Digital Transformation for Occupational Safety Awareness Training by Metaverse Technology

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***Abstract* – Occupational safety training is critical to ensuring a safe work environment. However, traditional training methods often fail to fully engage learners and replicate real-world scenarios. The emergence of metaverse technologies presents new opportunities to digitally transform occupational safety awareness training. In this study, a novel approach is proposed for occupational safety awareness training using immersive simulations within the metaverse. The approach was evaluated by analyzing the acceptance, effectiveness, and interaction with usability success rate and administered a user experience questionnaire (UEQ). The research results indicate that incorporating immersive technology enhances the quality of training experience. The proposed model achieved an average usability success rate of 71%, reflecting an overwhelmingly positive user experience. The UEQ scores confirm this positive trend, with users rating attractiveness and stimulation as good (respectively 1.78 and 1.70). At the same time, perspicuity, efficiency, reliability, and novelty received ratings surpassing the average (ranging from 1.22 to 1.51). The efficacy of an immersive approach for occupational safety training was 65.8%, which qualifies as sufficiently effective.**

These findings highlight the potential of immersive technology in advancing occupational safety training by enhancing engagement, comprehension, technology performance, and empowering learners in safety awareness journey.

***Keywords* – Immersive technology, metaverse, occupational safety, training, Virtual Reality.**

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1. Introduction

Training is a systematic process to enhance skills and enable adaptation to change. Educational technology should promote learner empowerment through active interaction [1]. Facilities provided by training institutions are crucial for convenience and motivation. Interaction is fundamental in learning between trainer and trainees, among trainees, and with materials [2], [3], [4]. Limited interactivity hinders learning objectives. Learning aims to cultivate intellectual abilities, curiosity, and skills through conceptual and experiential knowledge [5], [6]. Distance learning involves interactions between attendees, instructors, content, interfaces, media, social and psychological connections [7]. User Interaction encompasses communication, authority, and influencing digital environments through navigation, contact, editing, and communication [8], [9], [10], [11], [12].

Traditional face-to-face learning approaches led by instructors can sometimes cause learners to feel lonely, distant, and disengaged, lacking meaningful relationships and interactions [13]. Moreover, training participants often need further expertise to communicate the newly gained knowledge effectively [14]. Thus, implementing effective hands-on learning using online tools poses challenges for training institutions. Due to insufficient practical resources, institutions rely solely on theoretical online discussions rather than experiential hands-on practice.

However, as the Director of Indonesian Vocational Development has advised, the ideal learning ratio consists of 25% theory and 75% hands-on practicum since dependence on books and presentations alone can decrease motivation and active participation [15].

Educational developers can utilize learning interactions like drills, practice exercises, tutorials, games, simulations, discoveries, and problem-solving activities in creating interactive educational media tailored to the specific traits and circumstances of the learners [16]. In the future, immersive technology is expected to enhance training attendees' passion and motivation by providing more appealing visualizations and user interfaces, as seen in immersive technology to train teachers using simulated classrooms. Teacher preparation programs aim to equip novice educators with the skills and knowledge necessary to enter, be assigned, and engage in early childhood education.

As organizations undergo digital transformation, traditional training methods are deemed unreliable as they often fail to engage learners fully and provide immersive, hands-on experiences replicating real-world scenarios. This presents a critical need to transform current approaches, particularly occupational safety awareness training, as it involves the safety of the organizational workers. The emergence of metaverse technologies offers a timely solution to digitally transform occupational safety awareness training through immersive simulations that increase engagement, comprehension, and technology performance. Previous study has utilized cutting-edge virtual reality (VR) simulators like TeachLivETM to train novice educators by employing a virtual classroom replicating the physical layout. In these virtual environments, novice educators can refine and perfect research-based teaching practices using their physical and virtual (avatar) classrooms [17].

The objective of this study is to propose a novel approach for occupational safety awareness training using immersive simulations within the metaverse. This will be achieved by assessing the usability success rate and administering a user experience questionnaire (UEQ) for a case analysis that applies practical training for occupational safety awareness through integration into a virtual training environment, which can evolve into a future education system by incorporating immersive technology and specialized metaverse technology to enhance the enjoyment of digital learning [18], [19], [20]. The focus is on implementing the safety module by using 3D objects and settings to simulate an institutional training environment for attendees. This creates diverse applications for educational institutions.

The structure of this paper is as follows: Section 1 introduces the background and rationale for the research.

Section 2 provides the theoretical background of this research. Section 3 details the methodology utilized to conduct the study. Section 4 presents the key findings from the data analysis and discusses the implications. Finally, Section 5 summarizes the conclusions drawn from the research and proposes potential avenues for future work.

2. Theoretical Background

This section describes the theoretical background of occupational safety awareness training, immersive technology, and the metaverse utilized to digitally transform occupational safety awareness training. Immersive technologies, such as virtual and augmented reality, coupled with the metaverse, allow for highly engaging and spatially contextualized learning experiences regarding occupational hazards and injury prevention approaches for workers in the workplace.

2.1. Occupational Safety Awareness Training

Occupational safety awareness training refers to initiatives that instruct participants on risk recognition, preventative measures, and workplace hazards to enhance knowledge and comprehension of potential risks within the work environment and guide identification, reporting, and management. The training programs may encompass a variety of visual aids, including videos, interactive group discussions, statistics, real-life anecdotes, and stories. The subjects covered may include emergency action planning, machine security, infectious disease control, prevention of workplace violence, and emergency action planning [18].

2.2. Immersive Technology

Immersive technologies, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), play an increasingly vital role in training and education across diverse fields and industries. These technologies enable users to experience simulated environments and situations as genuinely as possible, thereby providing highly engaging and interactive learning experiences [17].

VR demonstrates substantial promise for occupational safety training by furnishing immersive, realistic environments where potentially dangerous workplace situations can occur without exposing workers to physical risk.

Studies indicate that VR safety training is more engaging and leads to superior knowledge retention than conventional training methods [15], [21]. For instance, VR simulations have trained workers in proper equipment handling, accident response protocols, and hazard identification. VR allows workers to experience accidents and safety violations from a first-person perspective and acquire muscle memory of appropriate emergency protocols.

AR and MR can augment physical workspaces with contextual training content and guidance. For example, AR helmets can overlay step-by-step instructions on machinery operation or highlight potential hazards in the user's field of view. MR blends physical and virtual content, enabling users to interact with virtual objects and avatars as being physically present. This facilitates collaborative, social learning, and mentoring.

2.3. Metaverse

The metaverse's conceptual framework represents the internet's progression towards persistent, interconnected virtual environments. As elucidated in Figure 1, the metaverse aims to integrate the physical and digital worlds, facilitating immersive social interactions between geographically distributed users. This convergence carries profound implications for the future of digital education and occupational training.

The metaverse can provide exceptionally realistic simulated environments for profoundly immersive training through synergistic combinations of virtual reality, artificial intelligence, and cloud computing. Learners may hone skills and procedures in settings nearly identical to real-world contexts. Intelligent virtual mentors and teammates can deliver personalized guidance, feedback, and simulations of team dynamics. Multimodal interfaces involving speech, gestures, haptics, and eye tracking may enable seamless communication between human and virtual agents during training.

The metaverse also can transform remote collaboration, knowledge exchange, and organizational culture in distributed workplaces. Employees across multiple physical locations could convene in shared virtual spaces for meetings, events, and informal interactions through customizable avatars. This could increase access to communal training assets, humanize remote communications, and strengthen institutional cohesion.

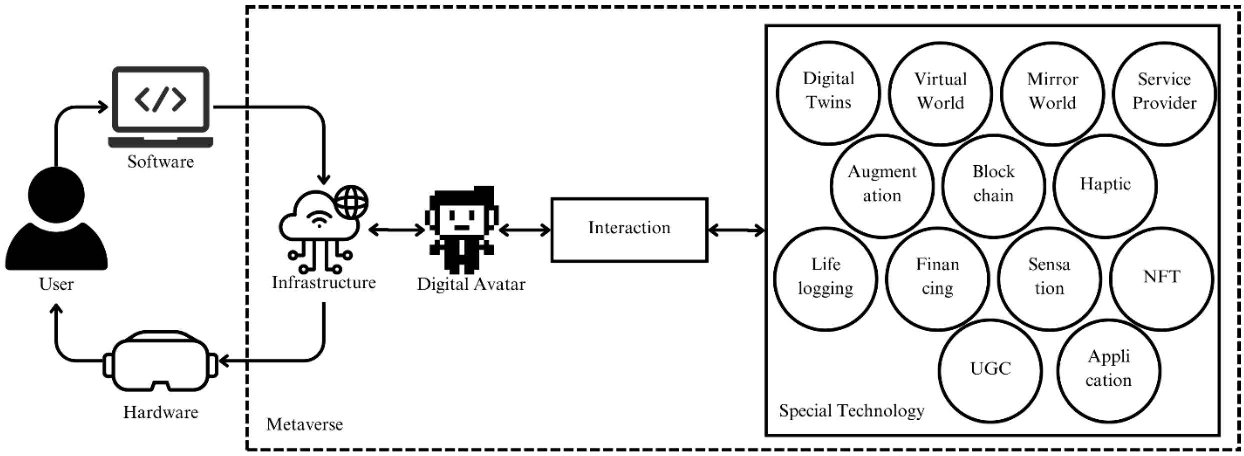

Figure 1. Metaverse framework

3. Research Methodology

The research methodology in this paper involves a study on implementing immersive simulations for improving occupational safety training. The authors propose a solution for immersive digital virtual training simulations within the metaverse and evaluate it by analyzing the acceptance, effectiveness, interaction, and experience. The study uses a quantitative approach and collects data from participants undergoing immersive training simulations.

The authors analyze the data to evaluate the proposed model and draw conclusions about the potential of immersive technology in advancing occupational safety training.

3.1. Requirement Analysis

This research explores the stakeholder perceptions of learners and instructors as stakeholders in the system's design [21]. Considering these perspectives, the system designed in this study utilizes stakeholder perceptions as a foundation for stakeholder requirement analysis [21].

Stakeholder requirement analysis is used to identify the needs of each level. The research focuses on the user layer, primarily training attendees' requirement analysis to identify specific needs. The analysis of stakeholders' requirements is presented in Table 1. Based on the stakeholders' requirements, it is reduced to system requirements. The requirements for the development design are determined to be accommodated by the system, as shown in Table 2.

The selection of learning technology is suggested to meet the training activity model, which consists of five learning activities, including the presentation of material. Interaction with the material, interaction with the facilitator, and interaction between training attendees. These activities are classified into two categories: *representative*, encompassing interactions with media, and *dialogic*, involving mutual engagement between people [22].

Table 1. Stakeholder requirements of training based on the metaverse

Variables	Stakeholder Requirements
Increase social presence	For more natural social experience in a training environment resembling a face-to-face class atmosphere
	Better interactions with instructors and classmates have been realized.
	It is simulating social experiences that enhance natural interactions.
Access to training	Requires access to a virtual environment that offers simulations and scenarios not limited by place and time.
	Access to training contexts that are difficult to reach in ordinary online training.
	Expanding knowledge and skills through immersive training experiences.
Increase understanding and knowledge	Obtaining appropriate and needed content.
	For more exciting and interactive training experience
	Gaining access to immersive content.
Increase training experience	Facing realistic situations and tasks in a virtual environment to develop practical skills.
	Applying haptic sensation, sight, and some limbs.
	Expecting more real practical experience to enhance understanding and skills.
Increase motivation and engagement	Innovative and exciting use of technology to generate interest and motivation in training.
	Increasing engagement in learner-driven training.

Table 2. System requirements

No.	System Requirements
1.	The system provides a training environment that resembles a face-to-face class.
2.	The system can synchronize user interaction features through communication and stable operation.
3.	The system provides a simulated social experience.
4.	The system is a virtual environment simulation that users can access without space and time limitations.
5.	The system encourages users to interact with training materials that are difficult to reach for regular online training.
6.	The system can provide training experiences that can increase knowledge and skills.
7.	The system provides appropriate and needed content (material access rights in videos and readings form).
8.	The system can provide an exciting and interactive experience.
9.	The system can provide access to immersive content.
10.	The system reflects activities and situations to improve the users' practical skills.
11.	The system can synchronize devices that support haptic sensation, virtual reality, and sensitivity to body movements.
12.	The system provides practical and real-life experiences, thereby enhancing understanding and skills.
13.	The system uses innovative and exciting technologies.
14.	The system can increase user involvement in training.

3.2. Element Task

The immersive element in training is a supplementary factor that can enhance participants' intrinsic motivation in training. An immersive experience can be achieved by designing a training environment and implementing a structured learning procedure [23]. The primary focus of immersive designs is the user layer. The user layer serves as the educational interface through which attendees are trained. This layer includes supplementary components such as practical lessons and a hall that allows users to freely engage with their surroundings and other users, allowing them to explore the world beyond the scope of the training experience. The use of virtual environments in education and training is justified by various factors, including innovative visualization techniques, enhanced interaction and motivation among trainees, and the acquisition of valuable skills and experiences by participants [24]. The virtual environment can be a method to acquire knowledge through firsthand experience.

User engagement is a term that encompasses behavioral, cognitive, and affective reactions [25]. Deep engagement can potentially help users learn a particular subject [26]. The interaction task directly affects user engagement by altering the degree of interactivity and involvement users experience in a system or application. Well-designed, intuitive, and user-friendly interaction tasks improve the user experience and increase engagement.

Figure 2 summarizes different user interaction tasks and the cues or controls a user can use to perform those tasks. The tasks are categorized into four groups: (1) Navigation, tasks that allow the user to move around in a virtual or real environment; (2) Contact, tasks that allow the user to interact with objects in the environment; (3) Editing tasks that allow the user to modify objects in the environment; and (4) Communication tasks that allow the user to communicate with other users or systems [27].

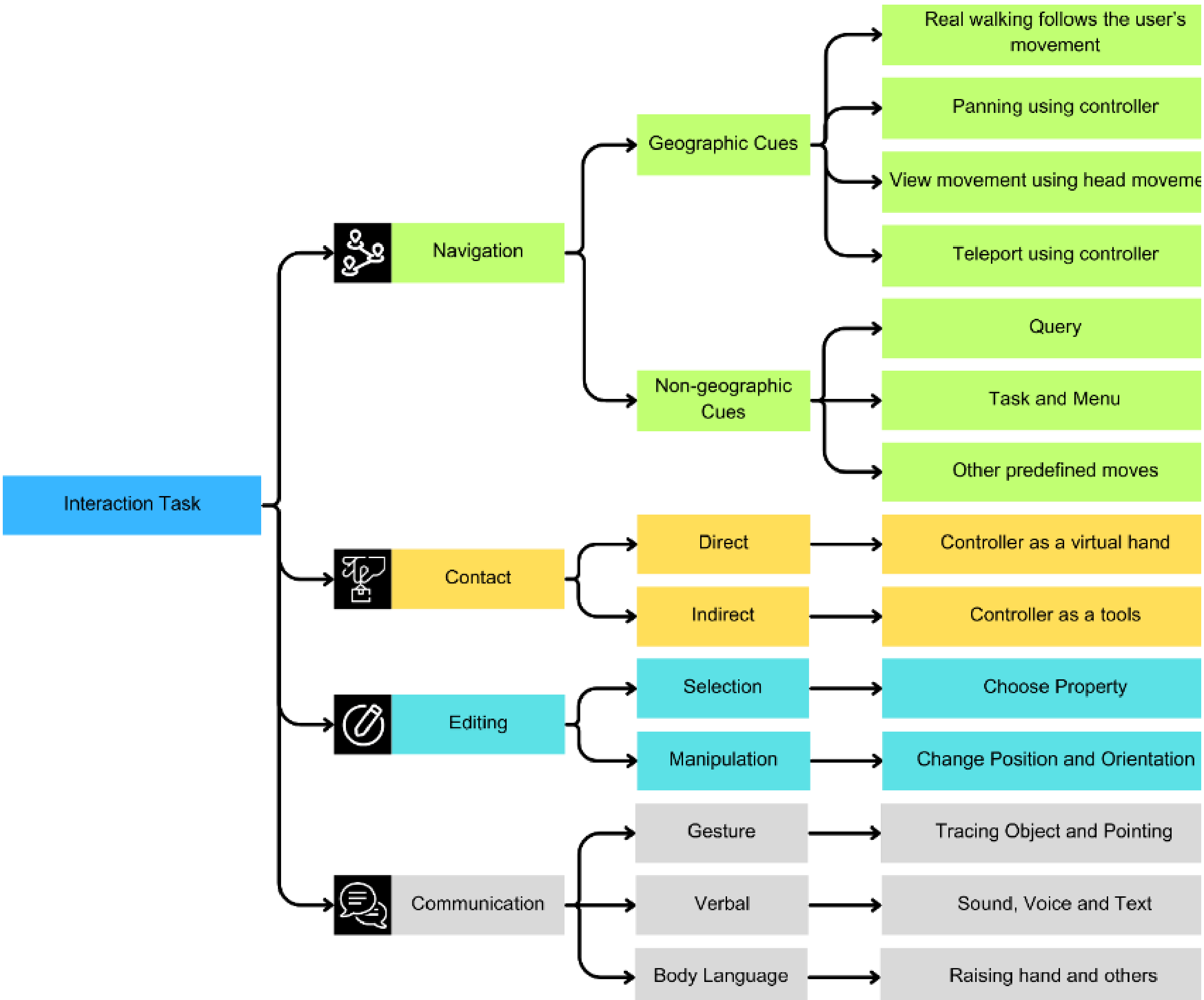

Figure 2. User interaction task for metaverse in education and training

3.3. Participants

The sample size for the study was determined using the Slovin method, with a tolerance limit of 10%. The formula for the Slovin method is shown in equation (1) as follows:

$$n = \frac{\mathrm{N}}{1 + \mathrm{Ne}^2} \quad (1)$$

where n: sample size; N: population size; and e: tolerance limit. The value of n was decided based on the maximum number of training attendees in one class, which is 36. To generate two sample groups, one consisting of training attendees who have learned the training module and the other consisting of training attendees who have not learned the training module, A total population size of n =72.

Therefore, as determined by the method, the minimum required sample size is 42 individuals participating in the training.

3.4. Assessment Procedures

The respondents' reactions in this study were assessed using a questionnaire test. The study included two sample groups: Group A, consisting of 21 individuals who attended training but had no prior safety module experience, and Group B, consisting of 21 individuals who attended training and had previous safety module experience. The data were gathered by conducting a questionnaire with 20 statement items representing eight variables: control, learning goal orientation, enjoyment, perceived ease of use, perceived usefulness, behavioral intention to use, immersion, and learning outcome [27]. The Likert scale was used to measure each statement to evaluate replies. A score of 1 indicated a response of "strongly disagree," and a score of 5 indicated a "strongly agree." Table 3 displays the variable and questionnaire statement.

Table 3. Questionnaire for user acceptance.

Parameters	Variables	Questions
Control (CTRL)	CTRL1	Free to choose what you want to see or do.
	CTRL2	Allow to control interactions.
Learning Goal Orientation (LGO)	LGO1	Enjoy the learning provided even though I make many mistakes.
	LGO1	Appreciate the learning that is provided because it makes me think.
Enjoyment (ENJ)	ENJ1	The process of learning using the system is enjoyable.
	ENJ2	Happy to use the system.
Learning Outcome (LO)	LO1	The knowledge and skills I gain from the system will be useful.
	LO2	Using the system has helped to improve understanding of the subject matter.
Perceived Usefulness (PU)	PU1	The system reduces stress.
	PU2	The system helps to manage time better.
	PU3	The system helps to think more clearly.
Behavioral Intention to Use (BIU)	BIU1	Want to use the system in the future?
	BIU2	Will continue to use the system in the future.
	BIU3	Plan to continue using the system in the future.
Immersion (IMR)	IMR1	Engaged in what to do in the system.
	IMR2	Get absorbed or lose track of time in the system.
	IMR3	Attention is not easily diverted to other things when using the system.
Perceived Ease of Use (PEU)	PEU1	Learning to operate the system is easy.
	PEU2	Interacting with the system requires little effort.
	PEU3	It is easy to become proficient in using the system.

The researchers also conducted a reliability analysis to ensure the internal consistency of the questionnaire items. Table 4 displays the different tasks that users will be asked to perform. The researchers will gather qualitative data to gain insights into the users' experiences and perceptions of the system's usability. User interaction is evaluated by success rate usability.

The user interaction assessment employs the Serious Gaming Interactive Questions (SGIQ) methodology. SGIQ seeks to enhance assessments by incorporating a virtual world into the questions and motivating respondents to achieve superior outcomes compared to previous attempts. SGIQ consists of three distinct question types: Find Equipment Questions (FEQ), Monitoring Patient Questions (MPQ), and Critical Care Questions (CCQ) [28].

Table 4. Questionnaire for user interaction

Questions	Variables	Answers	Interactions	SGIQ Categories
How should users simulate grabbing a fire extinguisher?	T1	Users should physically reach for the virtual object.	Haptic feedback when reaching for the extinguisher.	FEQ
What is the correct way to use a virtual fire hose?	T2	Users need to mimic the motion of operating a hose.	Haptic resistance and water pressure simulation.	FEQ
How can users check the status of a virtual oxygen tank?	T3	Users must interact with the tank to view indicators.	Haptic feedback and visual indicators on the tank.	MPQ
What actions simulate feeling the heat during a fire scenario?	T4	Users should feel increasing haptic warmth.	Gradual haptic temperature feedback.	CCQ
How do users perform a virtual fire extinguisher inspection?	T5	Users inspect the extinguisher through touch.	Haptic feedback for inspecting different parts.	FEQ
What is the correct way to carry a virtual injured person?	T6	Users simulate lifting and supporting the person.	Haptic feedback for lifting and carrying motions.	MPQ
How can users check for a virtual patient's vital signs?	T7	Users interact with medical equipment for readings.	Haptic feedback when touching vital sign monitors.	MPQ
How should users simulate grabbing a fire extinguisher?	T8	Users should physically reach for the virtual object.	Haptic feedback when reaching for the extinguisher.	FEQ
What is the correct way to use a virtual fire hose?	T9	Users need to mimic the motion of operating a hose.	Haptic resistance and water pressure simulation.	FEQ
How can users check the status of a virtual oxygen tank?	T10	Users must interact with the tank to view indicators.	Haptic feedback and visual indicators on the tank.	MPQ
What actions simulate feeling the heat during a fire scenario?	T11	Users should feel increasing haptic warmth.	Gradual haptic temperature feedback.	CCQ
How do users perform a virtual fire extinguisher inspection?	T12	Users inspect the extinguisher through touch.	Haptic feedback for inspecting different parts.	FEQ
What is the correct way to carry a virtual injured person?	T13	Users simulate lifting and supporting the person.	Haptic feedback for lifting and carrying motions.	MPQ

The assessment in this research analyzed the replies of 42 people in the experimental group. The field study gathers two distinct categories of research data: questionnaires from respondents and pretest-posttest data.

The variety of evaluation outcomes stems from two paired sample groups: Group A, which consists of training attendees without prior safety module instruction, and Group B, which consists of training attendees with prior safety module instruction. SGIQ was implemented using a virtual 3D simulation in this work.

The user interface (UI) presented the instruction, and the question scenarios devised restricted the interactions with objects.

4. Results and Discussions

This section examines the potential impacts of utilizing metaverse technology and immersive simulations for occupational safety training. It focuses on evaluating the efficacy of an immersive approach by considering the precise definition of dimensions, positioning, actions, and interactions required to develop a virtual training environment, as shown in Figure 3. Several analyses, including acceptance, effectiveness, interaction, and experience, are conducted to generate formative and summative evaluation questions assessing user progress during training and outcomes.

Figure 3. Virtual training environment for occupational safety awareness

4.1. Acceptance Analysis

Acceptance analysis in research uses respondent questionnaire data processing.

Researchers then subject the obtained data to a validity test to assess the questionnaire's suitability for evaluating and collecting research data [29].

The Pearson Product- Moment correlation test was used to measure each question variable on the questionnaire. The following equation (2) was used to test the Pearson Product Moment correlation:

$$r_s = \frac{n\sum xy - (\sum x) - (\sum y)}{\sqrt{\left(n\sum x^2 - (\sum x)^2\right) + \left(n\sum y^2 - (\sum y)^2\right)}} \quad (2)$$

where r_s: Pearson correlation coefficient; n: many respondents (sample size); x: the score obtained by the subject from each item; y: the total score obtained by the entire system.

Given a sample size of 42 respondents (n = 42) and a significance level of 5%, it is established that the r-table value is 0.304. Subsequently, the r-table values are compared to the Pearson Correlation values.

According to Table 5, the question variable exhibits a Pearson correlation value greater than 0.304, indicating that the question variable can be considered legitimate. A reliability test was performed to ascertain the degree of consistency in the data obtained from the questionnaire. The mentioned test pertains to using Cronbach's Alpha reliability test to assess the dependability of study variables. According to the reliability test results on each variable, it is evident that the questionnaire data variables exhibit high reliability and meet the criteria if they have a value of ≥ 0.8, as explained in Table 5. The test data for the current variables is considered reliable.

Table 5. Validity and reliability test

Parameters	Variables	Pearson Correlation	Cronbach's Alpha	Avg value (Likert)
CTRL	CTRL1	0.314	0.884	3.86
	CTRL2	0.394	0.883	3.83
LGO	LGO1	0.484	0.879	4.38
	LGO2	0.507	0.878	4.19
ENJ	ENJ1	0.713	0.872	4.35
	ENJ2	0.674	0.873	4.23
LO	LO1	0.311	0.883	4.14
	LO2	0.530	0.878	4.07
PU	PU1	0.639	0.874	4.21
	PU2	0.547	0.877	4.04
	PU3	0.631	0.874	4.07
BIU	BIU1	0.533	0.878	4.33
	BIU2	0.555	0.877	4.07
	BIU3	0.576	0.876	4.07
IMR	IMR1	0.495	0.879	4.16
	IMR2	0.684	0.874	3.59
	IMR3	0.661	0.874	3.61
PEU	PEU1	0.607	0.876	3.83
	PEU2	0.644	0.874	3.64
	PEU3	0.613	0.875	3.76

Table 5 displays the mean value of 4, out of a maximum scale of 5, obtained from the sample. A Likert scale was utilized for this assessment, with a range spanning from the minimum to maximum values. The mean score of 4 demonstrates that on average, the respondents' level of agreement aligned with the acceptability for each assessed variable of the proposed system.

4.2. Effectiveness Analysis

The evaluation for occupational safety training involved processing the data using the Wilcoxonsigned- rank test. The selection of this statistical test was justified by its appropriateness for making comparisons between two related, matched, or repeatedly measured sample groups in order to determine if there are significant differences in the rank ordering of their population means. This experiment was used by calculating the difference between the values before implementing the method or treatment (the formative assessment scores) and the values after the implementation (the summative assessment scores).

The purpose was to evaluate whether the safety training led to a statistically significant increase in knowledge and skills. In addition to the Wilcoxonsigned-rank test, the research also investigated the efficacy of utilizing an immersive approach for occupational safety training by employing the normalized gain test, also known as the N-gain test [30]. Table 6 provides the categorization for N-gain effectiveness where the normalized N-Gain value can be obtained by calculating using the equation (3):

$$g = \frac{s_f - s_i}{s_{max} - s_i} \times 100\% \quad (3)$$

where g: normalize gain; s_f: summative score test; s_i: formative score test; s_{max}: score ideal.

Table 6. Effectiveness category of N-gain

Percentage (%)	Categories
< 40	Ineffective
40 - 55	Moderately Effective
56 - 75	Effective
> 76	Highly Effective

The effectiveness analysis shown in Table 7 revealed the following results: the negative rank for the negative difference between training outcomes for formative and summative is 0. This value indicates no reduction in the value of the results from formative to summative values.

Positive ranks or the positive difference between training outcomes for formative and summative are 21 for Group A (which received the material for the first time) and 11 for Group B (who had previously received similar instruction). This value indicates that 32 respondents experience increased training outcomes from formative to summative. Ties are the same value between formative and summative training outcomes, which are 0 for group A and 10 for group B. Overall, ten respondents got identical scores before.

Table 7. Effectiveness analysis

Sample group	Summative - Formative	N	Mean Rank	Asymp. Sig.	N Gain	Std. Error
A	Positive Ranks	21	11.0	0.005	65.8	0.018
	Negative Ranks	0	0.00	-	-	-
	Ties	0	-	-	-	-
B	Positive Ranks	11	6.00	0.017	17.9	0.043
	Negative Ranks	0	0.00	-	-	-
	Ties	10	-	-	-	-

Formative and summative assessment instruments were used to derive the values before and after the training. The average N-gain value for Group A's training results was 65.8%. According to the established interpretation scale, this qualifies as an effective gain in knowledge.

In contrast, the percentage in Group B (which had previously received comparable instruction) that demonstrated proficiency in training was only 17.9%, indicating relatively ineffective training for this subset.

Figure 4 provides a visual display of the distribution of data from the practical training assessments given to the two groups of students. The formative and summative value results are compared side-by-side for Group A, which received the training for the first time, and Group B, which had previously received similar instruction.

The figure highlights the differences in knowledge gained between the two groups. The statistical analyses substantiate that the immersive occupational safety training approach led to significant learning and skill development for most trainees without prior exposure but was less effective among those with previous training.

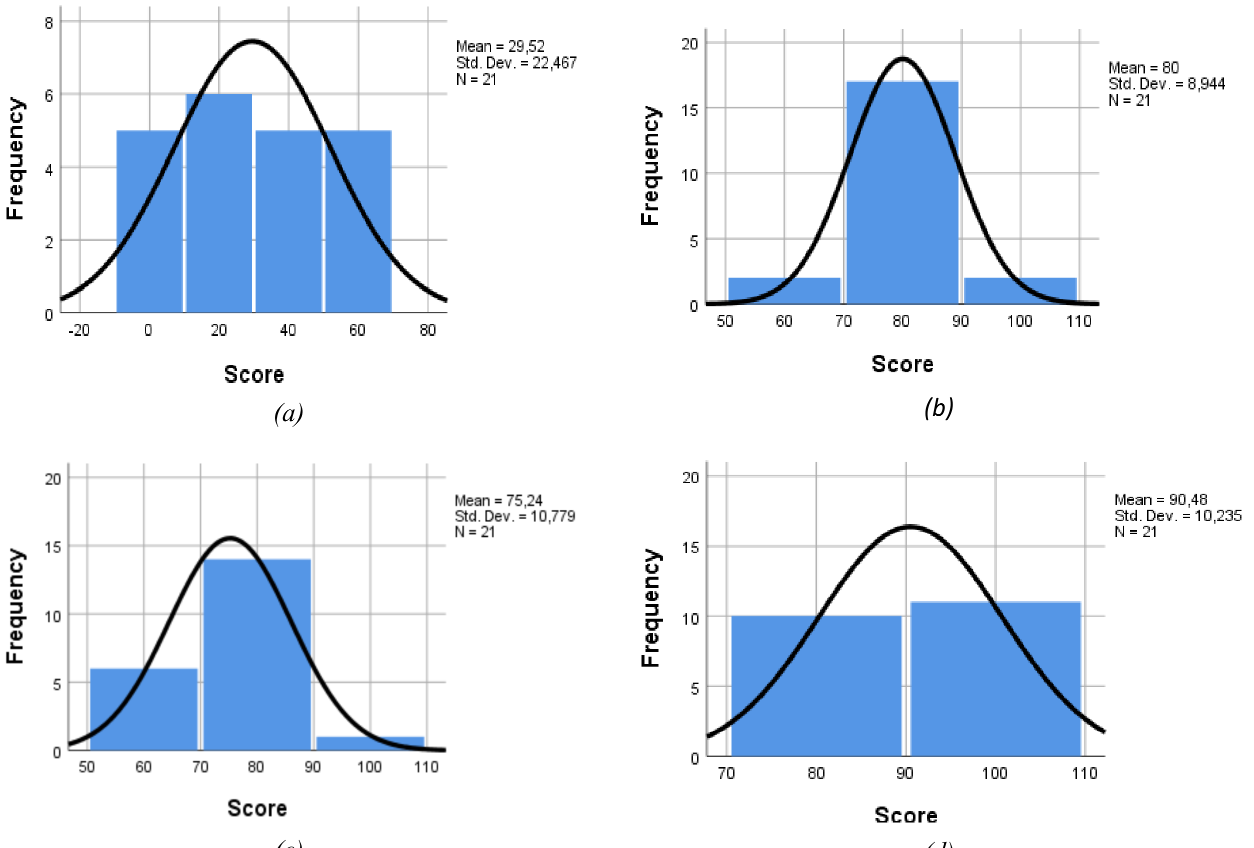

Figure 4. Distribution of data practical training (a) formative value group A, (b) summative value group A, (c) formative value group B, (d) summative value group B

4.3. Interaction Analysis

The test results of the respondents for interaction testing utilizing success rate usability are presented. The study involved conducting observations to evaluate the effectiveness of the SGIQ question design.

These observations were carried out on a sample of respondents. Figure 5 displays the findings of the observations. Based on data from thirteen performance tasks, the average success percentage for usability is 71%.

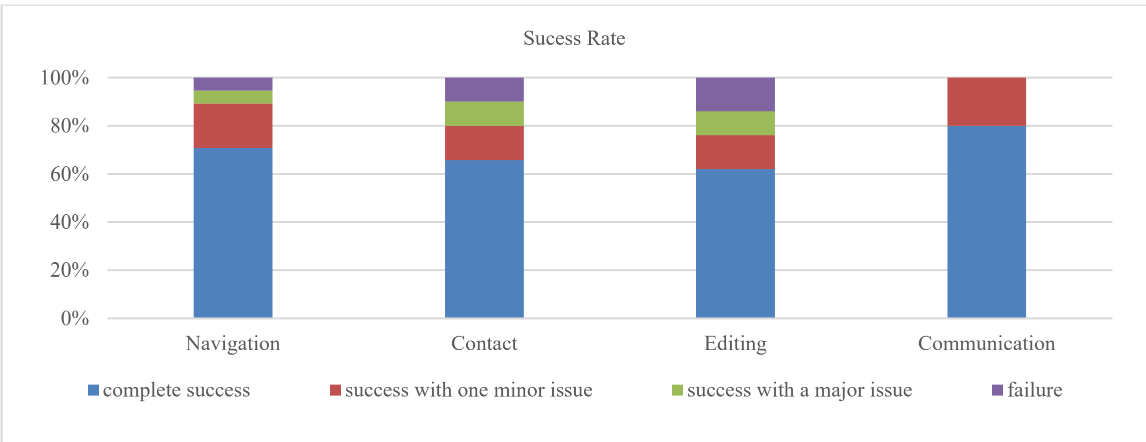

Figure 5. Interaction test using usability success rate

4.4. Experience Analysis

The device used in the research has limitations in exploring haptic sensors. Based on these limitations, it was found that to represent more real training, more exploration of the sensory system is needed so that the actual situation is transformed into a virtual one that provides practical experience and learning that matches reality. The sensory system is essential for receiving information about the surrounding environment that is used to take appropriate action.

Even with these limitations, researchers still try to analyze the user experience obtained results according to Figure 6.

The variables were selected through the user experience UX approach testing, employing the **user experience questionnaire** UEQ questionnaire. The data collected from the UEQ questionnaire provided insights into the user experience of metaverse education and training. This experience was evaluated based on six aspects: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty.

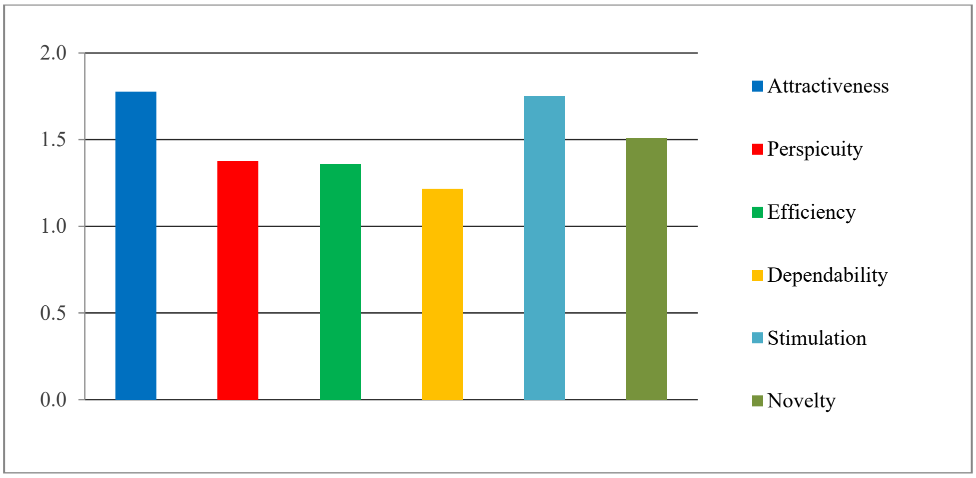

Figure 6. UEQ result for metaverse training

According to Figure 6, the category has a score of 1.778, which falls within the range of favorable evaluation scores between 0.8 and the maximum score of 3. The attractiveness category achieves the highest outcome compared to all other categories. It signifies that the respondents expressed a favorable preference for the metaverse's design in the education context. The score for the perspicuity category is 1.375, indicating a positive review. The respondents perceive the metaverse in education and training as easily attainable and well-recognized. The efficiency category of the metaverse in education and training earns a positive review with a score of 1.358. It signifies that the participants can effortlessly do their jobs without requiring exertion. However, this number is relatively low compared to other categories, indicating that the system involves enhancement to enhance efficiency.

The dependability category is rated at 1.217, indicating a positive grade. It signifies that the system link effectively redirects to the correct feature, and the controller functions well, instilling a sense of user control over the interaction. However, the dependability category scores the lowest among all other areas, indicating the system's need for growth and development.

The stimulation category is assigned a score of 1.680, placing it inside the favorable evaluation range. It signifies that the consumers experience a sense of motivation to utilize the system. The uniqueness category is assigned a score of 1.508, indicating a positive review. It signifies that the system possesses a high degree of creativity. The UEQ data analysis tool utilized the average score from each element within the current benchmark dataset to measure the defined scale. The benchmark result can provide a comparative assessment of the quality of metaverse education and training about other goods presented in Table 8 and the benchmark graph depicted in Figure 6.

Table 8. Metaverse training benchmark comparison results

Scales	Mean	Benchmark Comparison
Attractiveness	1.78	Good
Perspicuity	1.38	Above Average
Efficiency	1.36	Above Average
Dependability	1.22	Above Average
Stimulation	1.68	Good
Novelty	1.51	Good

By comparing the findings of the assessed product with the data in the benchmark, one can draw inferences about the quality of the product being evaluated compared to other items that already exist.

The study of the questionnaire responses indicates that the usage of a metaverse in education and training is currently perceived favorably by its users, surpassing the average impression.

Figure 7. illustrates that the system analysis indicates that all UEQ scales have demonstrated outcomes that are above average for the system's user experience.

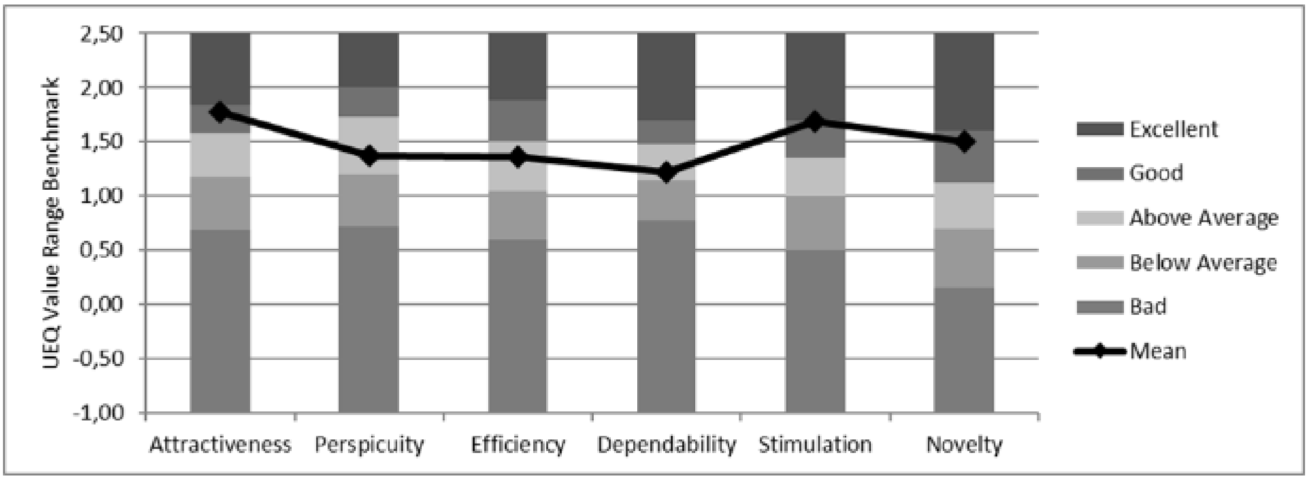

Figure 7. The graph of benchmark results for metaverse education

5. Conclusion

This study demonstrated that incorporating immersive simulations in a metaverse environment can significantly improve the quality of safety awareness training. With students engaging in this type of training, the interactive immersiveness of this course leads to an active path of involvement in decision-making and necessarily enables a better position to understand safety procedures. The results prove the applicability of the proposed model, where the usage success rate is 71% with extremely positive user experience comments. Most notably, user experience values surpassed average measures in the following key elements: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty. These findings highlight the promise of transformative technology for learning safety in the workplace, with the potential for better engagement, retention of knowledge and overall performance. Future research could delve deeper into the **user experience questionnaire** UEQ benchmark of other metaverse implementation use cases, examining how the length of time spent in this training approach impacts workplace safety behaviors and incorporate advanced haptic feedback systems to provide a more realistic and stronger impact on the training experience.

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