems like no disturbance in control.	4.1 (0.94)
6	UI-like button, pop-up window is well arranged and built up in the learning environment	4.6 (0.66)	13	It would be no stress in using simulation.	4.2 (1.4)
7	Simulations' design is easy to see.	4.9 (0.3)			

As a result, the aesthetic average was the highest at 4.84. The learning easiness average was 4.5. The operability average was relatively low at 4.2.

Overall, the simulation received a positive review. However, some points were observed that necessitate improvement. In terms of aesthetics, the interface design of the simulation was shown to be cool and helpful.

However, unlike the aesthetic aspect, it was found that the information and content provided for performing the learning task in the simulation should consider the learner's level. With respect to learning easiness, the content performed through the learning card is appropriate for the learning subjects, but it was confirmed that the task actually manipulated and performed was too easy for the learner. In terms of operability, it has been shown that the holo-lens may not operate quickly when the user wants to.

The direction of improvement of the simulation constructed based on this opinion is as follows. First, in consideration of the learner's level, more tasks for manipulation are needed. Second, due to the operability of the HoloLens 2, it is necessary to add a pre-training session to familiarize the simulation operation and guide the method of coping with error situations in advance.

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