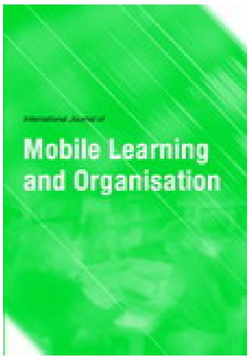

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Effects of an immersive virtual environment-based gaming approach on students' occupational health performance, immersion and motivation

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Abstract: To investigate the effects of immersive virtual environment-based gaming approach and conventional mobile learning environments on learning performance, learning immersion, and learning motivation, this study developed the immersive virtual environment-based gaming approach for occupational health education in emergency response knowledge about fire and chemical emergency handling. The study results indicated that students in the immersive virtual environment-based gaming approach had higher learning achievements, immersion, and motivation levels than the conventional mobile learning approach. Furthermore, the high and low-achieving groups within the immersive game-based learning approach motivation are not different, which means that the group with high and low-achieving students still have high learning motivation toward the proposed immersive virtual environment-based gaming approach regardless of their learning capabilities.

Keywords: immersive learning system; virtual reality; game-based learning; GBL; occupational health; learning immersion.

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1 Introduction

Occupational health (OH) is considered an effective system for managing the health, accident, and emergency of the staff in the workplace. However, there are still concerns about the rate of accidents, injuries, and risks in occupational. According to the statistics, there are an enormous number of work-related accidents and victims, more than one hundred million cases a year (Musungwa and Kowe, 2022). The same goes for accidents in neighbourhoods, streets, and factories related to daily life. For example, a car accident is a reason for gas or fuel leaking, a hazardous chemical that can cause fire, explosion, or toxic gas. As a result, the knowledge of chemical management and fire prevention are related topics which are needed for dealing with incidents that could be harmful to humans, animals, and environments, and the damages from the incidents can result in the long-term and the short-term (Feng and Cui, 2021). Therefore, OH learning has become an essential factor for preparing individuals to achieve the skills required for handling mental and physical health problems properly (Nielsen et al., 2018; Puranitee et al., 2022). Additionally, hands-on learning and experience are crucial in OH for providing the necessary skills for the individual to achieve a successful healthcare occupation through training through practical methods (Ching and Lazaro, 2019).

Experience-driven learning is an approach that can provide a practical and positive learning experience to the learners that results in more confidence and will in students (Kang and Martin, 2018). However, learning motivation, learning immersion, and learning performance are the factors that should be investigated to increase successful learning. First, learning motivation can influence the students' engagement and interaction in learning tasks (Chang et al., 2018); the students must be motivated because they are more likely to engage in the material and achieve a high level of learning performance. Second, learning immersion is vital for a virtual learning environment, and it provides a sense of presence and emotional reaction that could reflex the real-life behaviour of the learners (Bell et al., 2020). Moreover, the students are more likely to be motivated and engaged in the learning process when fully immersed, which could result in a positive learning experience. Third, learning performance is the factor for measuring the ability of the learner to achieve and retain knowledge, and it is a measure of the learning effectiveness of the designed process (Li, 2018). Therefore, the positive outcome of these factors plays a vital role in a better learning experience by contributing to the development and implementation of teaching and learning strategies and resulting in high student learning achievement.

Several studies applied mobile learning and application to enhance learning motivation and found positive effects on learning motivation and immersion (Hsu et al., 2023; Li et al., 2018; Nicolaidou et al., 2021; Önal et al., 2019). However, mobile learning alone has a gap in improving learning motivation and self-efficacy. Meanwhile, many studies pointed out that gamified and game-based learning (GBL) can stimulate better student learning experiences (Carrión Candel and Colmenero, 2022; Chan et al., 2019; Fan and Wang, 2020). Also, the game learning approach can result in higher immersion in students by integrating the contents with the virtual reality (VR) game system compared to the mobile learning approach (Nicolaidou et al., 2021). Moreover, applying GBL approach could result in positive psychological effects on the motivation and engagement of the students (Erümit and Yılmaz, 2021). Therefore, game-based and gamified learning can be practical tools for providing students with more engaging and motivating learning experiences in practical knowledge.

As a result, this study aims to develop immersive GBL to improve the OH learning experience, which requires experience-driven learning to promote the students' occupation skills since the GBL approach can promote the learning experience in motivation, immersion, and achievement of the students. Additionally, the benefits of immersive technology are considered influential in OH learning as it allows the students to learn in a virtual environment similar to the real-world context. Moreover, this study uses quasi-experimental research to collect data from two participant groups, the experimental group (EG) and the control group (CG). Therefore, this study investigated and aimed to answer the research questions as follows:

1. What is the learning performance between two participant groups after experiencing the immersive virtual environment-based gaming approach and conventional mobile learning system?
2. What is the immersion between two participant groups after using the proposed the immersive virtual environment-based gaming approach and conventional mobile learning system?
3. What is the learning motivation between two participant groups after using the immersive virtual environment-based gaming approach and conventional mobile learning system?

2 Literature review

2.1 VR technology in immersive learning environment

VR has been applied for various objectives and is considered one of the immersive learning environments (ILE) which utilises the benefits of extended reality (XR) in learning (Seprum and Wongwatkit, 2022). VR could be applied in various learning disciplines, for example, medical and nursing (Chang et al., 2019; Everson et al., 2022; Li et al., 2021), emergency and safety training (Buttussi and Chittaro, 2021; Li et al., 2022; Liang et al., 2019; Monteiro et al., 2021), engineering (Bohne et al., 2021), sport (Tsai et al., 2020; Wu et al., 2021), and more. Also, VR can provide an immersive learning experience to the users for enhancing various positive emotional, cognitive, affective, and longitudinal effects on the learners (Akgün and Atici, 2022; Makransky and Mayer, 2022; Ogrizović et al., 2021). Moreover, VR could provide a sense of immersion and presence, interaction, motivation, attention, and engagement, which are immersive experiences for the students.

Many studies investigated the effects of VR applications on motivation, immersion, and knowledge achievement. In motivation, the researchers have found that the application of VR that enhanced motivation and engagement could result in high achievement scores, including class attendance and a reduction of failed students (Barata et al., 2015; Kim et al., 2022; Lin et al., 2022). Moreover, the researchers indicated that high immersion could significantly impact the virtual world's sense of presence, body ownership, and agency (Waltemate et al., 2018), and it could benefit the student's learning experience in achieving the knowledge they required (Peixoto et al., 2021). The students can achieve the necessary skills and knowledge, including the learning achievement required with the appropriate application of VR (Buttussi and Chittaro, 2018; Gupta et al., 2019; Zawadzki et al., 2020). Additionally, another study (Hwang et al., 2022; Yang et al., 2021) found that the application of spherical video-based VR can provide a practical learning approach to professional training and experience learning with attention, relevance, confidence, and satisfaction (ARCS) model, which can enhance the learners' motivation and engagement in their learning outcomes.

With the ability of VR to provide an immersive experience to the students, this study aims to apply VR to an interactive and immersive virtual environment-based gaming approach. Therefore, this study proposes the investigation of immersion, motivation, and knowledge achievement, as these factors could determine the learning effectiveness in the system.

2.2 GBL to promote learning experience

GBL is one of the learning approaches applied in various learning situations. One of the reasons is the benefits of GBL that could promote the students' emotional, attitude, or positive psychological ways (Erümit and Yılmaz, 2021; Pondee et al., 2021). Additionally, many studies have applied the game-based or gamified learning approach in the classroom and found that the GBL could enhance knowledge and learning achievement of the students in various learning disciplines, for example, tourism (Chan et al., 2019), law (Yuratich, 2020), financial (Kalmi and Rahko, 2022), language learning (Chen, 2022) and more which this study did not cover. Moreover, the researchers pointed out that the application of gaming or GBL approach in learning could improve practical knowledge and motivation and promote perceptions (Tapingkae et al., 2020). Also, researchers revealed that one of the benefits of GBL is the enhancement of engagement, satisfaction, and motivation in learning the students (Hartt et al., 2020; Wang, 2022).

Among the factors that GBL could promote, learning experience has been one method that could benefit the student's experience. The GBL can promote the learning experience by providing students with problems, challenges, and logical learning experiences. It lets them analyse the solution to solve the problem and gain the skills while remaining engaging, motivating, and interacting with the learning design (Hwang and Chang, 2023).

Kang and Chang (2018) have applied gamified learning to promote the learning experience of autistic children by training them to take a shower and found an improvement in the children's performance, including motivation to participate of the children. It can be concluded the application of GBL to promote learning experience could provide benefits in content comprehension and encourage motivating, engaging experience to the students (Aynsley et al., 2018; Tahir and Wang, 2022).

From the benefits of the GBL that could providing more engaging, motivating, and attracting and also the positive psychological effects that could provide to the students. This study aims to utilise the GBL approach to promote learning experience to the students.

3 An immersive virtual environment-based gaming approach

As the OH has many learning topics available to transform into ILE, this study implemented one of the main topics, which is emergency response (ER). Traditional ER training still has limitations that should be considered, for example:

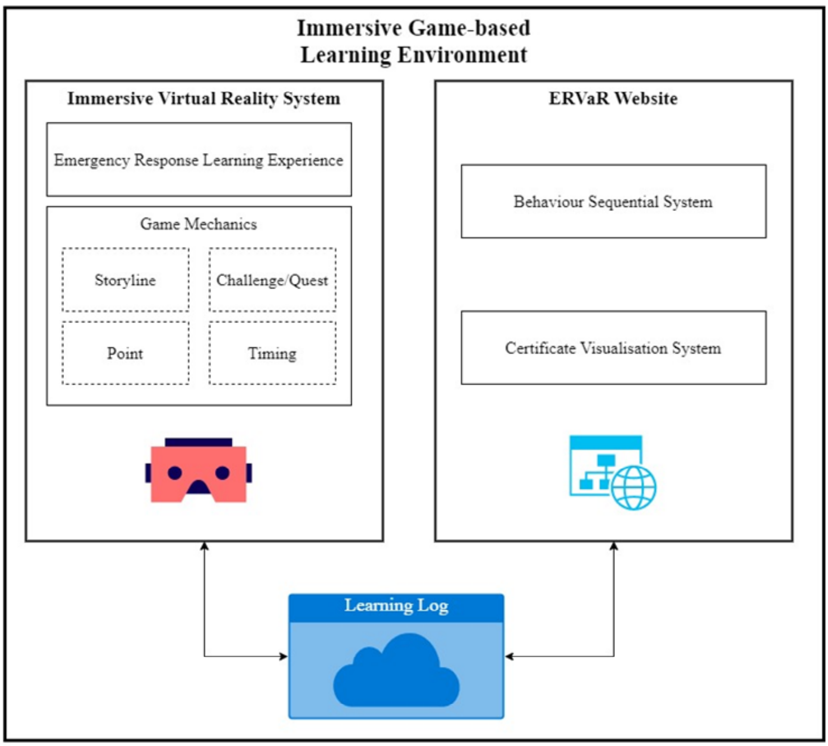
1 Expensive cost of equipment, vehicle, staff, place, and more (Pettersen et al., 2020).

2 The emergency drill requires a realistic training environment for effective emergency drills (Jayakumar et al., 2022).

3 Lack the exercise, training, learning, and skills could be significant factors that lead to accidents (Herovic et al., 2019; Wang et al., 2020).

Therefore, with the mentioned existing limitations of ER topic, the researchers considered the ER learning in fire prevention and control and chemical ER technique management topic as appropriate for GBL applications with the ILE approach to provide the immersive virtual environment-based gaming approach to the students.

Figure 1 Overall structure of an immersive GBL approach (see online version for colours)



3.1 Overall immersive GBL system

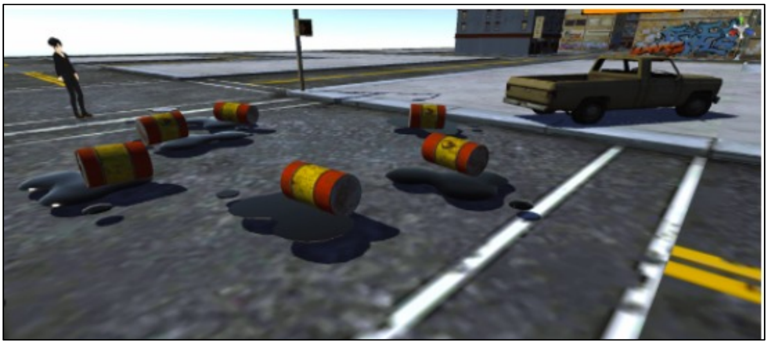
The proposed system is the immersive virtual environment-based gaming approach system that consisted of the immersive VR system and the emergency response virtual reality (ERVaR) website. First, the immersive VR system is a tool for providing the immersive virtual environment-based gaming approach to the students as they can train and gain ER experience while learning with game mechanics for more engaging and interactive experience. Second, the ERVaR website serves as a platform for sequential behaviour analysis and also for showcasing certificates that represent the learning outcomes achieved by the students.

3.2 Game mechanics

3.2.1 Game storyline

The students can immerse themselves in the ER storyline presented in the virtual world and gain knowledge and practical experience in each mission. The proposed system's overall story involves role-playing as an emergency officer or staff who witnesses an oil truck accident, as shown in Figure 2.

Figure 2 The oil truck accident in the ERVaR GBL system (see online version for colours)



Accordingly, the students must proceed according to the ER's procedure to handle the situation as an officer. Initially, a truck will load six barrels of diesel fuel on the road in front of the users. Then, the users must proceed according to the ER procedure with a time limit of 360 seconds or six minutes. There are five main tasks of the learning activity that the users must face as follow:

1 Contact staff – the process in which users must contact the direct team or officer immediately after they witness the accident as shown in Figure 3. Then choose a dialogue option to notify the operator correctly according to the situation; for example, the operator will ask, 'What kind of chemical that spilled?' the users have to choose one of these three options: 'solid', 'liquid', and 'gas'.

2 Perimeter – the task requires users to place traffic cones around a dangerous area where people are standing watching the accident as shown in Figure 4. Then those people will run away to a safe location if the users set the cones at the right point.

3 Confinement – in this process, the users must use a shovel to get six piles of sand and then place it on the six leaked diesel oil pounds within the time limits for explosion prevention as shown in Figure 5.

4 Fire extinguisher – After the confinement process, the instructors intend to provide a task or scenario that the users must use the fire extinguisher to put out the fire by emitting the flame within the scene as shown in Figure 6. Then, the users must pick up the fire extinguisher and select the correct sequence order as 'pull', 'aim', 'squeeze', and 'sweep'.

5 Put out the fire – If the users have done the fire extinguisher task correctly, then they have to aim the fire extinguisher at the base of the fire before the chemical is depleted as shown in Figure 7.

Figure 3 Dialog and conversation in the contact staff task (see online version for colours)

Figure 4 The perimeter task requiring the placing the cones on the road (see online version for colours)

Figure 5 Confinement task requiring the using shovel and sand to soak up the spill (see online version for colours)

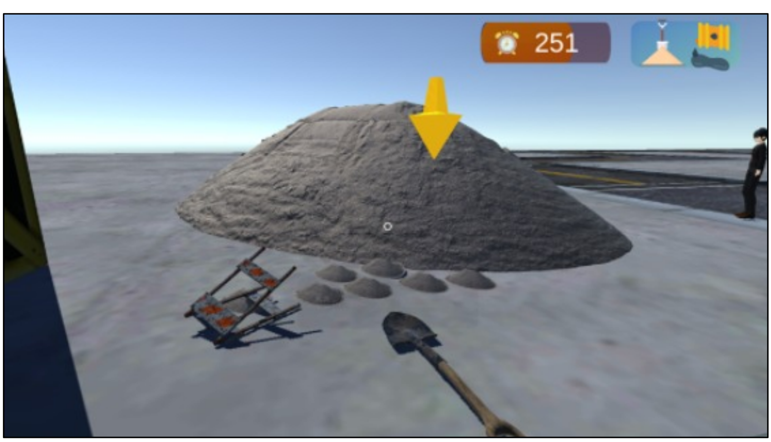


Figure 6 Fire extinguisher requiring the students to interact in correct order (see online version for colours)

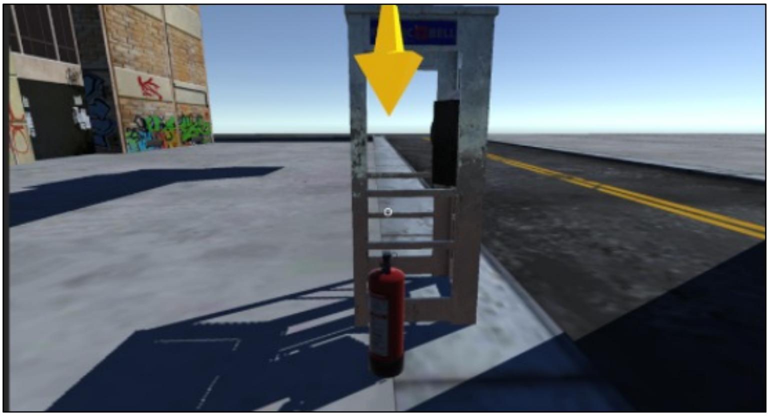
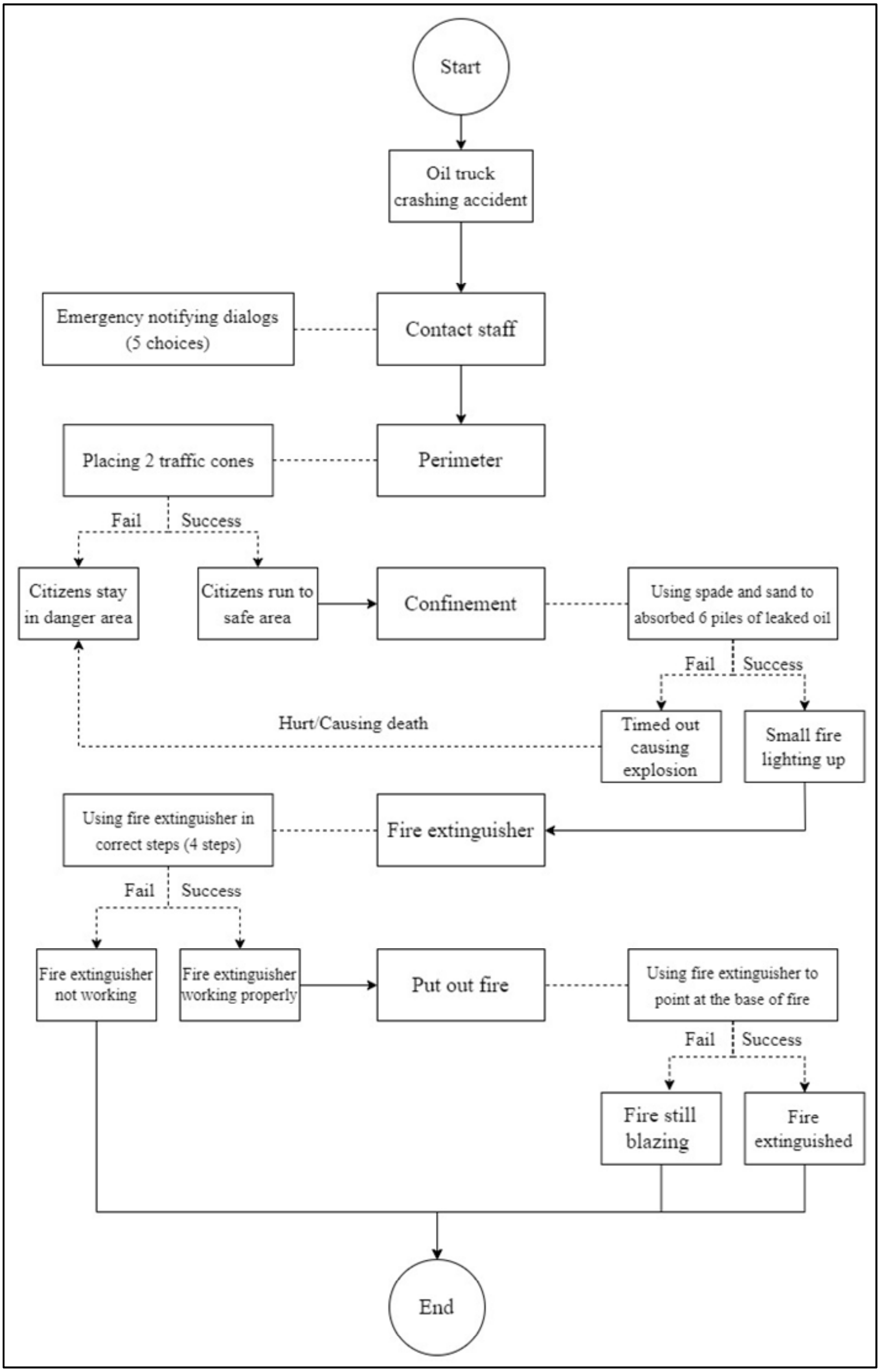


Figure 7 Put out the fire task requiring the using of extinguisher to aim at the fire (see online version for colours)

The procedure above is the correct process that the instructors designed. However, the students can do any process before or after in the virtual world. Instead, it will affect the overall score of the users if the sequences are incorrect. Additionally, the overall condition and flow in of the ERVaR are displays in Figure 8. The immersive virtual environment is developed using the Unity 3D program with Google Cardboard and Firebase plugin to create a VR experience and a cloud database for data storage. Moreover, the website development uses the Vue framework for creating a website for data visualisation, tests, and questionnaires.

Figure 8 The conditions and overall flows of the ERVaR GBL

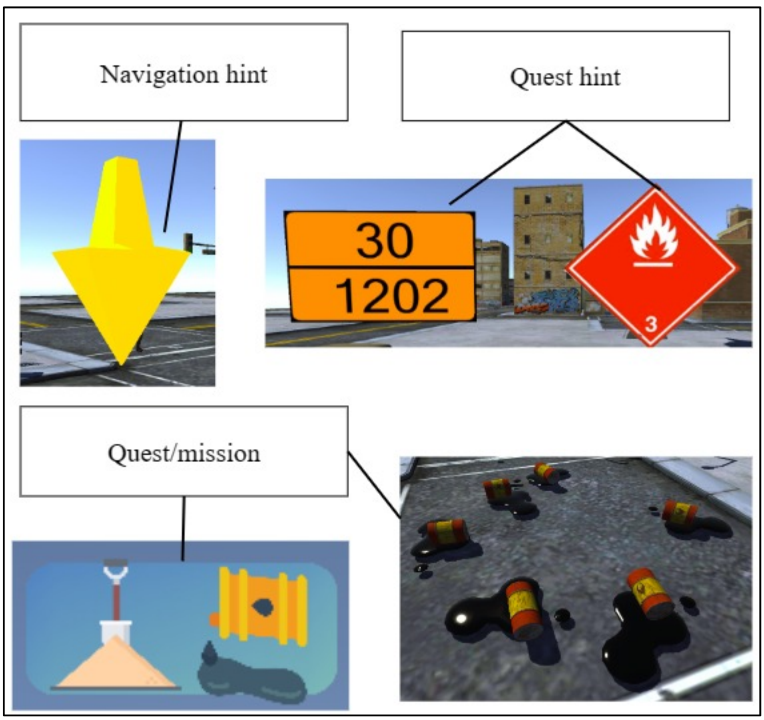


3.2.2 Challenge

While the students went through the immersive GBL experience, they had to handle the situation together with the challenge in each mission as they went on. These challenges were one of the learning mechanics for practising and providing hands-on learning to the students for readiness to solve an unexpected problem that could occur in a real-life emergency through the challenge and quest in an immersive environment.

Figure 9 illustrates the challenge and quest in the game. While the students go through the game, the system will not teach or tell them to do something specific, but it will give a hint in navigation and activity instead. The mission or quest was displayed with the icon on the top-right corner of the screen, and the hint was displayed in the virtual world environment to let the students see it while they explored.

Figure 9 Game mechanics in the immersive GBL system (see online version for colours)



3.2.3 Point system

As each storyline and mission has score criteria for checking the correctness and giving a point to the students. The criteria consisted of two correctness dimensions, as shown in Figure 10. First, sequence correctness was the criteria for checking whether the order or sequence in those students engaged with the activity in the virtual world was correct. Second, the activity correctness was used to check whether or not the students finished each mission properly. For example, the students must place the cones in the right spot on the road; if they place them correctly before the time runs out, they can continue the mission.

Figure 10 Scoring and point criteria of each mission in the ERVaR system

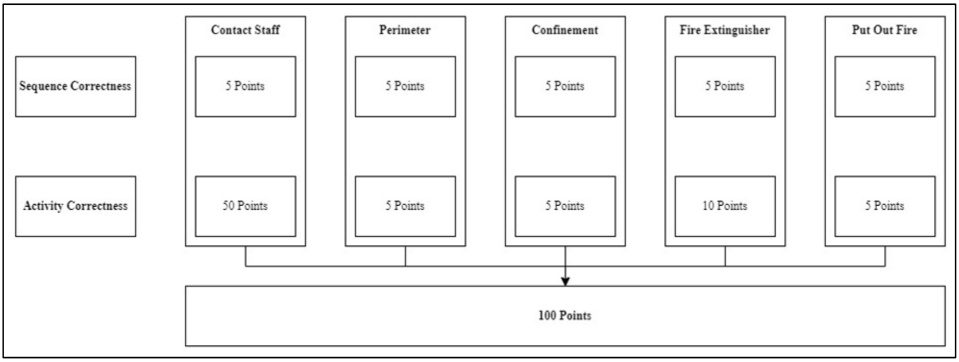
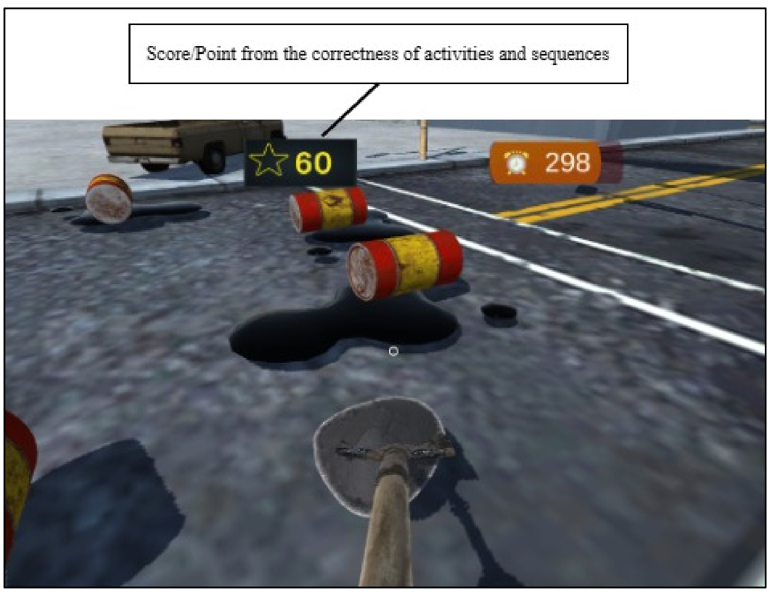


Figure 11 Scoring and point in the immersive GBL system (see online version for colours)



As shown in Figure 11 the point system displayed the students' scores according to the sequence and activity correctness. The score started from zero and then increased as the students appropriately performed in the virtual world. This mechanic provides real-time feedback to the students on whether they perform it correctly or still incorrectly and must find a way to improve.

3.2.4 Timing

The overall timing in the game starts from 360 seconds or six minutes and will decrease over time. Therefore, the students must handle every mission within the time limits under pressure. Additionally, there is a bonus time for the students with the condition that the students have to answer all the dialogue questions correctly in the 'contact staff' mission at the beginning. The students will receive an additional bonus time of 10 seconds, as illustrated in Figure 12.

Figure 12 Bonus time condition at the beginning of the learning game system

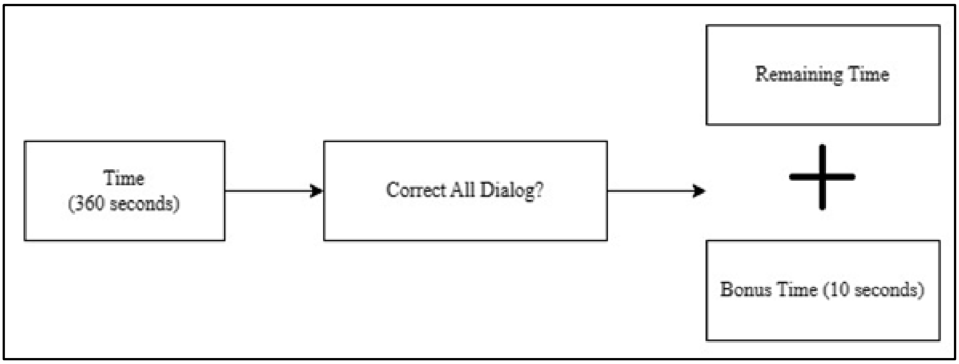


Figure 13 Timing mechanic in the immersive GBL system (see online version for colours)

According to Figure 13, the timing bar shows the time limit for the students. As each mission has a limited time. The students must proceed and manage their time accordingly. Therefore, the experience that this timing mechanic benefits the students would be working under pressure, stressful, and demanding situations for quick decisions as the ER officer.

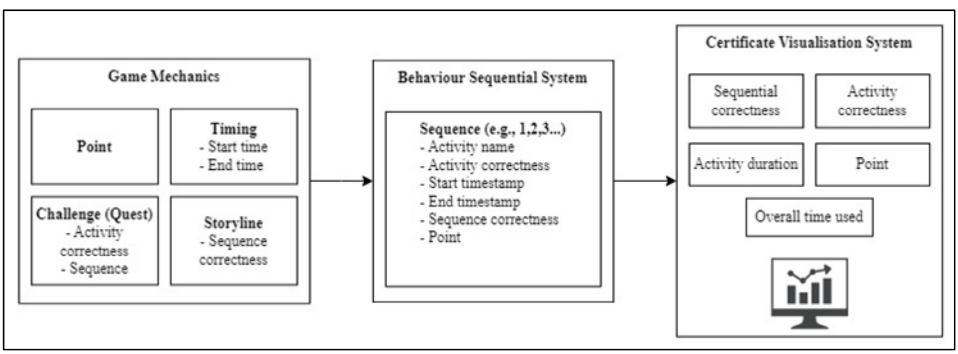
3.3 Behaviour sequential system

According to Figure 1, one of the main parts of the Immersive virtual environment-based gaming approach is the ERVaR website, which is the system's website for analysing and visualising the behaviour data. The ERVaR website consists of two features: the behaviour sequential system, which is the behaviour analysis system, and the certificate visualisation system, which is the system for displaying and visualising the output from the behaviour analysis system to the teachers and students. Therefore, the logic and process of these two functions are described in this section.

3.3.1 Analysis

Figure 14 displays the system analysis process of the immersive GBL system. The process starts with the game mechanics that send all necessary data to the sequential behaviour system. Then the behaviour sequential system will gather the data which are required for behaviour analysis, for example, sequence – the information to determine the activity order of the students in the virtual world; activity name – the information which shows the activity that the student performs like 'perimeter', and more. These data will be kept for visualisation and feedback to the students in the certificate visualisation system next.

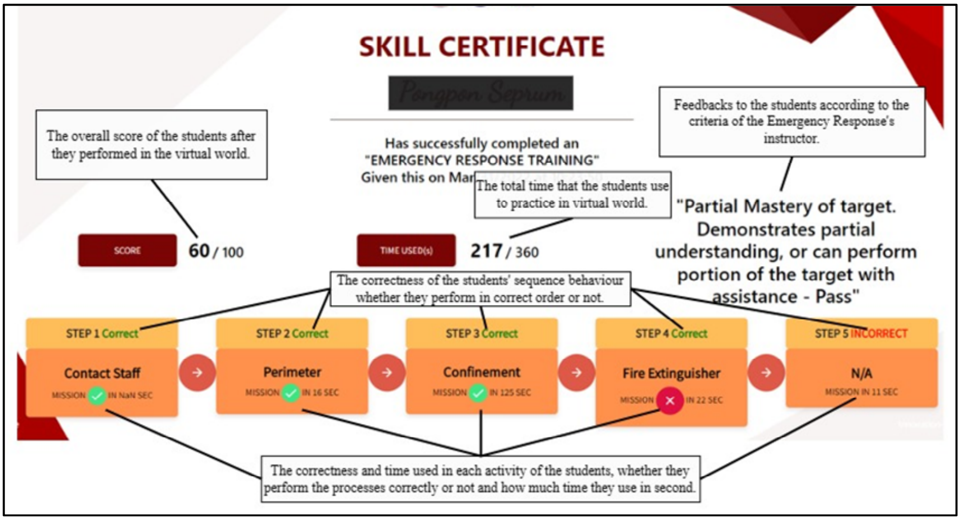
Figure 14 The sequential behaviour system and certificate visualisation system logic



3.3.2 Certificate

According to Figure 15, the certificate visualisation system shows the sequential behaviour of the students. Therefore, the visualisation system will gather the required data and check whether they are correct. For example, to check the sequential correctness, the system would analyse the process to determine whether the students' activity sequence would be as 'contact staff perimeter confinement fire extinguisher put out fire' if not, the system will show the word 'INCORRECT' in red on the certificate as shown in Figure 15. Moreover, the behaviour analysis system can provide more precise feedback to the instructor as they can see the necessary information that must be considered in ER learning.

Figure 15 Dashboard as the skill certificate of the student on the website (see online version for colours)



4 Experiment design

4.1 Participants

There were two groups of participants in this study. First, the EG that learned through an immersive virtual environment GBL approach comprised 133 third-year undergraduate students in the OH and safety program. Second, the CG that learned through a conventional mobile learning approach from the university with OH learning consisted of 117 undergraduate students. Also, the average age of both the participant groups is 20 with 171 females (68%) and 79 males (32%). The two participant groups were recruited from the two specific classes with a purposive sampling method to comply with their availability and contextual conditions.

4.2 Measuring tools

The study collected data through pre- and post-questionnaires, including pre-test, pre-learning motivation, post-test, post-learning immersion, and post-learning motivation. The questionnaires were verified by instructors and experts. Additionally, the study collected behaviour sequence, overall score, and overall time data from students as they completed the learning process in the immersive virtual environment-based gaming approach.

The study used pre- and post-tests consisting of ten multiple-choice questions each. The tests evaluated participants' ER knowledge of fire prevention and control and chemical ER technique management. The tests were designed by instructors, with a maximum score of ten points and were verified by experts, demonstrating acceptable internal reliability with a Cronbach's alpha of 0.690. The pre- and post-tests can be used to answer research question 1 related to learning performance.

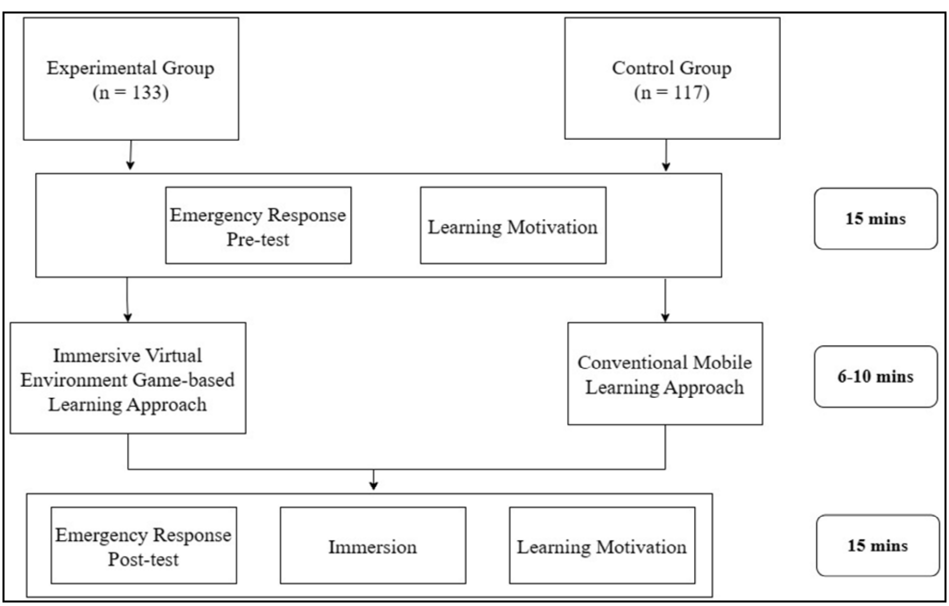
For immersion measurement in this study, the engagement, engrossment, and immersion questionnaire from Nicolaidou et al. (2021) was adapted. The questionnaire consists of 21 rating scale questions using a seven-point Likert scale, with eight questions on engagement, six on engrossment, and seven on immersion. The adapted questionnaire was tested on a similar group of participants to confirm its internal reliability, with a Cronbach's alpha of 0.780. Thus, the adapted questionnaire is suitable for answering research question 2 related to examining the immersion experience.

In this study, a questionnaire based on the attention, relevance, confidence, and satisfaction (ARCS) model from Hao et al. (2019) was adapted to examine learning motivation. The ARCS questionnaire comprises 18 rating scale questions using a five-point Likert scale, with five questions on attraction, four on relevance, three on confidence, and six on satisfaction. The adapted questionnaire's internal reliability was tested with a similar group of participants, with a Cronbach's alpha of 0.810. Thus, the adapted ARCS questionnaire is appropriate for answering research question 3, which investigates learning motivation.

4.3 Research procedure

The research experimental design process has been visualised in Figure 16. Both the EG and CG take a pre-test and learning motivation questionnaire. The EG then experiences the proposed immersive virtual environment-based gaming approach, while the CG experiences the conventional mobile learning approach. After the intervention, both groups take the same post-test, immersion questionnaire, and learning motivation questionnaire.

Figure 16 The overall experimental process design



5 Experimental results

5.1 Analysis of learning performance

Initially, the data distribution was tested using Shapiro-Wilk's test. The result showed that the data is normally distributed ($p > 0.05$) with Levene's test of homogeneity of variances. Therefore, the ANCOVA was used to analyse the post-test scores of the two groups. The ANCOVA was performed using pre-test scores as a covariate variable, post-test scores as a dependent variable, and learning approach (conventional mobile learning approach and immersive virtual environment-based gaming approach) as an independent variable.

Table 1 shows a significant difference between the two groups of the students' post-test scores ($F_{(1,246)} = 30.452$, $p < 0.001$, $n^2 = 0.110$). The result supported that the proposed immersive system could provide better learning achievement to the students.

Table 1 ANCOVA analysis of students' post-test scores of learning achievement

Group	*n*	*Unadjusted*		*Adjusted*		$F_{(1,246)}$	η^2
		M	*SD*	*M*	*SE*		
CG	117	1.709	1.833	4.793	0.330	30.452**	0.110
EG	133	7.228	1.063	6.386	0.228		

Note: $^{**}p < 0.01$.

This study also analysed the interaction between the learning approach and learning achievement levels. Therefore, the K-means clustering was executed on both groups' post-test scores to determine their learning achievement levels. The result indicated the two groups of learning achievement levels: low-achievement ($n = 117$, $M = 1.400$, $SD = 1.340$) and high-achievement ($n = 133$, $M = 7.240$, $SD = 0.980$). The ANCOVA was performed using pre-test scores as a covariate variable, post-test scores as a dependent variable, learning approach (conventional mobile learning approach and immersive virtual environment-based gaming approach) and learning achievement (low and high) as independent variables. The homogeneity of regression was conducted before performing the two-way ANCOVA. As shown in Table 2, the result was statistically significant between two independent variables ($F_{(1,245)} = 5.502$, $p = 0.020$, $\eta^2 = 0.022$). Moreover, Table 3 shows descriptive data of the learning achievement on each learning approach.

Table 2 Result of two-way ANCOVA on student's learning achievement

Source	*SS*	*df*	*MS*	*F*	η^2
Learning approach	5.429	1	5.429	5.137*	0.021
Achievement level	102.347	1	102.347	96.853**	0.283
Learning approach × Achievement level	5.814	1	5.814	5.502*	0.022

Note: $^{*}p < 0.05$, $^{**}p < 0.01$.

Table 4 shows the simple main effect conducted to analyse the interaction effects further. The result revealed a statistically significant high achievement level for students between the two learning approaches ($F(1,245) = 0.056$, $p = 0.005$, $\eta2 = 0.000$). The high-achievement level students of the immersive virtual environment-based gaming approach have higher post-test scores (M = 6.488, SD = 0.179) than the high-achieving students of conventional mobile learning post-test scores (M = 6.391, SD = 0.332). Also, the two learning approaches had no significant difference in low-achieving students' post-test scores. Moreover, the students with different achievement levels (high and low achieving groups) in conventional mobile learning ($F(1,245) = 132.160$, $p = 0.000$, $\eta 2 = 0.350$) and immersive virtual environment-based gaming approach($F(1,245) = 22.863$, $p = 0.000$, $\eta 2 = 0.085$) were significantly different on the post-test scores of learning achievements. This result can be implied that the students with high achievement levels were the ones who benefited from the proposed approach the most compared to the other groups in the conventional mobile learning approach.

Table 3 Descriptive data of the learning achievements

Learning approach	*Achievement level*	*n*	*M*	*SD*
Conventional mobile learning	Low	107	2.290	0.205
	High	10	6.391	0.332
Immersive game-based learning	Low	4	3.856	0.514
	High	129	6.488	0.179

Table 4 Simple main-effect analysis of the students' learning achievements

Dependent variable	*SS*	*df*	*MS*	*F*	η^2
Learning approach					
Low	0.060	1	0.060	0.056	0.000
High	8.643	1	8.643	8.179*	0.032
Achievement level					
Conventional mobile learning	139.656	1	139.656	132.160**	0.350
Immersive game-based learning	258.896	1	24.160	22.863**	0.085

Note: **p* < 0.05, ***p* < 0.01.

5.2 Analysis of learning immersion

The data distribution normality test was conducted using the Shapiro-Wilk test to investigate the experimental and CGs' immersion. The result showed a non-normal data distribution. Therefore, the Mann-Whitney U test was used for the non-parametric independent variables of the immersion. Also, Table 5 displays the overall immersion comparison between the conventional mobile learning ($n = 117$, $M = 2.700$, $SD = 0.460$) and immersive virtual environment-based gaming approach ($n = 133$, $M = 6.280$, $SD = 0.600$). The result showed a significant difference between the two approaches ($U = 0$, $Z = –13.769$, $p < 0.001$) and reject the null hypothesis.

For examining the deeper immersion (engagement, engrossment, and total immersion) between the two learning approaches, whether there was a difference in which dimension of the immersion. Furthermore, Table 6 shows a statistically significant of all three dimensions of immersion in engagement ($U = 0$, $Z = –13.780$, $p < 0.001$), engrossment ($U = 0$, $Z = –13.790$, $p < 0.001$), and total immersion ($U = 11$, $Z = –13.750$, $p < 0.001$) in the immersive virtual environment-based gaming approach group. This result indicated the rejection of null hypothesis that the immersive virtual environment-based gaming approach could provide a better immersion than the conventional mobile learning approach.

Table 5 Overall immersion comparison using Mann-Whitney U test

Source	*n*	*M ± SD*	*Mean rank*	*Sum of ranks*	*U*	*Z*
Conventional mobile learning group	117	2.700 ± 0.460	59.000	6,903.000	0	–13.769***
Immersive game-based learning group	133	6.280 ± 0.600	184.000	24,472.000		

Note: ***p < 0.001

Table 6 Engagement, engrossment, and immersion comparison using Mann-Whitney U test

Dimension	*Source*	*n*	*M ± SD*	*Mean rank*	*Sum of ranks*	*U*	*Z*
Engagement	CG	117	2.940 ± 0.350	59.000	6,903	0	–13.780***
	EG	133	6.260 ± 0.600	184.000	24,472		
Engrossment	CG	117	2.500 ± 0.450	59.000	6,903	0	–13.790***
	EG	133	6.370 ± 0.580	184.000	24,472		
Total immersion	CG	117	2.690 ± 0.530	59.090	6,914	11	–13.750***
	EG	133	6.300 ± 0.570	183.920	24,461		

Note: ***$p < 0.001$.

Table 7 The Pearson's correlation coefficient of the EG students' immersion among six dimensions of the questionnaire

Dimension		*Interest*	*Usability*	*Emotional attachment*	*Focus of attention*	*Presence*	*Flow*
1	Engagement						
1.a	Interest						
1.b	Usability	0.460*					
2	Engrossment						
2.a	Emotional attachment	0.790*	0.530*				
2.b	Focus attention	0.490*	0.680*	0.570*			
3	Total immersion						
3.a	Presence	0.370*	0.810*	0.540*	0.840*		
3.b	Flow	0.560*	0.750*	0.780*	0.730*	0.810*	

Note: *$p < 0.05$.

Additionally, while the immersion of the EG students is high, the Pearson's correlation coefficient was conducted on each pair of immersion dimensions of the EG. As shown in

Table 7, the result shows a significant relationship between the six dimensions. It could be interpreted that students can immerse and receive an immersive experience from the proposed VR learning system.

Table 8 Overall comparation of the learning motivation between EG and CG using Mann-Whitney U test

Data	*Group*	*n*	*M* ± *SD*	*Mean rank*	*Sum of ranks*	*U*	*Z*
Pre-learning motivation	CG	117	4.840 ± 1.340	61.120	7,151.000	248	–13.320***
	EG	133	4.710 ± 0.0420	182.140	24,224.000		
Post-learning motivation	CG	117	2.700 ± 0.310	59.010	6,904.000	1	–13.800***
	EG	133	4.830 ± 0.230	183.990	24,471.000		

Note: ***$p < 0.001$.

Table 9 Attention, relevance, confidence, and satisfaction comparison between the EG's high and low-achieving students

Dimension	*Learning achievement*	*n*	*M* ± *SD*	*Mean rank*	*Sum of ranks*	*U*	*Z*
Attention	High	129	4.840 ± 0.220	67.020	8,646.000	255.000	–0.040
	Low	4	4.880 ± 0.080	66.250	265.000		
Relevance	High	129	4.840 ± 0.240	67.100	8,656.500	244.500	–0.200
	Low	4	4.840 ± 0.080	63.630	254.500		
Confidence	High	129	4.780 ± 0.290	67.050	8,649.500	251.500	–0.090
	Low	4	4.840 ± 0.110	65.380	264.500		
Satisfaction	High	129	4.850 ± 0.230	67.100	8,656.500	244.500	–0.200
	Low	4	4.850 ± 0.080	63.630	254.500		

5.3 *Analysis of learning motivation*

To better understand the students' motivation for both learning approaches, the mean difference statistic was conducted to find whether there was any difference in pre-motivation and post-motivation between conventional mobile learning and immersive virtual environment-based gaming approach. The Shapiro-Wilk test found a non-normal data distribution ($p < 0.05$). As a result, a Mann-Whitney U test was used for non-parametric independent variables. Table 8 indicates that there were significant differences in both pre-learning motivation ($U = 248$, $Z = –13.320$, $p < 0.001$) and post-learning motivation ($U = 1$, $Z = -13.800$, $p < 0.001$), and rejected the null hypothesis. Also, the students with an immersive virtual environment-based gaming approach had higher pre-motivation and post-motivation.

Further analysis was conducted for the EG motivation on learning achievement investigation to find whether there was a difference in motivation between high-achieving and low-achieving students. The Mann-Whitney U test was applied for non-parametric independent variables. The result revealed no significance between high-achieving and low-achieving students on motivation, as shown in Table 9. This result implied that the students still have high motivation in the immersive VR experience, whether their achievement levels were high or low.

6 Discussion and conclusions

6.1 Discussion

The findings of this study suggest that students achieve higher learning outcomes in immersive virtual environment-based gaming approach. This finding is consistent with a study that employed a VR with a reflective cycle-based approach in healthcare training and found effective improvements in students' learning achievement, sense of presence, critical thinking, and problem-solving awareness (Hwang and Chang, 2022). The engaging and interactive nature of GBL environments, which provide challenge, exploration, and adventure, likely motivates students to engage in the learning process (Hung et al., 2018). Immersive virtual environment-based gaming approach provide feedback on student performance, allowing them to reflect on mistakes and improve accordingly (Yang and Chen, 2021). In addition, these environments simulate real-life situations, enabling students to practice problem-solving and critical thinking skills in a safe and controlled environment. With a trial-and-error learning approach, students can develop a deeper understanding and transfer their knowledge to real-world situations (Wong and Lim, 2018). Providing interactive learning opportunities where students are encouraged to experiment and make mistakes without fear of failure can enhance learning achievement, self-efficacy, and communication skills while making learning enjoyable (Hwang et al., 2022). These findings align with those of Yang et al. (2020), which demonstrated that immersive virtual environment-based gaming approach can offer better learning outcomes for students.

The second finding of this study concerns the immersion of students in immersive virtual environment-based gaming approach, which was significantly higher than that of students in conventional mobile learning environments. This result was expected, as modern smartphones with gyroscope sensors can provide a VR function to the user through the mobile device. While the VR function in smartphones may offer a lower level of immersion than high-end VR devices, it can still provide a similar immersive experience. This finding contradicts the results of another study that compared immersive virtual environment-based gaming approach with mobile learning approach in language learning (Nicolaidou et al., 2021), which found no significant difference between the two approaches. Further investigation using Pearson's correlation coefficient revealed strong positive correlations between the six dimensions of immersion. The strongest correlation was found between emotional attachment and interest (0.790), suggesting that students with a strong emotional attachment to the system tend to have a higher level of immersion. Additionally, a strong positive correlation was found between usability and presence (0.810), indicating that the more accessible the immersive virtual environment-based gaming approach, the more realistic the student's experience. Positive correlations were also found between focus of attention and presence (0.840) and flow and presence (0.810), suggesting that students who can focus and experience flow tend to have a higher realistic feeling, contributing to their immersion in the learning experience.

This study found that students in immersive virtual environment-based gaming approach were more motivated than those in conventional mobile learning environments. This result may be due to the engaging, motivating, and interactive nature of GBL, which has positive psychological effects on students. Table 9 shows that the post-learning motivation means for the low-achieving group were higher than those for the high-achieving group for the attention and confidence dimensions. However, it is important to note that the sample size of the low-achieving group is very small, which may affect the representativeness of the results. Another significant finding was the deeper insight gained when investigating the impact of immersive virtual environment-based gaming approach motivation on learning achievement level (high achieving group and low achieving group). Comparing each dimension of motivation (attention, relevance, confidence, and satisfaction) between high- and low-achieving students through the Mann-Whitney U test, there was no significant difference between the two groups. This suggests that motivation was the same for both groups, indicating that students can enjoy the immersive virtual environment-based gaming approach regardless of their learning capabilities. These findings align with those of Kim et al. (2022), who found that VR could result in high immersion and motivation among students. Furthermore, this study's findings are similar to those of Wang et al. (2022), who used a GBL approach to promote learning achievement, engagement, and motivation among students and found effective enhancement of knowledge and positive flow experience.

6.2 Conclusions

In summary, this study developed an immersive virtual environment-based gaming approach for ER learning to provide students with a virtual learning experience that is fun, engaging, and fosters trial-and-error learning in a damage-free environment. The study was conducted with two groups of students: a CG of 117 students using a conventional mobile learning approach and an EG of 133 students using an immersive VR approach with GBL. The study also investigated the pre-data (knowledge and motivation) and post-data (knowledge, motivation, and immersion) of the participants. The results show that the immersive virtual environment-based gaming approach with a GBL approach provided higher learning achievement, learning motivation, and immersion for the students compared to the conventional mobile learning approach. The novelty of this study lies in its detailed examination of the learning factors (achievement, immersion, motivation) in each dimension of those factors, providing deeper insights and findings.

Several recommendations for various practitioner roles can be illustrated. First, the trainer, teacher, and instructor can apply the idea of using VR in training as it can provide students with an interactive virtual training environment. Second, the learner, student, or trainee could use the immersive VR for trial-and-error training to achieve a training experience with challenges in the virtual world. Third, the education technology developer or related roles could consider the application of VR in smartphones for mobile or ubiquitous education with the GBL approach to enhance the students' learning experience. Moreover, GBL can also be applied and recommended to various roles in the education field. First, it can provide an engaging and interactive learning experience to the students and leads to better motivation and learning outcomes, and this is the advantage the educators or learning designers can take or apply to their learning process. Additionally, GBL can provide trial-and-error learning environments and give students real-time feedback on their performance; this could be a significant benefit for healthcare-related roles where hands-on practice plays a vital role in success.

Moreover, this study could share several limitations for future studies. Regarding the ERVaR system, the scenario in immersive VR currently has only one scenario, but the ER scenario may require other situations for training and providing the experience to the students; for example, the emergency drills in the library, labs, classroom, and factory, and more (Buttussi and Chittaro, 2021; Li et al., 2022; Liang et al., 2019; Monteiro et al., 2021). Moreover, one of the limitations of immersive VR technique applications is the device limitation. Future researchers can keep in mind that using VR techniques on a smartphone means lower immersion and lower autonomy controlling sense (grab or interact using hands or controller) in the virtual world. Additionally, the author would like to share further studies on improving the results of learning performance, learning immersion, and learning motivation, as the current participant groups in this study are the comparison between conventional mobile learning and immersive game-based mobile learning. Besides, this study aims to investigate and analyse other participant groups, for example, in another country, role, and age.

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