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Implementing Virtual Reality for Fire Evacuation Preparedness at Schools

Rashika Tasnim Keya [1,*], Ilona Heldal [1,*], Daniel Patel [1], Pietro Murano [2] and Cecilia Hammar Wijkmark [1]

[1] Department of Computer Science, Western Norway University of Applied Sciences, P.O. Box 7030, 5020 Bergen, Norway; daniel.patel@hvl.no (D.P.); cecilia.hammar.wijkmark@hvl.no (C.H.W.)
[2] Department of Computer Science, Oslo Metropolitan University, P.O. Box 4 St. Olavs Plass, 0130 Oslo, Norway; piemur@oslomet.no
* Correspondence: rashika.tasnim.keya@hvl.no (R.T.K.); ilona.heldal@hvl.no (I.H.)

Abstract

Emergency preparedness training in organizations frequently involves simple evacuation drills triggered by fire alarms, limiting the opportunities for broader skill development. Digital technologies, particularly virtual reality (VR), offer promising methods to enhance learning for handling incidents and evacuations. However, implementing VR-based training remains challenging due to unclear integration strategies within organizational practices and a lack of empirical evidence of VR's effectiveness. This paper explores how VR-based training tools can be implemented in schools to enhance emergency preparedness among students, teachers, and staff. Following a design science research process, data were collected from a questionnaire-based study involving 12 participants and an exploratory study with 13 participants. The questionnaire-based study investigates initial attitudes and willingness to adopt VR training, while the exploratory study assesses the VR prototype's usability, realism, and perceived effectiveness for emergency preparedness training. Despite a limited sample size and technical constraints of the early prototype, findings indicate strong student enthusiasm for gamified and immersive learning experiences. Teachers emphasized the need for technical and instructional support to regularly utilize VR training modules, while firefighters acknowledged the potential of VR tools, but also highlighted the critical importance of regular drills and professional validation. The relevance of the results of utilizing VR in this context is further discussed in terms of how it can be integrated into university curricula and aligned with other accessible digital preparedness tools.

Keywords: virtual reality; serious games; emergency; preparedness; education; training; user flow; technology integration; user experience; case

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1. Introduction

Emergency preparedness remains a critical aspect of public safety. To mitigate the impact of emergencies and disasters on people and property, safety training is essential [1,2]. Organizations are responsible for equipping their employees with the knowledge to handle emergency situations, often through courses, evacuation drills, videos, informational texts, or posters. While safety training to handle emergencies would be necessary for all of us, the majority of the population can be considered to lack the knowledge required to know what to do in real emergency situations [2]. Preparing people with essential training can begin as early as school age [3]. However, insufficient funding, policy gaps, and the lack of realistic training and practices are current significant impediments to effective preparedness.

Training for emergency preparedness in schools requires vast resources and specialized competencies that educational institutions may not possess. Training can be made more accessible with support knowledge acquisition and retention by utilizing new technologies such as augmented and virtual realities (ARs and VRs) and serious games (SGs). AR may help to triage mass casualties [4], handle evacuation systems [5], and train healthcare providers [6]. VR can be used to create high-quality experiences and improve the cost-effectiveness and performance completeness of training [7]. Today, VR is often used together with SGs for training citizens [8] and students in various educational contexts [9,10]. Utilizing gameplay via SG can enhance motivation, retention, and engagement [5,11]. While VR and SG show their usefulness for training in general, according to our present knowledge, VR-based emergency training is not yet utilized by schools or universities beyond illustrating its capabilities or for research studies. The real evacuations or training to handle incidents for pupils and students at schools and universities are performed today as always, often through evacuation drills after hearing a fire alarm or managing to put out the fire in a barrel with a fire extinguisher on the school yard. There are several limitations to these live simulations for larger groups, such as the lack of realism in simulating a real training situation on training grounds or specific drills that necessitate the need for referees to supervise and assess each student on a one-to-one basis, or in small groups during scenarios. A VR environment, on the other hand, can simplify the process and provide students with immediate digital data analysis and feedback [11,12].

Implementing VR-based training in schools involves careful consideration of both technological and methodological aspects. Different training methods and tools require tailored strategies to achieve desired learning outcomes effectively [13,14]. Factors such as immersion and user experience are essential not only for engagement but also for improving learning retention and effectiveness [15]. Additionally, successful implementation of VR training in schools requires appropriate management [16], promised cost-effectiveness [17], seamless integration into existing educational activities [18], and rigorous validation to ensure reliability and trustworthiness [19]. Earlier studies collectively indicate that awareness of school disaster preparedness is growing, e.g., [20,21], there remains a need for more user-centered, behaviorally informed, and technologically supported approaches for training. Building on these insights, the present study focuses on incorporating stakeholder input to design a more engaging and practical disaster preparedness initiative for schools.

The aim of this paper is to illustrate the current possibilities and limitations of implementing VR-based training for emergencies at a university by understanding the practical applicability of VR applications and by evaluating the intentions to use it among different stakeholders.

The methodology follows the traditions of design science research (DSR) [22]. Its overarching research approach investigates a proof-of-concept artifact, grounded in the organization's needs, and is informed by existing theoretical knowledge in the area of using VR and SG for emergency training at schools and universities. Data and information are derived from two studies: a questionnaire study that informs us about organizational needs and possibilities for such training, and an exploratory study investigating user experiences using a VR and SG prototype. Together, these two studies enabled us to examine both the perceived relevance and the practical implementation of such technology through the following three research questions:

- RQ1: How does using VR technologies influence students' motivation to participate in emergency preparedness training?
- RQ2: What are the opinions of the different stakeholders on the use of VR applications for fire drills to teach relevant fire evacuation?
- RQ3: How to use VR in school fire drills for fire safety, preparedness, and evacuation?

To further generalize the results and examine the competitive advantages of using VR and SG for emergency preparedness training, this study was conducted as part of a national initiative linked to the EU-funded B-Prepared project (see [23], and further description in Section 2, Technologies for Training and the B-Prepared Project). Although the VR prototype discussed here was developed independently by students in a university context, and not officially part of the B-Prepared products, it was inspired by the project's objectives and tested in a similar educational context. From the B-prepared project, we utilize the Inclusive VR for Knowledge Transfer (IVR-KT) framework for planning and assessing emergency preparedness training in education that was developed earlier [14]. This framework facilitates the discussion of the possibilities and challenges associated with implementing an educational module that incorporates immersive technologies for teaching emergency preparedness in schools and universities. Consequently, the findings offer valuable insights relevant to broader discussions on disaster preparedness supported by digital technologies.

The structure of this paper is as follows: After a brief description of the theoretical and practical background influencing the study (Section 2), the methodology is presented in Section 3. Section 4 presents the results from the two studies and connects these to issues influencing implementation of VR-based evacuation training at schools and universities. Section 5 discusses the findings, current limitations, and presents future research directions. Section 6 concludes the paper.

2. Technologies for Training and the B-Prepared Project

Training is a key and mandatory component in developing capabilities to handle emergencies [24]. More precisely, the goal of emergency preparedness training is to enhance individuals' ability to adapt to the unique and novel needs that emerge during an incident or disaster, and to establish standards for performing tasks [25]. It has long been a fundamental concern in organizational contexts, relying on learning strategies, training technology, and development efforts to prepare its workforce. Handling incidents and disasters can be complex, and training is often costly. Utilizing new technologies to train students about disaster and emergency preparedness in an educational institution can make training more affordable and accessible in a more engaging way (e.g., according to present reviews and a study about overall usability [7,8,11]).

Training on disaster preparedness as a self-help measure in the educational curriculum is a new concept to motivate students to learn about emergencies and disaster situations. With the development of consumer-grade VR hardware, immersive training simulations have become affordable for competency training [12,14].

People use different technologies every day. To access training opportunities, students should also have the opportunity to use the technologies they are accustomed to, thereby gaining the necessary knowledge for preparedness. The research behind this paper is based on technologies from the project B-prepared [23] incorporating several everyday technologies and applications for emergency preparedness. These are standard technologies commonly found at universities. The applications are designed to support preparedness at several European universities by enabling students to train for prior incidents and disasters in the countries where the universities are located. The project's technologies include a mobile application, a VR application, a knowledge platform for disasters and incidents, and a learning management system (LMS) (see Figure 1).



Figure 1. The B-prepared products (see further [23]).

The B-prepared project's technologies, which we contrast with our VR technology are the following:

- The mobile technology includes guided walks in real locations, illustrating well-known emergencies through gamified experiences. For example, these may include events such as the flood of the Danube in Budapest or the collapse of the Ponte Morandi bridge in Genoa. The walks can be followed on-site using real-time GPS or offline through a pre-downloaded map. These are enriched with puzzle-based games, quizzes, and informational prompts designed to help users understand the disaster context and learn how to respond effectively. Augmented reality (AR) features are also planned to enhance interactivity.
- B-prepared also includes gamified VR applications called 'VR-prepared' currently for flood scenarios, garage fires, resuscitation, and for this paper, evacuations from school fire situations, with serious game elements. In these applications, players can enter the virtual environment using a head-mounted display (HMD) and perform various tasks to learn about wildfires, floods, and fire evacuation from buildings. The aim of VR-prepared is to learn how to evacuate themselves in similar situations. While there are many VR applications aimed at supporting specific emergency training, there are no containers for this connected to other possibilities, allowing experience-based training situations for multiple users.
- To support knowledge-sharing on incidents and disasters, a platform called 'Disastropedia' has been developed [26], which is a similar concept to Wikipedia, including content regarding how to prepare citizens for disaster situations and how advanced technologies can be used in these situations. There are also many similar approaches to the need for and construction of disaster support management systems [27,28]. However, these are not connected to different technical solutions.
- All the products the project develops are integrated into a learning management system (LMS) called 'RU-prepared' where students can register their accounts and, by using single sign-on (SSO), students can receive access to those resources. Gamification of education is a strategy for increasing engagement by incorporating game elements into an educational environment [29]. The role of this LMS is to support training at several universities by allowing applications to learn about typical emergency situations and to provide training at different levels ranging from easier to more complex situations.

While the official VR-prepared modules within B-Prepared [23] focus specifically on flood and wildfire scenarios, the VR fire evacuation game developed in this project represents an additional educational asset aimed at exploring the feasibility of integrating VR-based disaster preparedness training into schools.

3. Methodology

This study draws inspiration from the principles of design science research (DSR) [22], particularly in its focus on addressing a practical problem, fire evacuation training in schools through the development and evaluation of a VR-based prototype. However, the study did not follow a complete DSR cycle involving iterative refinement and multiple development phases; instead, it focuses on the initial phase of the DSR cycle, which is called grounded design by Rohde et al. [30]. It adopted an exploratory and evaluative approach to examine the needs and user experiences of a prototype in an educational context.

The prototype was developed during an early phase of the B-Prepared [23] initiative with the aim of illustrating the potential of using VR for emergency preparedness at our university in Norway. Given its developmental stage and resource constraints, the prototype had limited functionality, positioning this evaluation as a pilot study intended to gather preliminary insights and highlight usability challenges, rather than serving as a finalized training solution.

The methodology is based on the literature on developing VR applications for performing school fire evacuations, and two studies for data collection from key stakeholders (students, teachers, firefighters, and administrative personnel). The results from these two studies were discussed based on the opinions of an expert in planning education and the use of VR in organizations, and on investigating the applicability of the VR application in relation to the B-prepared project's products, particularly the IVR-KT framework.

3.1. Study1: Stakeholder Questionnaire Study

In the first phase, preliminary stakeholder perspectives were gathered through questionnaires targeting students, teachers, and firefighters. The aim was to capture expectations, attitudes, and perceived opportunities or barriers related to VR-based preparedness training, prior to engaging with the VR prototype.

The questionnaire included common questions about preparedness attitudes and VR-specific questions about perceived usefulness, realism, and training potential. Questions were based on established fire safety guidelines and the emergency procedures at Norwegian universities [31]. Three tailored versions of the questionnaire were used (students, teachers, and firefighters), sharing a common core of 20 items for students and teachers, and 18 for firefighters. While many questions varied between different stakeholders, all included a common part that gathered opinions on attitudes toward using VR for this purpose.

Responses were collected from 12 stakeholders (7 students, 3 teachers, and 2 firefighters). The results informed us about the subsequent prototype development and the potential use of such VR applications on a broader scale for training at universities. Through this study, we contributed to the relevance cycle of DSR.

3.2. Study2: Exploratory User Study

Following the questionnaire study, an exploratory user study was conducted with 13 participants (9 students, 2 teachers, and 2 administrative staff) who interacted with the VR prototype in an observational session. During the session:

- User behaviors were observed and documented.
- Decision-making patterns and interaction challenges were noted.
- All participants completed a post-experience questionnaire to capture perceived usability and learning.

A structured behavior evaluation rubric was later applied to analyze behavioral performance in six key categories (see Section 4.4).

3.3. The VR Application: "Fire Evacuation Game"

The fire evacuation training prototype was developed using Unity 6 (Unity Technologies, Surat, India), a widely adopted game engine with strong support for VR development. Custom scripts were written in C# with Visual Studio 2022 (Microsoft Corporation, Redmond, DC, USA). The application was deployed on Oculus Quest 3 standalone headsets (Meta, Menlo Park, CA, USA), offering an immersive, room-scale VR experience. The "HVL Fire" application was created based on simplified floor plans derived from MazeMap (Televenture, Trondheim, Norway) visualizations of a specific building at the Western Norway University of Applied Sciences. ProBuilder within Unity was used to replicate these layouts manually. Additionally, reference images and assets from the Unity Asset Store were imported to simulate the physical environment's accurate appearance, including colors and furniture.

The application developed for this study simulates a school-based fire evacuation scenario. Within the simulation, participants responded to a series of dynamic fire emergency events and were required to execute safe evacuation behaviors. The scenario structure and corresponding player actions are detailed in Table 1.

While the prototype provided an immersive walkthrough of the evacuation scenario, it was developed under significant resource constraints and as a student-led initiative. As such, it included only basic visual effects, limited interaction options, and minimal feedback mechanisms. These technical limitations may have affected user engagement and task clarity, which could partly explain the finding that only five participants completed the evacuation on their first attempt (see Section 4.4). The current version should be considered an early-stage demonstrator, with substantial opportunities for enhancement in fidelity, instructional design, and adaptive feedback to support user learning.

Table 1. The VR fire evacuation game scenario overview.

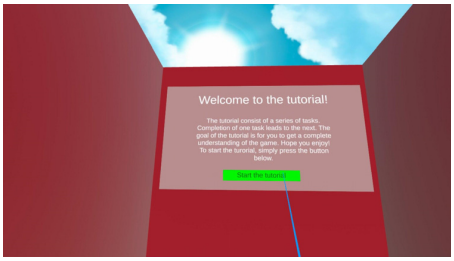
Scene	Image	Content
1st scene		This consists of menus where players can choose options to start the game or play the tutorial. This is the first scenario that players encounter when opening the HVL Fire game.
Tutorial		The tutorial section introduces basic game mechanics and controls required to play the main game. Players practice essential actions such as using a fire extinguisher with the controller to put out fires and navigate between rooms using the joystick.

Table 1. *Cont.*

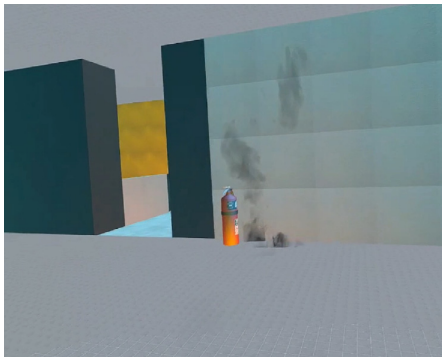
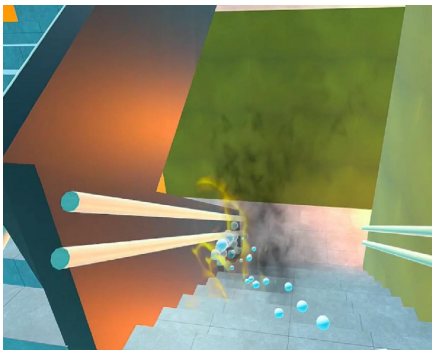
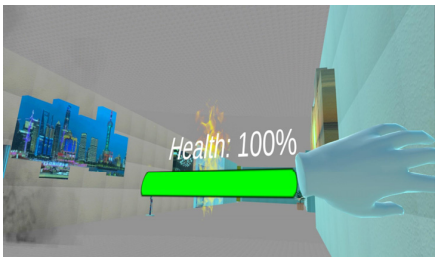
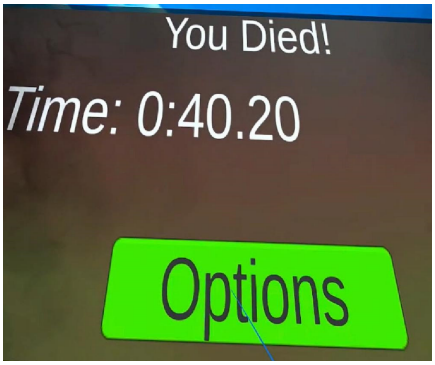
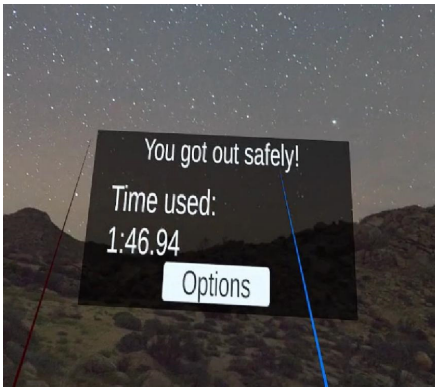
Scene	Image	Content
The first scene of the game starts in a classroom.		The 1st scene of the game shows the fire in a classroom, and the player must find the route to evacuate themselves. The classroom is on the 4th floor in the 'E' section of a specific building.
Evacuate the classroom and have a fire extinguisher ready.		If the player can exit the classroom through the door, the next scene is a corridor with a fire extinguisher located beside the stairs route. Players can go to the extinguisher and hold it while using the stairs, as there could be fire on the stairs.
Using a fire extinguisher to extinguish fires.		The player encounters a fire on the stairs and uses a fire extinguisher to extinguish it in order to proceed to the next floor.
Checking health on the left hand.		There is a health bar in the player's left hand. Initially, it is 100%, and over time, if the player spends a significant amount of time near the fire, the health percentage can decrease, ultimately leading to death when it reaches 0%.
When the health bar reaches 0% the player will die and can return to the lobby to start the game again if they wish.		When the health bar goes down to 0%, the player will lose the game. It shows 'you died!' with a window and the time spent by the player, along with the option button where the player can go back to the start menu to choose their options again.

Table 1. *Cont.*

Scene	Image	Content
Evacuation door from the building		If players can save themselves from fire and can go down to the first floor using the stairs, they can see the exit doors that can lead them out of the building.
Evacuation time		When players evacuate themselves from the building, a window display shows the time spent evacuating, and there is an options button that allows them to return to the start menu.

4. Results

This section presents the findings in response to the three research questions posed in the study. First, we summarize insights from questionnaire-based evaluations with stakeholders and findings from participants in the exploratory study. Then, we provide additional observations from an exploratory behavioral analysis of user interaction with the VR prototype.

4.1. RQ1: How Does Using VR Technologies Influence Students' Motivation to Participate in Emergency Preparedness Training?

In the questionnaire study, all student participants expressed interest in experiencing emergency preparedness drills through virtual reality. In response to the question about technology integration, the majority supported the idea that teachers should learn to use VR-based technologies and incorporate them into classroom activities. Additionally, when asked whether their institution (HVL) should officially implement VR fire evacuation training, the students agreed that such training should be introduced within their own institution or departments.

In the exploratory evaluation, students who experienced the VR fire evacuation prototype largely retained their positive attitudes toward it. Four out of seven students agreed that VR drills could be as effective as traditional drills while offering more accessible and repeatable training. Eight students found the system easy to use and expressed confidence using it.

However, several students reflected in their feedback on the limitations of the current prototype. Some participants reported motion discomfort, particularly on stair navigation, and suggested usability improvements such as more explicit guidance and extending the "health bar" to increase learning time. While these limitations indicate areas for

development, the overall responses suggest that immersive VR-based serious games sustain or even enhance students' motivation toward preparedness training.

Student interest in VR-based drills was high during the questionnaire phase (12 participants, see Figure 2), and mainly remained positive after trying the prototype in the exploratory study (13 participants), although perceived effectiveness dropped slightly, probably due to missing realism and early usability problems.

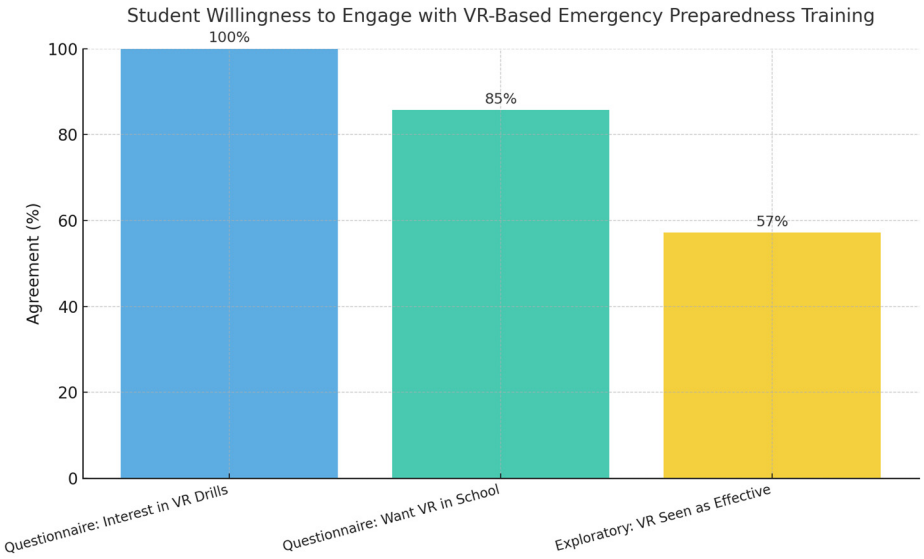


Figure 2. Comparison of student answers regarding their willingness to use VR for emergency preparedness training across the questionnaire study and the exploratory evaluations.

4.2. RQ2: What Are the Opinions of the Different Stakeholders on the Use of VR Applications for Fire Drills to Teach Relevant Fire Evacuation?

Teachers and firefighters participating in the stakeholder questionnaire were strongly supportive of introducing VR-based fire preparedness tools in education, as indicated by their responses. However, their rationales differed as follows: teachers emphasized the need for training and technical support, while firefighters stressed the importance of realism and continued reliance on physical drills. One teacher noted the following:

"VR can be valuable, but teachers need clear guidance and support for implementation."

In contrast, the exploratory evaluation revealed a more complex picture. Among the two participating teachers, one agreed that the VR prototype could be an effective supplement to traditional drills, while the other strongly disagreed due to difficulty navigating stairs and interacting with the system. This participant commented that *"Managing the interaction with the game felt as difficult as solving the game itself."* Other responses highlighted broader usability issues. Several participants faced difficulties handling key interactive elements such as the fire extinguisher, which could not be easily retrieved if it was dropped, indicating a limitation stemming from prototype-level interaction design and VR controller sensitivity. Visual indicators such as exit signs and floor maps were also insufficiently clear, contributing to user hesitation and disorientation. Such feedback may also reveal how actual experience can expose practical limitations not foreseen in conceptual discussions.

These findings underscore the gap between optimistic initial expectations and the practical challenges that emerged through direct interaction. While stakeholders expressed strong conceptual support, hands-on experience exposed usability issues and integration barriers showed a number of real needs to be addressed. For VR-based fire preparedness training to be effectively adopted in schools, improvements in interface design, realism, and educator support structures will be essential.

4.3. RQ3: How to Use VR in School Fire Drills for Fire Safety, Preparedness, and Evacuation?

The expert participant reviewed the results from the questionnaire study and the exploratory study, and raised the following question from an expert in a firefighting: "*How to use VR training for so many? Your university cannot buy VR headsets for all students. Additionally, for practitioners, it isn't easy to understand why VR technologies need to be used for learning evacuation. At the present stage, they cannot imagine how a learning context can be created for large organizations and many people.*" But, according to our initial argumentation, the VR application is only a part of a larger system that is envisioned to be used for evacuation.

Further, the same expert noted that the most important thing is "*to understand the context of evacuation. The organization has the responsibility to evacuate everyone from the building safely and efficiently. This involves supporting individuals in finding evacuation routes using signs, maps, and accessible doors, among other means. If the employer is a school or university, they must provide their employees with education on how to respond to incidents and disasters, such as using a fire extinguisher or checking on people who may be left in classrooms or laboratories.*" Following these thoughts, she pointed out that the school management has the responsibility to focus on providing this course and ensure that the escape routes for everybody are clear enough.

Participants in the exploratory study identified key practical barriers to VR integration within schools, including spatial setup, usability, and the need for educator support. The stakeholder questionnaire revealed strong interest across teachers, students, and firefighters in integrating VR into educational settings. Teachers responded positively when asked whether a small VR-based module could be included in their course, noting its potential to complement traditional drills. However, they emphasized the need for adequate equipment, technical training, and institutional support to ensure successful implementation.

From exploratory testing, participating teachers raised critical concerns that highlight some essential implementation challenges. One teacher noted, *"Some issues with the boundary, when started by the wall, caused visual confusion"*, indicating limitations in spatial setup and physical classroom conditions.

These insights suggest that while the conceptual adoption of VR for fire drills is well supported, effective classroom integration will require significant improvements in usability, infrastructure, and instructional support.

4.4. Behavior Observations from the Exploratory Study

Beyond the questionnaire responses, an exploratory analysis of in-game behavior was conducted from the 13 user sessions. To deepen the understanding of participants' behavioral performance, an evaluation rubric was used based on six behavioral categories: route selection, decision-making, extinguisher use, movement and delay, health awareness, and learning improvement, see Table 2. Each behavior was rated on a scale from 0 (incorrect), 1 (improvable), to 2 (correct).

Observed behaviors were analyzed in relation to core fire evacuation principles derived from the Norwegian Building Authority, TEK17, which sets out the technical standards for construction in Norway, including fire safety measures [32] for the National Preparedness and Crises and Research Organization in Norway [31] with the aim of identifying gaps in procedural knowledge and practical decision-making during emergencies. The objective is to identify gaps in procedural knowledge and practical decision-making during simulated emergency situations.

A comparison between key behavioral expectations and actual user behaviors in the VR fire evacuation scenario is provided in Appendix A (Tables A1 and A2).

Table 2. Observed key behavioral issues.

Behavioral Pattern	The Number of Participants Affected/Whole Number of Participants	Observed Impact	Design Implication
Hesitation or delay in route choice	9/13	Increased evacuation time, failed attempts	Provide more explicit visual cues and reduce ambiguity in available evacuation routes.
Missed or failed to use the extinguisher	7/13	Fire not extinguished, user stress increased	Improve interaction mechanics and error recovery (e.g., pick-up logic and more precise handling instructions)
Stayed near the hazard too long	6/13	Higher in-game risk, failed health condition	Warn users about proximity risks or danger zones
Overuse or incorrect extinguisher use	5/13	Wasted time, the fire spread further	Add error feedback or a cooldown mechanism
Repeated trial-and-error navigation	8/13	Frustration, immersion break	Add an onboarding scenario or adaptive guidance

Table 2 summarizes key behavioral observations during the exploratory VR fire evacuation study, indicating common challenges and areas for improvement in user training design.

The results showed that only five participants successfully evacuated the virtual school building during their first attempt, highlighting a gap between theoretical knowledge and practical response. This performance gap may partly reflect the novelty of using VR technology and the technical limitations of the early-stage prototype. Participants exhibited behaviors such as hesitation in selecting escape routes, difficulty locating fire extinguishers, excessive time spent near hazardous areas, and repeated reliance on trial-and-error methods. Many participants initially appeared excited but became hesitant due to the fear of making mistakes or difficulty in understanding how to operate the VR controllers as it was their first experience with VR technology. Three participants who agreed to attempt the scenario a second time showed improved performance, whereas others declined the opportunity. Additionally, specific game mechanics required improvements; for instance, the health bar provided unclear feedback and reduced too rapidly, a concern explicitly mentioned by some participants.

These behavioral patterns underscore the need for more guided or adaptive feedback mechanisms within VR training environments. Although not formally included in the evaluation framework, the observed behaviors highlight clear gaps in situational awareness and reveal opportunities for enhancing scenario clarity, pacing, and participant onboarding in future iterations.

5. Discussion, Limitations, and Future Research

5.1. Implementing VR for Emergency Preparedness Training: Facilitating Knowledge Transfer

The integration of immersive VR technologies into educational settings offers a transformative approach to emergency preparedness training. The IVR-KT (Inclusive Virtual Reality for Knowledge Transfer) framework consists of two parts: one focusing on organizational integration (see Figure 3) outlining steps such as aligning with management, infrastructure readiness, and staff training to ensure sustainable VR adoption in schools; the second part, a VR game design framework, which guides the development of inclusive, motivational, and feedback-rich virtual training experiences. Together, these components offer both strategic and pedagogical guidance for implementing VR-based emergency preparedness training in educational contexts.

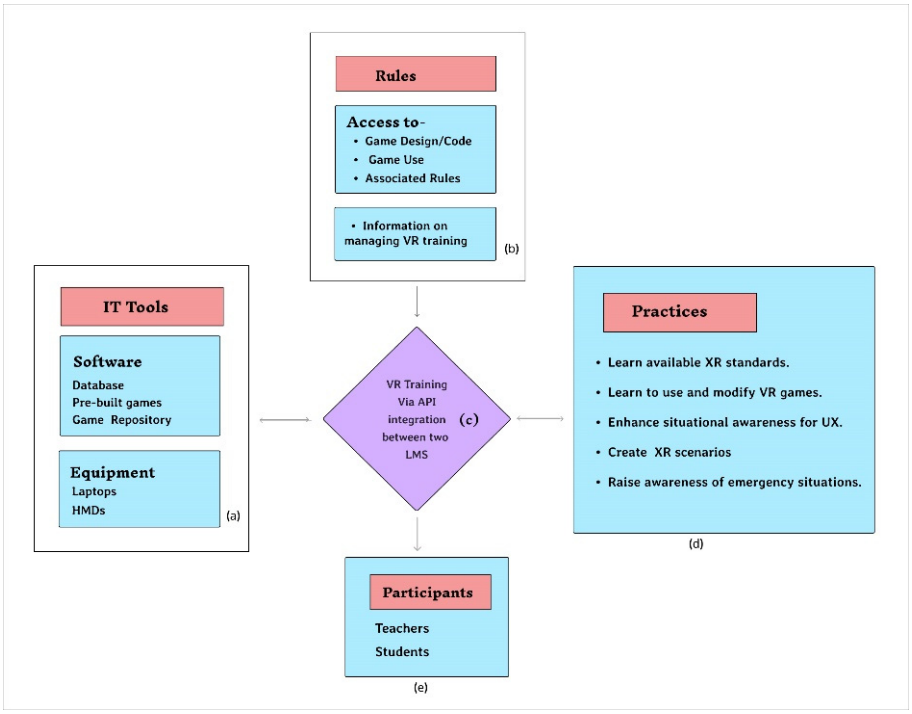


Figure 3. The Inclusive Virtual Reality for Knowledge Transfer (IVR-KT) framework, enhancing the focus areas one needs to focus on for implementing VR in education (adopted from [14]). (**a**) *IT Tools*: Necessary software and hardware (e.g., databases, HMDs). (**b**) *Rules*: Access to design/code, usage guidelines, and VR policies. (**c**) *Integration*: Central VR training integrated via API between two LMSs. (**d**) *Practices*: Learning standards, creating XR scenarios, and improving UX. (**e**) *Participants*: Involvement of students and teachers in the training process.

The IVR-KT framework emphasizes that successful VR training requires not only engaging game mechanics but also institutional support to effectively adapt and integrate immersive technologies. As noted in prior research, the presence of competent individual teachers alone is insufficient in system-level coordination, and support is essential for meaningful technology adoption in education (cf., [18].) Therefore, the separate focus is needed on the (a) IT tools, the necessary software and hardware (e.g., databases, HMDs) teachers can use. The (b) rules regarding access to design/code, usage guidelines, and VR policies may also influence the selection of IT tools and need to be considered. Overall implementation is of course influenced by (c) integration, how the central VR training, via API between two LMSs can be handled, to have a usable supporting IT tool in a particular education. (d) Practices, earlier and new learning standards on creating XR scenarios, and improving UX have to be used or defined. Of course, the (e) participants involvement of students and teachers in the training process needs to be defined prior the choice and use of each new VR tool.

In our current study, while we did not explicitly follow the IVR-KT framework, the principles align closely with our findings. Participants demonstrated increased motivation and engagement when interacting with the VR training modules, reflecting the framework's emphasis on immersive learning environments. However, challenges such as usability issues and the need for clearer guidance highlight areas where the IVR-KT's VR game design framework components, like user-centric design and iterative feedback mechanisms, could be further applied to enhance the learning experience. Melo et al. [33] provided qualitative guidance for interpreting presence levels using the Igroup Presence Questionnaire (IPQ), contributing to improved understanding of user experience in VR training environments. This aspect aligns with the IVR-KT framework's emphasis on presence

and user engagement, as well as inclusive and user-centered design, to optimize learning and engagement in preparedness training. Our current implementation is still limited in scope, focusing on a prototype fire evacuation scenario and lacking multi-modal interaction and advanced accessibility features proposed in IVR-KT. By focusing on the framework's core elements, such as scenario realism, learner inclusivity, and knowledge assessment, educators and developers can create more effective and impactful training programs.

5.2. Towards the Adoption of the Suggested VR Game Training in Classes

Based on the findings of this study, it is evident that stakeholders, including students, teachers, and fire safety professionals, support the idea of integrating virtual reality into school-based disaster preparedness training. However, enthusiasm alone does not guarantee institutional adoption. Practical implementation models are essential to support meaningful policy changes and ensure their successful use. For example, for utilizing the VR product in the B-prepared ecosystem, a proposed user flow must be defined for the existing educational structures. This includes the flow, for example, from students registering for a course and gaining access to interact with multiple learning modalities (VR simulations, mobile products, and various online content) as they define their possible activities, which teachers and firefighters can validate. The teachers need to know about possible training situations and using this in the LMS and the firefighters must align these activities to learning goals, i.e., what is necessary to be performed in order to handle the situation, and when handling it, how help can be provided to others and what should be reported to the emergency professionals who may arrive during the time to the scene. These activities need to be tracked and measured through the LMS.

Teachers and administrators should be able to assign activities, monitor student engagement, and evaluate preparedness outcomes across all possible tools used.

However, the successful integration of such multi-modal preparedness training ecosystems into formal education is not without challenges. Previous research [34] highlights several barriers, including technical limitations, inadequate teacher training, misalignment with curriculum standards, and organizational resistance. Findings from Wijkmark et al. [35] further emphasize that integration is not only about technical deployment within organizations but also about adapting pedagogical practices and institutional processes to incorporate such technologies into educational settings meaningfully. Additionally, Hettervik et al. [36] underscore similar challenges when integrating game-based learning tools in biomedical laboratory science education, including issues related to institutional acceptance, alignment with existing curricula, and the need for supportive teaching strategies to maximize learning impact. The newness of the immersive technology can also be an attraction factor, while it does not necessarily support learning [15]. We will conduct interviews with leaders and management to explore how they can utilize VR for employee and student education. The current study, utilizing VR education, should be used in this context to illustrate this possibility to leaders and managers. Leaders and managers are also responsible for developing policies for utilizing resources for these purposes [37]. These resources also include, in addition to the necessary education, new technologies, applications, and regular maintenance.

These issues are equally relevant when attempting to embed VR simulations, mobile AR walks, and collaborative online platforms within existing LMS structures and school practices. Future research should focus on piloting the integration model, evaluating learning outcomes, and refining the integration pathway based on feedback from students and educators regarding their experiences with the model.

5.3. Current Limitations and Future Works

While the study offers promising insights into the stakeholder adoption of VR-based fire evacuation training, several limitations should be acknowledged. First, a stronger connection to the complete DSR [22,38] process is needed, including multiple development iterations and systematic evaluations. While the design science research methodology would be more informative if we had the opportunity to examine further steps in the development of the examined artifact, it is resource-demanding due to the interest of both technological and educational development in the following steps. Additional limitations may include the somewhat overlapping focus on incidents and disasters, as well as the use of only one prototype of an incident in this examination. Following the instructions from Rohde [30], the IVR-KT framework and the functional VR prototype helped us to investigate attitudes towards VR acceptance at schools systematically. While the overall responses were positive regarding the use of VR for fire evacuation training, the findings should be interpreted cautiously and not generalized to all forms of VR or serious game-based preparedness tools.

Although the study draws on the B-Prepared project, which involves 15 different partner organizations, ranging from developers to information and social science researchers, a systematic literature review would contribute to a better understanding of the state-of-the-art in VR implementation as an educational practice. While the broader aim of the B-Prepared project is to foster digital preparedness through an integrated ecosystem of serious games and educational tools, including other technologies and applications, this study focused solely on the VR serious game prototype. As such, it does not yet fully reflect the complete potential of the ecosystem to support digital preparedness in school curricula or community-level resilience. Further work is needed to explore how the full B-Prepared suite can be integrated into schools' digital learning environments, including testing additional tools and validating learning outcomes in varied contexts. This includes evaluating mobile AR applications, LMS-based engagement, and broader curricular alignment across institutions.

Future work could also explore the possibility of automatically collecting more quantitative data, such as user telemetry data. This could provide valuable insights into user performance and decision-making patterns. The VR-based fire evacuation training could be enhanced by incorporating dynamism and AI-driven events. Furthermore, the interaction design within the system could be improved. As mentioned above, certain participants had difficulty using the fire extinguisher. Improved, more natural interaction could help address usability issues such as hand-tracking for grasping and using objects, and enhance immersion.

The study focused on a controlled scenario and did not test long-term adoption, learning outcomes, or broader behavioral change. While firefighters participated in the questionnaire study and endorsed the tool's conceptual potential, the prototype itself was not formally validated by emergency professionals due to its early development stage and practical constraints. Future iterations should involve systematic validation by professional responders to ensure that both the simulation of fidelity and the embedded procedural guidance align with real-world fire safety standards and do not inadvertently reinforce incorrect or unsafe behaviors. Therefore, future research should investigate how different types of serious games and preparedness tools, including those within the B-Prepared ecosystem, perform across various user groups and institutional settings [23].

6. Conclusions

This study explored the potential of VR-based fire evacuation training to enhance disaster preparedness within educational settings.

Unlike mobile or web-based tools, which are generally accessible using standard devices, VR training requires both specialized equipment and a certain level of technical familiarity, particularly among educators. Therefore, this study aimed to assess the initial willingness of university stakeholders (students and teachers) and first responders (e.g., firefighters) to adopt VR-based emergency preparedness training, and to evaluate user experiences through a pilot prototype based on simplified floor plans of a real campus building derived from MazeMap visualizations.

The findings from the stakeholder questionnaire revealed strong initial interest, particularly among students, who expressed enthusiasm for gamified learning formats. However, the exploratory evaluation exposed a gap between user expectations and actual hands-on experience. While part of this gap can be attributed to the early-stage nature of the prototype and its limited design scope, additional barriers have also emerged. Some participants experienced motion sickness, others struggled with two-controller navigation or found object interaction unintuitive. A few users appeared hesitant to engage fully, potentially due to discomfort with making mistakes in a visible, simulated setting. Despite these limitations, participants overall remained supportive of integrating immersive tools into preparedness education, highlighting the promise of VR-based learning when carefully aligned with user needs and accessibility considerations.

While the prototype used in this study is not part of the official B-Prepared VR modules, it aligns with the broader project goals by demonstrating how stakeholders from the school perceived VR emergency training in educational contexts. The results indicate that VR-based preparedness tools hold promise but must be further refined, both in design and educational integration, to ensure effectiveness, accessibility, and transfer of knowledge in real-world classroom settings.

Future work should examine long-term implementation, curriculum alignment, and measurable learning outcomes to develop inclusive, scalable, and evidence-based preparedness programs.

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Appendix A

Table A1. Rubric-based behavioral scores of individual participants across six behavior categories.

Participant ID	Behavior Category	Criteria/Expected Behavior	Observed Behavior	Evaluation (0 = Incorrect, 1 = Improvable, and 2 = Correct)
P01	Route Selection	Chose staircase closest to classroom	Followed longest route	1
P01	Decision-Making	Did not attempt jumping/made safe choices	Made safe choices	2
P01	Use of Extinguisher	Used extinguisher only when needed; did not empty it	overused and emptied it	0
P01	Movement and Delay	Evacuate immediately and directly	Did not waste time	1
P01	Health Awareness	Checked health bar and acted accordingly	Casually checked	1
P01	Learning Improvement (Retry)	Showed improvement on second try	Did not retry	1
P02	Route Selection	Chose staircase closest to classroom	Followed longest route	0
P02	Decision-Making	Did not attempt jumping/made safe choices	Made safe choices	2
P02	Use of Extinguisher	Used extinguisher only when needed; did not empty it	Used fire extinguisher wisely	2
P02	Movement and Delay	Evacuate immediately and directly	Roamed halls, checked other rooms	0
P02	Health Awareness	Checked health bar and acted accordingly	Checked health bar	2
P02	Learning Improvement (Retry)	Showed improvement on second try	Evacuate successfully in first attempt	2
P03	Route Selection	Chose staircase closest to classroom	Followed closest route	2
P03	Decision-Making	Did not attempt jumping/made safe choices	Considered jumping out of the window	0
P03	Use of Extinguisher	Used extinguisher only when needed; did not empty it	Used fire extinguisher wisely	2
P03	Movement and Delay	Evacuate immediately and directly	Checked the other room and delayed a bit	1
P03	Health Awareness	Checked health bar and acted accordingly	Checked health bar	2
P03	Learning Improvement (Retry)	Showed improvement on second try	Evacuate successfully in first attempt	2
P04	Route Selection	Chose staircase closest to classroom	Followed longest route	0
P04	Decision-Making	Did not attempt jumping/made safe choices	Made safe choices	2
P04	Use of Extinguisher	Used extinguisher only when needed; did not empty it	Overused and emptied it	0

Table A1. *Cont.*

Participant ID	Behavior Category	Criteria/Expected Behavior	Observed Behavior	Evaluation (0 = Incorrect, 1 = Improvable, and 2 = Correct)
P04	Movement and Delay	Evacuate immediately and directly	Tried not to be delayed	1
P04	Health Awareness	Checked health bar and acted accordingly	Did not check health bar	0
P04	Learning Improvement (Retry)	Showed improvement on second try	Did not retry	1
P05	Route Selection	Chose staircase closest to classroom	Followed closest route	2
P05	Decision-Making	Did not attempt jumping/made safe choices	Considered jumping out the window	0
P05	Use of Extinguisher	Used extinguisher only when needed; did not empty it	Overused in first attempt	1
P05	Movement and Delay	Evacuate immediately and directly	Tried not to be delayed	1
P05	Health Awareness	Checked health bar and acted accordingly	Casually checked	1
P05	Learning Improvement (Retry)	Showed improvement on second try	Evacuate successfully in second attempt	2
P06	Route Selection	Chose staircase closest to classroom	Followed longest route	0
P06	Decision-Making	Did not attempt jumping/made safe choices	Made safe choices	1
P06	Use of Extinguisher	Used extinguisher only when needed; did not empty it	Overused	1
P06	Movement and Delay	Evacuate immediately and directly	Tried not to be delayed	1
P06	Health Awareness	Checked health bar and acted accordingly	Did not check health bar	0
P06	Learning Improvement (Retry)	Showed improvement on second try	Did not retry	1
P07	Route Selection	Chose staircase closest to classroom	Followed longest route	0
P07	Decision-Making	Did not attempt jumping/made safe choices	Made safe choices	1
P07	Use of Extinguisher	Used extinguisher only when needed; did not empty it	Overused	1
P07	Movement and Delay	Evacuate immediately and directly	Tried not to be delayed	1
P07	Health Awareness	Checked health bar and acted accordingly	Casually checked	1
P07	Learning Improvement (Retry)	Showed improvement on second try	Did not retry	1
P08	Route Selection	Chose staircase closest to classroom	Followed longest route	0
P08	Decision-Making	Did not attempt jumping/made safe choices	Made safe choices	2

Table A1. *Cont.*

Participant ID	Behavior Category	Criteria/Expected Behavior	Observed Behavior	Evaluation (0 = Incorrect, 1 = Improvable, and 2 = Correct)
P08	Use of Extinguisher	Used extinguisher only when needed; did not empty it	Overused	1
P08	Movement and Delay	Evacuate immediately and directly	Tried not to be delayed	1
P08	Health Awareness	Checked health bar and acted accordingly	Checked health bar	2
P08	Learning Improvement (Retry)	Showed improvement on second try	Behavior improved in the second attempt	1
P09	Route Selection	Chose staircase closest to classroom	Followed longest route	0
P09	Decision-Making	Did not attempt jumping/made safe choices	Made safe choices	2
P09	Use of Extinguisher	Used extinguisher only when needed; did not empty it	Overused	0
P09	Movement and Delay	Evacuate immediately and directly	Tried not to be delayed	1
P09	Health Awareness	Checked health bar and acted accordingly	Did not check health bar	0
P09	Learning Improvement (Retry)	Showed improvement on second try	Did not retry	1
P10	Route Selection	Chose staircase closest to classroom	Followed closest route	2
P10	Decision-Making	Did not attempt jumping/made safe choices	Made safe choices	2
P10	Use of Extinguisher	Used extinguisher only when needed; did not empty it	Used fire extinguisher wisely	1
P10	Movement and Delay	Evacuate immediately and directly	Attempted to go upstairs due to fear of dying as health bar was low	0
P10	Health Awareness	Checked health bar and acted accordingly	Checked health bar	2
P10	Learning Improvement (Retry)	Showed improvement on second try	Evacuate safely in first attempt	2
P11	Route Selection	Chose staircase closest to classroom	Followed longest route	0
P11	Decision-Making	Did not attempt jumping/made safe choices	Made safe choices	2
P11	Use of Extinguisher	Used extinguisher only when needed; did not empty it	Overused	0
P11	Movement and Delay	Evacuate immediately and directly	Tried not to be delayed	1
P11	Health Awareness	Checked health bar and acted accordingly	Casually checked	1
P11	Learning Improvement (Retry)	Showed improvement on second try	Behavior improved in the second attempt	1

Table A1. *Cont.*

Participant ID	Behavior Category	Criteria/Expected Behavior	Observed Behavior	Evaluation (0 = Incorrect, 1 = Improvable, and 2 = Correct)
P12	Route Selection	Chose staircase closest to classroom	Followed longest route	0
P12	Decision-Making	Did not attempt jumping/made safe choices	Made safe choices	2
P12	Use of Extinguisher	Used extinguisher only when needed; did not empty it	Overused	1
P12	Movement and Delay	Evacuate immediately and directly	Tried not to be delayed	1
P12	Health Awareness	Checked health bar and acted accordingly	Casually checked	1
P12	Learning Improvement (Retry)	Showed improvement on second try	Evacuate successfully on the second attempt	2
P13	Route Selection	Chose staircase closest to classroom	Player refused to continue playing as soon as they experienced fire due to fear	1

Table A2. Average rubric scores by behavior category (0 = incorrect, 1 = improvable, and 2 = correct).

Behavior Category	Average Score (0–2)
Decision-Making	1.5
Health Awareness	1.08
Learning Improvement (Retry)	1.42
Movement and Delay	0.83
Route Selection	0.62
Use of Extinguisher	0.83

References

1. Hale, A.R. Is safety training worthwhile? *J. Occup. Accid.* **1984**, *6*, 17–33. [CrossRef]
2. Fazeli, S.; Haghani, M.; Mojtahedi, M.; Rashidi, T.H. The role of individual preparedness and behavioural training in natural hazards: A scoping review. *Int. J. Disaster Risk Reduct.* **2024**, *105*, 104379. [CrossRef]
3. Muhyi, M.; Hakim, L.; Sucipto, A. Physical activity in physical education: A dynamic approach to earthquake disaster mitigation in schools. *Retos Nuevas Tend. En Educ. Física Deporte Y Recreación* **2025**, *65*, 320–329. [CrossRef]
4. Chen, Y.; Fennedy, K.; Zhang, J.; Sim, Y.J.; Zheng, C.; Yen, C.C. Bridging Simulation and Reality: Augmented Virtuality for Mass Casualty Triage Training-From Landscape Analysis to Empirical Insights. In Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems, Yokohama, Japan, 26 April–1 May 2025; pp. 1–28.
5. Catal, C.; Akbulut, A.; Tunali, B.; Ulug, E.; Ozturk, E. Evaluation of augmented reality technology for the design of an evacuation training game. *Virtual Real.* **2020**, *24*, 359–368. [CrossRef]
6. Ricci, S.; Calandrino, A.; Borgonovo, G.; Chirico, M.; Casadio, M. Virtual and augmented reality in basic and advanced life support training. *JMIR Serious Games* **2022**, *10*, e28595. [CrossRef] [PubMed]
7. Feng, Z.; González, V.A.; Amor, R.; Lovreglio, R.; Cabrera-Guerrero, G. Immersive virtual reality serious games for evacuation training and research: A systematic literature review. *Comput. Educ.* **2018**, *127*, 252–266. [CrossRef]
8. Hsu, E.B.; Li, Y.; Bayram, J.D.; Levinson, D.; Yang, S.; Monahan, C. State of virtual reality based disaster preparedness and response training. *PLoS Curr.* **2013**, *5*. [CrossRef]
9. Collins, J.; Regenbrecht, H.; Langlotz, T. Expertise and Experience in VR-supported learning: Achieving a deep non-verbal comprehension of four-dimensional space. *Int. J. Hum.-Comput. Stud.* **2021**, *152*, 102649. [CrossRef]
10. Goedicke, D.; Li, J.; Evers, V.; Ju, W. Vr-oom: Virtual reality on-road driving simulation. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, Montreal, QC, Canada, 21–26 April 2018; pp. 1–11.

11. de Carvalho, P.V.R.; Ranauro, D.O.; de Abreu Mol, A.C.; Jatoba, A.; de Siqueira, A.P.L. Using serious game in public schools for training fire evacuation procedures. *Int. J. Serious Games* **2022**, *9*, 125–139. [CrossRef]
12. Scorgie, D.; Feng, Z.; Paes, D.; Parisi, F.; Yiu, T.W.; Lovreglio, R. Virtual reality for safety training: A systematic literature review and meta-analysis. *Saf. Sci.* **2024**, *171*, 106372. [CrossRef]
13. Abich IV, J.; Parker, J.; Murphy, J.S.; Eudy, M. A review of the evidence for training effectiveness with virtual reality technology. *Virtual Real.* **2021**, *25*, 919–933. [CrossRef]
14. Keya Tasnim, R.; Heldal, I.; Froland Hettervik, T.; Székely-Keresztesi, O.; Székely, Z.; Kon, E. Emergency Preparedness Training Using Virtual Reality Games: Allowing Knowledge Transfer in the Digital Age. In Proceedings of the European Conference on Knowledge Management, Veszprém, Hungary, 5–6 September 2024; pp. 369–378.
15. Makransky, G.; Andreasen, N.K.; Baceviciute, S.; Mayer, R.E. Immersive virtual reality increases liking but not learning with a science simulation and generative learning strategies promote learning in immersive virtual reality. *J. Educ. Psychol.* **2020**, *113*, 719. [CrossRef]
16. Kontogiannis, T. Training effective human performance in the management of stressful emergencies. *Cogn. Technol. Work.* **1999**, *1*, 7–24. [CrossRef]
17. Sarin, R.R.; Cattamanchi, S.; Alqahtani, A.; Aljohani, M.; Keim, M.; Ciottone, G.R. Disaster education: A survey study to analyze disaster medicine training in emergency medicine residency programs in the United States. *Prehosp. Disaster Med.* **2017**, *32*, 368–373. [CrossRef]
18. de Vaujany, F.-X.; Fomin, V.; Haefliger, S.; Lyytinen, K. Rules, Practices and Information Technology (IT): A Trifecta of Organizational Regulation. *Inf. Syst. Res.* **2017**, *29*, 755–773. [CrossRef]
19. Uhl, J.C.; Zechner, O.; Baetzner, A.; Birrenbach, T.; Egger-Lampl, S.; Schrom-Feiertag, H.; Tscheligi, M. Mixed reality training for medical first responders: System evaluation and recommendations. *Virtual Real.* **2025**, *29*, 69. [CrossRef]
20. Wijkmark, H.C.; Heldal, I.; Metallinou, M.M. Can Remote Virtual Simulation Improve Practice-Based Training?–Presence and performance in incident commander education. *PRESENCE Virtual Augment. Real.* **2019**, *28*, 127–152. [CrossRef]
21. Asad, M.M.; Naz, A.; Churi, P.; Tahanzadeh, M.M. Virtual reality as pedagogical tool to enhance experiential learning: A systematic literature review. *Educ. Res. Int.* **2021**, *2021*, 7061623. [CrossRef]
22. Hevner, V.A.R.; March, S.T.; Park, J.; Ram, S. Design science in information systems research. *MIS Q.* **2004**, *28*, 75–105. [CrossRef]
23. European_Comission. B-Prepared: Building PREPAREDness with Collaborative Knowledge Platform, Gamification and Serious Game. Available online: https://cordis.europa.eu/project/id/101121134/it (accessed on 12 July 2025).
24. Wilson, J.P.; Gosiewska, S. Multi-agency gold incident command training for civil emergencies. *Disaster Prev. Manag.* **2014**, *23*, 632–648. [CrossRef]
25. Gamboa-Maldonado, T.; Marshak, H.H.; Sinclair, R.; Montgomery, S.; Dyjack, D.T. Building capacity for community disaster preparedness: A call for collaboration between public environmental health and emergency preparedness and response programs. *J. Environ. Health* **2012**, *75*, 24.
26. Ekon. Disastropedia. Available online: https://disastropedia.com/ (accessed on 20 November 2024).
27. Webpage. Bprepared. Available online: https://b-prepared-project.com/ (accessed on 20 November 2024).
28. Arain, F. Knowledge-based approach for sustainable disaster management: Empowering emergency response management team. *Procedia Eng.* **2015**, *118*, 232–239. [CrossRef]
29. Barata, G.; Gama, S.; Jorge, J.A.; Gonçalves, D.J. Relating gaming habits with student performance in a gamified learning experience. In Proceedings of the First ACM SIGCHI Annual Symposium on Computer-Human Interaction in Play, Toronto, ON, Canada, 19–21 October 2014; pp. 17–25.
30. Rohde, M.; Brödner, P.; Stevens, G.; Betz, M.; Wulf, V. Grounded Design-a praxeological IS research perspective. *J. Inf. Technol.* **2017**, *32*, 163–179. [CrossRef]
31. Sikersiden. National Preparedness and Crises, Is a Collaboration Between 33 Universities, Colleges, and Research Organizations in Norway. 2025. Available online: https://www.sikresiden.no/en/nationalpreparedness (accessed on 20 November 2024).
32. One Planet Network. Regulation on Technical Requirements for Construction Works (TEK17). 2017. Available online: https://www.oneplanetnetwork.org/knowledge-centre/policies/regulations-technical-requirements-construction-works-tek17 (accessed on 20 November 2024).
33. Melo, M.; Gonçalves, G.; Bessa, M. How much presence is enough? qualitative scales for interpreting the igroup presence questionnaire score. *IEEE Access* **2023**, *11*, 24675–24685. [CrossRef]
34. Radianti, J.; Majchrzak, T.A.; Fromm, J.; Wohlgenannt, I. A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Comput. Educ.* **2020**, *147*, 103778. [CrossRef]
35. Wijkmark, C.H. *Virtual Reality for Fire and Rescue Service Professionals' Training*; Western Norway University of Applied Sciences: Bergen, Norway, 2024.

36. Frøland, H.T.; Heldal, I.; Braseth, T.A.; Nygård, I.; Sjøholt, G.; Ersvær, E. Digital Game-Based Support for Learning the Phlebotomy Procedure in the Biomedical Laboratory Scientist Education. *Computers* **2022**, *11*, 59. [CrossRef]
37. Fomin, V.; Hammar Wijkmark, C.; Heldal, I. Implementation of a weakly structured system as a case of digital transformation–a study of an emergency response training organization. In Proceedings of the 57th Hawaii International Conference on System Sciences, Beach Resort, HI, USA, 3–6 January 2024.
38. Hevner, A.R. A three cycle view of design science research. *Scand. J. Inf. Syst.* **2007**, *19*, 4.

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