Exploring the Design of Virtual Software for Fire Safety Education in Senior Elementary School Students

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Abstract

Education increasingly recognizes that traditional teaching methods may not sufficiently engage students. This study primarily focuses on the development of the game fire education. This research uses descriptive quantitative methods to describe the development of the Virtual Software for Fire Safety Education game, involving 26 students with experience in game design and testing for initial validation. This preliminary study will guide future experiments involving senior elementary school students, providing foundational insights for further research. Findings highlight game-based learning's capacity to foster engagement and understanding in fire safety education, underscoring its broader application potential.

Keywords: *digital game based learning; fire education; adventure games*

Abstrak

Pendidikan semakin menyadari bahwa metode pengajaran tradisional mungkin tidak cukup melibatkan siswa. Penelitian ini berfokus pada pengembangan game fire education. Penelitian ini menggunakan metode kuantitatif deskriptif untuk menggambarkan pengembangan Perangkat Lunak Virtual untuk permainan Edukasi Keselamatan Kebakaran, yang melibatkan 26 siswa yang memiliki pengalaman dalam desain permainan dan pengujian untuk validasi awal. Studi pendahuluan ini akan memandu eksperimen di masa depan yang melibatkan siswa sekolah dasar tingkat atas, memberikan wawasan dasar untuk penelitian lebih lanjut. Temuan-temuan menyoroti kapasitas pembelajaran berbasis permainan untuk mendorong keterlibatan dan pemahaman dalam pendidikan keselamatan kebakaran, menggarisbawahi potensi penerapannya yang lebih luas.

Kata kunci: pembelajaran berbasis permainan digital; pendidikan kebakaran; permainan petualangan

Introduction

Knowledge often flows from professionals to the community through traditional methods of disaster education. Therefore, in traditional methods of disaster education, knowledge flows without adequate community engagement. Besides this, incorporating community knowledge in disaster-related decision-making processes through face-to-face participatory methods could be costly and time-consuming. Fire, a severe natural disaster, annually causes substantial destruction, casualties, and property losses

worldwide. Nevertheless, many fire incidents can be preventable by enhancing fire risk awareness among community members and providing practical fire safety knowledge (Kankanamge et al., 2022).

Currently, domestic disaster preparedness lacks adequate education and training. Insufficient and outdated disaster education materials contribute to diminished student engagement. Therefore, there is a need to increase public willingness to learn about fire evacuation. (Prensky, 2003) proposed that the 21st century is the era of digital game-based learning, where technology and learning evolve from computer-assisted learning to digital learning and further integrate gaming into education. Recent academic initiatives advocate for gamification in learning, aiming to combine education with entertainment and convey educational concepts through gameplay (Hanson-Smith, 2020). These learning approaches leverage various technological tools and demonstrate diverse effectiveness. Insights into methods for delivering disaster education are provided from a new perspective. This is not to diminish the importance of traditional disaster education methods but to enhance them through integration with modern technology. It is undisputed that disaster education is one of the important ways to improve disaster preparedness. Therefore, it is very necessary to strengthen and popularize disaster education (Kankanamge et al., 2022).

This study integrates fire evacuation concepts with educational games and evaluates their impact on elementary school students. We create a virtual world through digital games where students acquire and apply knowledge through game-based tasks. The interactive nature of these activities facilitates deep understanding and learning, which is particularly appealing and practical for young students (McFarlane et al., 2002).

Fire services organizations implement community risk reduction mechanisms to improve fire prevention and preparedness (Simpson et al., 2014). Fire safety education helps reduce the likelihood that children will misuse or be harmed by fire. Although a large body of evidence informs current practice, no overarching, evidence-based frameworks guide effective education programs. Such guidelines are needed to develop new programs and to evaluate and modify existing ones (Pooley et al., 2021).

Alessi & Trollip (1984) divided games into seven categories: adventure games, board games, card or gambling games, war games, logic games, psychomotor games, and role-playing games. According to the definition of adventure games by Altınbaş (2023), Adventure Games (AVG) is a significant category of computer games. Players will explore from the central perspective in the game and use clues to discover unknown plots, clues, and maps.

This game type focuses on "exploration" and exploring unknown plots, clues, and maps. We can respond in different ways by feeling the tension caused by the unknown (Fouché, 2024). According to statistics from Hirameki International Group, nearly 70% of computer games released in Japan in 2006 were adventure games. Recently, such games have transcended cultural barriers and become popular among players worldwide. For example, Electronic Arts, the most significant game manufacturer in the United States, launched the pop-up game Cause of Death on the iOS platform in 2010.

Learning through play, also known as learning gamification, is learning through gamification. "Gamification" does not mean "playing games" but applying "game elements" to "non-game scenes." There are three core elements of gamification: points, rewards (Benefits), and rankings (Leader board), remembered by the English abbreviation PBL. Gamified teaching is the application of these three elements to the teaching scene. It is a popular teaching theory and educational practice at present. Transforming students' interest in games into motivation for learning can make teachers' efforts more effective. This is at the heart of gamified learning research. There are currently two tendencies in this view: (1) The theory of learning through assessment is cited, and students are guided into a learning state by using teaching game software or electronic textbooks to connect the teaching content with games or online competitions. It avoids the rigidity and boringness of the traditional teaching model. This method is currently being trialed in some primary schools in Hong Kong. The pilot schools include Yau Ma Tei Catholic Primary School (Hoi Wang Road) and the Buddhist Wong Chao Sum Primary School in Tseung Kwan O. (2) The game itself is learning. Therefore, through an in-depth study of game characteristics, the learning mechanism is reshaped based on these characteristics so that the learning process has the nature of a game rather than just presenting learning content in the form of a game.

So, what is digital gamification learning? Digital gamification learning is an educational method that combines game elements and learning objectives, aiming to improve learners' participation, motivation, and learning effects. Game-based teaching can enhance student participation and master practical experience (Colarusso, 1993; Vázquez-Calatayud et al., 2024). Prensky (2003) believes that digital game-based learning is the close combination of educational content and computer games, and it can also be defined as any educational game on a computer or online. The game-based learning model of Garris et al. (2002) can also describe in detail what digital game-based learning is. First, designing an educational game that integrates teaching content and game characteristics is necessary. Secondly, this game can immerse People in facing challenges, which continuously triggers a cycle of judgment, execution, and system feedback. Finally, they achieve a specific learning goal through investment in this kind of game. Therefore, to put it simply, digital game-based learning uses digital games with inherent learning elements to achieve a specific learning outcome.

Therefore, after the literature review, this study focuses on fire treatment, assists elementary school students with fire education issues, and develops an "Adventure Game (AVG)" for first-person disaster prevention education. Compared with other game types, in adventure games, players explore from the central perspective and unearth unknown plots, maps, etc., based on clues, emphasizing the "exploration" game feature.

By feeling the tension the unknown brings, players must respond differently to the situation. This design helps increase player participation and investment, achieving educational purposes more effectively. Therefore, through the use of adventure games, we can give students a deeper understanding of fire disaster prevention knowledge and improve their ability to respond to fire events while enjoying the game's fun. We hope that this study can provide helpful information for the development of the field of

disaster education and values and contribute to the safety of students and the community.

Research Method

Target audience

Based on the above observations, Taiwan's current school education system has shortcomings. The existing elementary school fire education primarily focuses on theoretical knowledge, lacking practical training for responding to fires. This makes it difficult for students to manage fire risks effectively in real-life situations. Additionally, the education methods are monotonous and fail to address the diverse needs of different students.

In this context, we have chosen elementary school students as the subjects of our research, focusing on their fire education, which holds significant importance. Considering the game's difficulty level, we selected upper-grade elementary students as the reference group for our study. Upper-grade students have a specific learning foundation, enabling them to understand and apply fire safety knowledge more deeply. Conversely, elementary students generally have lower comprehension and practical application skills regarding fire knowledge and response, necessitating more education and guidance. Moreover, their behavioral patterns when facing fires may differ from other age groups, so focusing on their fire education is crucial.

The reviewed literature shows that integrating 3D adventure game technology into elementary school fire education offers significant advantages. Firstly, 3D adventure games provide opportunities to simulate actual fire scenarios, allowing students to practice emergency responses in a realistic environment, thus enhancing their practical skills. Secondly, the game's design can be adjusted according to the students' age and cognitive levels, offering an educational experience that meets actual needs and improves learning outcomes.

Level design

Level 1: Severe Outdoor Fire Scenario

Scenario Description: In the first level, the fire originates outdoors and is extremely severe, with thick black smoke billowing in. The player must complete three crucial tasks to handle this extreme situation.

- Task 1: Close the Door**: The** player's primary task is to close the indoor door to prevent smoke from entering and to keep the indoor air relatively clean.
- Task 2: Find a Mask**:** The player must locate a mask to avoid inhaling smoke and prevent choking or unconsciousness.
- Task 3: Call for Help**:** The player must go to the balcony, dial 119 to report the fire, and seek assistance. This is the correct response in an emergency.
- Standalone Event: If the player attempts to hide in the bathroom, a dialogue box will appear, warning them that it is not advisable and may increase the danger.

- **Learning Objective:** The player must complete going to the balcony and calling for help within a limited time. This encourages the player to learn quick decision-making and response skills in a fire emergency.

Level 2: Self-Escape from Severe Indoor Fire

Scenario Description: In the second level, the fire originates indoors and is severe, but the outdoor smoke is relatively less. The player must complete multiple key tasks in sequence to ensure their safety.

- Task 1: Leave the Starting Room: The player must quickly leave the starting room to avoid the fire spreading to that area.
- Task 2: Close the Door: Immediately close the door to isolate the fire source after leaving the room.
- Task 3: Head to the Stairs: The player needs to quickly move towards the stairs and find an exit to go downstairs.
- Task 4: Escape Downstairs: The player must continue to descend the stairs, ensuring they leave the high-risk area.
- Task 5: Find the Exit: The player must follow the emergency exit signs to find a safe exit and successfully escape.
- Standalone Event: The player must learn to use a fire extinguisher when necessary to control the fire.
- Learning Objective: This level's goal is to teach the player how to escape on their own in an indoor fire scenario, including proper escape procedures, closing doors for safety, and using a fire extinguisher.
- Points System: Points can be earned based on the player's performance during the escape, such as quick escape times, effective use of escape tools, and correctly answering fire-related questions. These points can be displayed within the game and used to unlock special rewards or be showcased on a leaderboard.

Game Design

This study aims to create an educational tool that teaches fire response skills through gameplay. The game scenarios are designed based on various response situations, allowing players to simulate real-life fire escape experiences in a virtual environment. The key elements of the research include fire severity assessment, selection of appropriate escape methods, and integration of real-world fire response skills. Fire Severity Assessment: In the game scenarios, participants need to closely examine the virtual fire scene, considering factors such as the spread of the fire and smoke density to assess the fire's severity effectively. This element reflects the player's ability to observe and analyze fire situations deeply, compelling them to make careful and wise decisions based on their observations. Escape Method Selection: Depending on the severity of the fire, the game offers different escape method options. These include calling for help from a window and self-evacuation. The challenge lies in the player's ability to quickly and wisely choose the most suitable escape method within a limited time to ensure their safety. This highlights the importance of fire response strategies and enhances the player's decision-making abilities. Integration of Real-World Response Methods into the Game: The game simulates real-world fire escape scenarios, incorporating actual

response methods such as moving low to the ground, avoiding smoke, closing doors, using fire extinguishers, and considering escape signs. Through the simulation of virtual scenarios, players can experience and learn to respond appropriately to fire conditions, helping to develop their fire response skills and intuition. The game level and design description can be seen in Table 1, and the game concept flowchart in Figure 1.

Table 1 Level Game Description and Design of Scenes and Key Fire Handling Concepts

Operation Interface	Learning Concept Design	Game Show	Directions
Game Start Page	Increase interest in learning		The color contrast is strong and attracts players' attention.
First and Second-Level Game Intro Animations	Familiar with game background		The introductory animation guides players to familiarize themselves with the game background and operations, and cute-style 2D paintings are drawn to bring players into the game.
First Round	Learning Target: ● Close The Door ● Wear a Mask ● Call 119		The first level is designed to focus on basic fire escape methods. Through dialogue instructions, you will learn the necessary steps to escape.
Independent Event	Respond appropriately to the fire situation		Inform players why the elevator is unavailable
Task Interface			Help players understand mission requirements and goals
Second Level	Learning target: ● Leave The Room ● Use a Fire Extinguisher ● Follow The Escape Instructions		The second level has more learning objectives and escape techniques. Players need to pass the first level before they can continue to participate. It gradually

| Operation Interface	Learning Concept Design	Game Show	Directions
	• Escape From a Low Position		guides players to master the concept of escape.
Game Pass Success/Failure Screen	The option to re-challenge encourages players to try again and apply the knowledge and skills they learned from previous failures.		Giving players feedback on whether they have passed the level also represents the player's successful acquisition of fire escape knowledge.
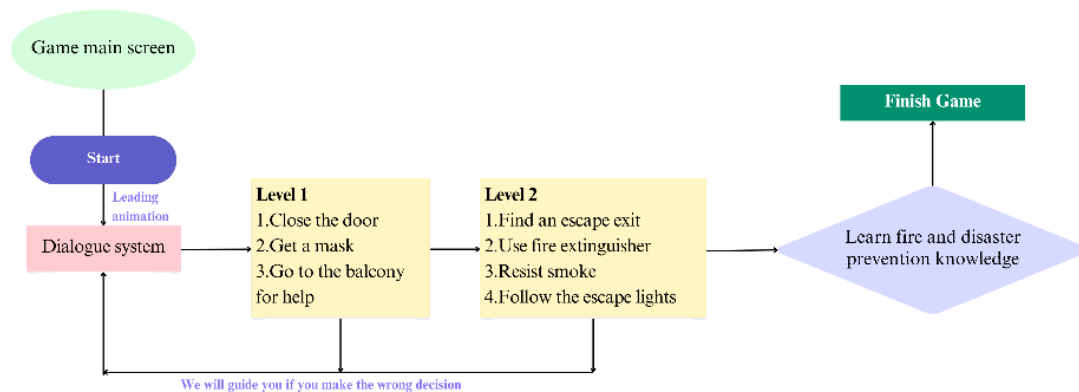
Figure 1 Game Concept Flow Chart

Results

This study primarily focuses on the development of the game itself. A total of 26 university students with game design and testing experience were invited to participate in the initial validation. This preliminary study will guide future experiments involving senior elementary school students, providing foundational insights for further research.

1. Mastery of Escape Steps:
   ➤ 73.1% of participants reported they could "very clearly" understand the escape steps after playing the game.

➢ 26.9% stated the steps were "clear" but could benefit from more diverse or detailed instructions to better accommodate various learning needs.

2. Acquisition of Disaster Prevention Knowledge:
   ➢ A majority, 96.2%, affirmed they learned new knowledge about disaster prevention.
   ➢ This highlights the game's potential as an effective educational tool.

3. Sense of Urgency in Fire Scenarios:
   ➢ 57.7% of participants experienced an "obvious" sense of urgency in the fire scenarios, suggesting the game's ability to create realistic and engaging environments.
   ➢ However, 38.5% reported only a "clear" sense of urgency, indicating room for improvement in scene design to enhance this aspect.

4. Scene Realism and Immersion:
   ➢ 57.7% of participants found the scenes "very realistic and immersive," with high ratings, particularly from older students.
   ➢ For younger players, such as elementary students in grades 1-4, 42.3% described the scenes as "clear," suggesting potential visual and interactive design adjustments.

5. Interface Design:
   ➢ 50% of respondents found the interface "very clear and easy to understand," while the remaining 50% rated it as "clear."
   ➢ These findings suggest that further refinement could enhance usability and player engagement while the interface is functional.

6. Game Difficulty:
   ➢ 57.7% of participants rated the game difficulty as moderate, aligning with the target audience of elementary school students in grades 5-6.
   ➢ However, 30.8% found it "slightly difficult," and 11.5% rated it "very difficult," indicating a need for adjustable difficulty levels to accommodate different age groups.

Five key recommendations have been identified for adjustments and improvements based on the previous questionnaire analysis. As a 3D fire education game, FIRE MENTOR requires continuous testing of the overall 3D space design, including dimensions, proportions, and shapes, to ensure players are not constrained by spatial limitations that might detract from the gameplay experience or reduce their interest in the game. Carefully designed sound and other special effects are incorporated to enhance immersion and provide an engaging gaming experience. In terms of user interface (UI) design, a more dynamic and appealing style is proposed to increase player engagement. During the gameplay, timely prompts are provided through dialog scenarios, mission objectives, and a sense of urgency to immerse players further. Additionally, a health bar system is included to instill a sense of accomplishment as players complete their tasks, thereby improving learning outcomes. To reduce cognitive

overload, the spread of flames in the game temporarily halts when a dialog box appears, allowing players to process information without the pressure of time constraints.

Discussion

The findings of this study indicate that the current game-based learning design can potentially support fire safety education. Over 96% of participants reported acquiring new knowledge on disaster prevention, and a majority demonstrated a clear understanding of escape procedures. Additionally, the game's design instilled a sense of realism and urgency, significantly contributing to participants' engagement and motivation.

This game-based approach addresses the limitations of overly theoretical and non-interactive teaching compared to traditional fire education methods. By simulating real-life fire scenarios, the game improved learners' disaster response skills and decision-making abilities. These results align with prior research highlighting the potential of digital games to foster practical skills and knowledge (Garris et al., 2002; Prensky, 2003).

However, particular areas for improvement were identified. For instance, 38.5% of participants suggested that the realism and sense of urgency in the game scenarios could be enhanced. Feedback indicated that the interface design and game difficulty could be more inclusive to accommodate a broader range of learners. These findings suggest that future game iterations incorporate adjustable difficulty levels and age-appropriate interactive elements.

From a practical perspective, the educational game developed in this study is a valuable tool for elementary school fire education. It offers a replicable model for other types of disaster education. The multi-scenario simulations and real-time feedback mechanisms allow learners to practice and internalize effective response strategies. Game-based learning is an engaging and effective approach to promoting disaster preparedness and safety awareness.

Future research could expand the participant pool to include learners from diverse age groups to validate the game's applicability further. Moreover, exploring the integration of artificial intelligence features, such as adaptive difficulty adjustment and real-time feedback, could enhance learning outcomes.

Conclusion

This study validates the value of digital game-based learning in fire safety education and offers insightful implications for future educational game designs. By fostering proactive engagement and interactive learning, the developed game provides a promising avenue for advancing disaster education and inspiring innovative practices.

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