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Effectiveness of Virtual Reality-Based Health Promotion and Safety Training in Schools

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Health and safety within the school environment are essential to ensuring a secure and sustainable learning process. Data from the Ministry of Health (2022) indicate that only 45% of secondary schools have an established emergency preparedness programme. A preliminary assessment at SMK Atisa Dipamkara also revealed substantial gaps: 73% of students had never participated in a fire simulation, and existing training remained conventional without interactive media. Nutritional issues were similarly prominent, as 60% of students frequently skipped breakfast, potentially impairing concentration and physical endurance. This study examined the effectiveness of a virtual reality (VR)-based training model integrating fire emergency simulation and balanced nutrition education. The study was conducted at SMK Atisa Dipamkara, Tangerang, from May to July 2025. A quasi-experimental design was employed involving 100 respondents assigned to VR and conventional training groups. Data were collected through knowledge tests, skills assessments, and Likert-scale satisfaction questionnaires. The findings demonstrate significant improvements in knowledge and skills among participants receiving VR training ($p < 0.001$), with outcomes superior to the conventional group. High satisfaction scores ($M = 4.36$; $SD = 0.53$) reflected strong perceptions of realism, interactivity, engagement, and active participation. VR-based training effectively addresses critical gaps in school preparedness and represents a strategic approach for strengthening comprehensive safety and health promotion programmes in educational settings.

Keywords: Virtual Reality, Fire Preparedness, Nutrition Education, Health Promotion

INTRODUCTION

Health and safety within the school environment are two fundamental aspects in establishing a safe, productive, and sustainable learning process. The Ministry of Health of the Republic of Indonesia reported that only 45% of secondary schools have an integrated program for emergency preparedness and health promotion (World Health Organization, 2023). According to data from the World Health Organization, 20–30% of injury incidents among school-aged children occur in educational settings, including accidents caused by fire, falls, or exposure to hazardous materials. The Health Promoting School Framework emphasizes that an ideal educational environment must integrate three main components: health education, a safe physical environment, and school health services (World Health Organization, 2021). Previous studies suggest that disaster preparedness education interventions are associated with improved student readiness in dealing with disaster risks (Adiyoso & Kanegae, 2013).

A preliminary study conducted with 30 respondents at SMK Atisa Dipamkara indicated that most training participants did not yet fully understand the stages of evacuation, the use of fire extinguishers, or the identification of potential fire hazards within the school environment. A total of 73% of respondents stated that they had never participated in a real fire simulation, and 67% reported that they had only received information through lectures without practical sessions. Based on initial observations and interviews with teaching staff, the annual fire training activities still employ conventional approaches such as lectures, video screenings, and manual field demonstrations without the support of interactive learning media. Previous studies have shown that conventional approaches lead to low participation rates and fail to provide experiences that adequately resemble actual emergency situations (Demirkol, D., & Aydın, 2023). The lack of active involvement in training without immersive simulations often results in limited practical emergency-response skills. VR-based training has proven to improve learning outcomes and enhance emergency-response skills more effectively (Calisanie et al., 2025).

In addition to safety-related concerns, initial observations revealed issues related to nutrition behavior and healthy eating habits within the school environment. Most students consume fast food or snacks high in sugar and fat available in the school canteen, while the intake of

fruits and vegetables remains low. Interviews with school health teachers indicated that approximately 60% of students frequently skip breakfast before going to school, which may impair learning concentration and physical endurance. This condition demonstrates that students' nutrition literacy is still limited and has not been supported by engaging and contextual educational activities. Previous research indicates that nutritional intake is associated with cognitive function, concentration, and learning ability, highlighting the need for more effective nutrition education strategies in school settings (Ismasnawati et al., 2025). Interactive and digital-based nutrition education approaches have been shown to support improvements in nutrition knowledge and healthy dietary behaviors among adolescents (Baranowski et al., 2016).

Virtual reality (VR) technology has rapidly developed and offers innovative solutions in training, creating significant opportunities for learning innovation, including Occupational Health and Safety (OHS) training and health promotion within educational settings. VR consistently enhances participant engagement, knowledge retention, and learning effectiveness in complex scenarios. Its immersive environments enable participants to practice in high-risk situations without exposure to physical danger (Luaran et al., 2025). Virtual Reality (VR) provides an innovative approach for fire emergency training by presenting immersive and dynamic simulation environments that allow participants to engage directly in fire scenarios resembling real conditions without physical risk, thereby improving engagement and learning retention (Makransky & Mayer, 2022).

Innovative learning approaches are required to equip and educate students with balanced-nutrition behaviors as part of school health promotion. The VR technology enables the presentation of interactive simulations that illustrate the application of balanced-nutrition principles, healthy food selection, and the impact of dietary behaviors on overall health. In nutrition education, this technology is capable of providing interactive scenarios that demonstrate balanced-nutrition concepts, healthy food choices, and the long-term consequences of unhealthy dietary habits. The development of interactive learning media can enhance students' understanding and engagement, particularly in nutrition-related topics. The use of simulation-based or gamified technologies, including VR, can serve as an effective approach to improving nutrition literacy through more engaging and contextual learning experiences (Franco-Arellano et al., 2024).

The use of Virtual Reality (VR) has emerged as an innovative alternative that provides simulated experiences closely resembling real conditions. The integration in two domains simultaneously, fire -preparedness and balanced-nutrition education, remains limited in previous studies, particularly within the context of Indonesian schools. This intervention presents novelty in both its learning approach and scope of materials. it has been shown to significantly enhance knowledge retention and practical skills in safety and health training.. (Steen et al., 2024). Therefore, this study aims to evaluate the effectiveness of VR in improving participants' knowledge, skills, and satisfaction, and to compare it with conventional training methods that are typically implemented.

METHOD

This study employed a quantitative approach using a quasi-experimental design, specifically a pretest–posttest control group design. The research was conducted at SMK Atisa Dipamkara, Tangerang, during the period from May to July 2025. The study population comprised all members of the SMK Atisa Dipamkara school community, including students, teachers, and administrative staff. Although purposive sampling was considered appropriate for the quasi-experimental design, it may introduce selection bias and limit the generalizability of the findings beyond the study setting. The sample was divided into two groups: an experimental group (n = 50) that received Virtual Reality (VR)–based training and a control group (n = 50) that received conventional training methods. This grouping was implemented to enable a comparative analysis of the effectiveness of the two training approaches within the context of school health and safety training. Of the 100 participants, the majority were students, with a smaller proportion of teachers and administrative staff. All participants were analyzed as a single group to evaluate the overall effectiveness of VR-based training in a school setting.

The data collection procedure began with the selection of participants through an official school announcement and the distribution of invitations to eligible respondents who met the inclusion criteria. Each prospective participant received a written explanation of the study objectives and procedures through an information sheet and subsequently provided informed consent prior to participation. The instruments used in this study consisted of knowledge and skills tests, as well as perception and satisfaction questionnaires, which were designed to obtain comprehensive data on the effectiveness of the training and participants' perceptions.

Participants' knowledge and skills were assessed through pre-test and post-test measurements aimed at evaluating learning outcomes before and after the training intervention. The fire safety knowledge test assessed participants' understanding of evacuation procedures, the use of fire extinguishers (APAR), and the identification of potential fire hazards. The nutrition literacy test evaluated knowledge related to healthy breakfast practices, adequate hydration, and appropriate menu selection. The knowledge and skills instruments were developed by the authors based on relevant literature and the objectives of the training program, and content validity was ensured through expert judgment. Reliability testing demonstrated acceptable internal consistency, with Cronbach's alpha values exceeding the recommended threshold of 0.70.

A skills observation checklist was used to assess participants' practical abilities in emergency situations, including evacuation procedures and the use of portable fire extinguishers (APAR) during the simulation. In the nutrition education component, the assessment focused

on participants' understanding of healthy breakfast consumption prior to physical activities, adequate hydration, and the ability to select balanced meal options within the school environment.

Participants' acceptance of the Virtual Reality–based training media was assessed using perception and satisfaction questionnaires developed based on a five-point Likert scale, covering aspects of content clarity, simulation realism, ease of use, participant engagement, and learning relevance. Training for the experimental group was conducted using a Virtual Reality (VR) application, whereas the control group received conventional training methods consisting of lectures, educational video presentations, and manual demonstrations.

The data obtained in this study were analyzed using descriptive and inferential statistical approaches. Descriptive analysis was employed to describe respondents' characteristics and to present the distribution of mean values for participants' knowledge, skills, and perceptions related to the training intervention. The results were presented in the form of frequencies and percentages for categorical variables, and mean values, standard deviations, and minimum–maximum ranges for numerical variables. Inferential statistical analyses were conducted using the following methods:

1. A paired sample t-test was used to measure differences between pre-test and post-test scores within each group.
2. An independent sample t-test was applied to compare the effectiveness of VR-based training and conventional training methods.
3. Quantitative descriptive analysis of the perception questionnaire results was performed to determine participants' levels of acceptance and satisfaction with the use of Virtual Reality (VR) technology in occupational health and safety (OHS) training. Effect sizes were calculated to estimate the magnitude of differences between groups.

Perception and satisfaction questionnaire data were analyzed descriptively using mean values and standard deviations and were categorized based on predefined satisfaction score ranges. The reliability of the perception instrument was assessed using Cronbach's alpha. Data analysis was performed using SPSS version 25 for Windows, with a significance level set at $\alpha = 0.05$. All respondents were provided with written information regarding the study objectives, procedures, potential benefits and risks, as well as their right to withdraw from the study at any time without any consequences. The study was conducted in accordance with ethical research principles.

RESULT AND DISCUSSION

The characteristics of the respondents in this study showed an age range of 15 to 52 years, with a mean age of 20.84 years (SD = 9.62), reflecting a participant composition predominantly consisting of students, with the involvement of teachers and educational staff. Experience with fire simulation was relatively low, with a mean value of 0.27 (SD = 0.45), indicating that the majority of respondents had never participated in such training. Experience related to nutrition education was also limited (M = 0.33; SD = 0.47), indicating minimal exposure of participants to nutrition literacy programs prior to the implementation of the study.

Table 1.
Subject Characteristics

Variable	Min	Max	Mean ± SD
Age (years)	15	52	20.84 (9.62)
Fire simulation experience (0 = no; 1 = yes)	0	1	0.27(0.45)
Nutrition education experience (0 = no; 1 = yes)	0	1	0.33 (0.47)
Baseline nutrition literacy (0–100)	32	78	54.13 (10.92)
Basic fire safety knowledge (0–100)	40	75	62.84 (8.21)
Nutrition behavior index (scale 1–5)	1	4	2.61 (0.71)
Familiarity with VR (scale 1–5)	1	4	2.03 (0.89)

Baseline nutrition literacy scores ranged from 32 to 78, with a mean of 54.13 (SD = 10.92), indicating a moderate level of basic nutrition knowledge. Baseline fire safety knowledge also varied (40–75), with a mean score of 62.84 (SD = 8.21), reflecting suboptimal foundational competence. Participants' nutrition behavior index fell within the low to moderate category (M = 2.61; SD = 0.71). Familiarity with Virtual Reality (VR) technology was relatively low (M = 2.03; SD = 0.89), indicating that most respondents were not accustomed to the use of simulation-based technologies. Overall, the respondent characteristics demonstrate limited prior experience in fire safety, nutrition education, and VR technology.

Effectiveness of Virtual Reality (VR)–Based Training on Improvements in Knowledge and Skills

Table 2.
Results of the Effectiveness Test of Virtual Reality (VR)–Based Training

Variable	Pre test	Post Test	p-value	sign
Fire preparedness	62.84	86.18	0.000	<0.05
Balanced nutrition education	65.12	84.68	0.000	<0.05

The results indicate that participants receiving VR-based training demonstrated statistically significant improvements in knowledge and skills related to both fire

preparedness and balanced nutrition education ($p < 0.001$). These findings indicate meaningful pre–post score improvements following the VR-based intervention. In addition to statistical significance, effect sizes were calculated to estimate the magnitude of these improvements, providing further insight into the educational relevance of the intervention.

Virtual Reality (VR)–based training had a significant effect on improving the knowledge and skills of the school community, both in terms of fire preparedness and balanced nutrition education. The use of VR serves as an effective learning medium by providing visual and sensory experiences that closely resemble real-life situations, thereby encouraging active engagement, strengthening attention, and enhancing information retention among participants. VR environments are capable of generating higher levels of emotional arousal compared to other media, which can influence participants' emotional engagement, although the impact on learning outcomes may vary (Parong & Mayer, 2021). These findings align with modern experiential learning theory, which emphasizes the importance of direct experience and multisensory interaction in the formation of knowledge and skills (Kolb & Kolb, 2017).

Experience-based learning enables participants to understand and internalize concepts through active involvement, reflection, and practical application within simulated contexts. In VR training, this process is evident in participants' ability to recognize safety procedures, perform systematic evacuations, and correctly operate portable fire extinguishers (APAR) without exposure to real-world risks. VR consistently enhances learning outcomes by integrating cognitive, affective, and psychomotor elements. Well-designed virtual environments can optimize experiential learning through visual realism, interactivity, and immediate feedback. VR design elements that allow intensive interaction with virtual environments contribute to higher-quality learning experiences (Radianti et al., 2020).

From the perspective of nutrition education, VR simulation modules focusing on healthy menu selection and balanced eating habits were also proven to enhance participants' understanding of fundamental nutrition concepts. Virtual environments that facilitate exploration of food choices and the consequences of dietary behaviors enable students to learn through visual and contextual experiences. This process strengthens participants' awareness of the relationship between food choices, energy levels, and long-term health outcomes. The use of VR in nutrition education increased students' self-efficacy in adopting healthy eating behaviors by 32% compared to conventional lecture-based methods.

VR-based interventions can enhance participant engagement and help internalize abstract nutrition information into more concrete and contextually relevant knowledge for everyday life (Sung et al., 2024). The effectiveness of VR can be explained through two primary mechanisms: increased learning engagement and enhanced situational awareness, both of which are difficult to achieve through traditional training methods (Borsci et al., 2022).

Comparison of Effectiveness between VR-Based and Conventional Training

Table 3.
Comparison of Pre–Post Score Changes between VR-Based and Conventional Training

Variable	VR	Conventional	p-value	sign
Fire preparedness	62.84	86.18	0.000	<0.05
Balanced nutrition education	65.12	84.68	0.000	<0.05

The results presented in Table 2 indicate a significant difference between the VR-based training group and the conventional training group across both measured aspects ($p < 0.05$). Participants in the VR group demonstrated greater mean score improvements compared with those receiving conventional training. These findings suggest that VR-based training may offer comparative advantages in supporting learning outcomes within school health and safety education, although causal interpretations should be made cautiously given the quasi-experimental design. The use of VR has been proven to effectively simulate fire scenarios in a safe, controlled, and realistic manner, making it an effective method for learning evacuation behaviors and enhancing emergency preparedness (Kinateder et al., 2014). Immersive experiences in VR enhance participants' engagement, attention, and cognitive processes through realistic situational simulations, thereby strengthening understanding and knowledge retention in accordance with experiential learning principles that emphasize the importance of direct experience in skill and knowledge development (Makransky & Mayer, 2022).

VR allows users to experience simulations that closely resemble real-world conditions, thereby strengthening cognitive processes such as focus, deep engagement, and repeated learning experiences without risk. Consequently, immersive VR experiences support the formation of long-term memory and enhance training effectiveness compared to traditional methods (Bueckle et al., 2022). The use of VR in emergency response training within educational facilities has been shown to produce faster and more accurate responses during fire simulations compared to traditional methods. Fire safety training that does not involve simulated experiential learning has been found to reduce skill retention and emergency response readiness (Arslanyilmaz, 2020).

With regard to the nutrition education variable, the VR-based training group demonstrated greater improvements in understanding balanced nutrition concepts compared to the conventional group. Conventional nutrition education methods are often less effective in sustaining learners' interest and fail to provide

contextual learning experiences (Teo et al., 2021). The observed improvement in understanding can be attributed to the interactive visualization effects of VR, which help participants comprehend the relationships among food choices, energy requirements, and their impacts on health. The use of VR in nutrition education shows strong potential for increasing student engagement and understanding of healthy eating behaviors through more interactive and immersive learning experiences (Liao et al., 2025).

Participants' Satisfaction with the Use of VR

Table 4.
Participants' Satisfaction Levels with VR Media

Variable	Mean	Std. Dev	Category
Clarity and accuracy of content	4.32	0.58	Satisfied
Simulation realism and attractiveness	4.61	0.46	very satisfied
Ease of use of the media	4.18	0.54	Satisfied
Participant engagement and interactivity	4.44	0.49	very satisfied
Relevance to the learning context	4.26	0.57	very satisfied
Overall mean	4.36	0.53	very satisfied

Categorization: Very dissatisfied (1.0 - 1.79); dissatisfied (1.8 - 2.59); moderately satisfied (2.6 - 3.39); satisfied (3.4 - 4.19); very satisfied (4.2 - 5.0) (Aldhafeeri & Alosaimi, 2020).

The results presented in the table indicate that the majority of participants provided positive evaluations of the VR-based training. The overall mean score (M = 4.36; SD = 0.53), which falls within the very satisfied category, indicates that participants perceived the VR media as highly effective in facilitating content understanding, enhancing engagement and active participation, and providing a more engaging and safe learning experience.

A study entitled Optimizing Performance and Satisfaction in VR Tasks demonstrated that optimally designed VR environments—characterized by high interactivity, intuitive user controls, and adequate levels of immersion—significantly improve task performance, learning satisfaction, and knowledge retention among participants. This occurs because. Participants' satisfaction was influenced by several key factors, including perceived ease of use, perceived usefulness of the technology, and the level of interactivity. The Technology Acceptance Model (TAM) explains that user acceptance of new technology is highly dependent on operational ease and perceived benefits (Davis, 1989). In this context, VR provides added value by minimizing the boredom often associated with traditional training methods and by enabling participants to actively engage in situations that closely resemble real-world environments. Satisfaction levels with VR-based learning tend to be high when media design fulfills three key elements: visual realism, ease of navigation, and relevance to the learning context (Aldhafeeri & Alosaimi, 2020). The implementation of VR for fire evacuation preparedness in schools has been shown to increase participants' enthusiasm and responsiveness to realistic simulated scenarios (Keya et al., 2025).

The high level of participant satisfaction reinforces that VR is not only pedagogically effective but also psychologically and socially acceptable to users in educational settings. From a psychological perspective, the immersive experiences generated by VR can be explained through Flow Theory, which emphasizes the importance of full engagement and a balance between challenge and skill in creating optimal learning experiences. Immersive experiences in Virtual Reality can enhance participants' concentration and engagement because users enter a state of flow, defined as a condition in which learning challenges are well matched to individual abilities. This state of flow makes the learning process more engaging, focused, and profound (Moneta & Knight, 2017). These findings further strengthen the potential for broader adoption of VR in occupational health and safety (OHS) training and health promotion programs in schools, in alignment with the Health Promoting School (HPS) principles that integrate safety, health, and technology-based interactive learning.

CONCLUSIONS

The use of Virtual Reality (VR) as a training medium for health and safety promotion in schools is effective in improving the knowledge and skills of the school community, particularly in fire preparedness and understanding of balanced nutrition concepts. Comparisons between VR-based training and traditional methods indicate that VR-based training demonstrated greater improvements compared with conventional training methods. Furthermore, the high level of participant satisfaction demonstrates that VR is well accepted as an innovative training medium, as it is perceived to be realistic, easy to use, and relevant to learning needs. One limitation of this study is the relatively short duration of the intervention, which may not fully represent long-term behavioral changes among participants. To optimize the implementation of VR as a training medium for health and safety promotion, future studies are recommended to involve a larger number of schools with diverse characteristics, extend the evaluation period, and develop more comprehensive VR content.

SUGGESTION

Virtual Reality (VR)–based training is recommended as a complementary approach to improve school health and safety promotion, particularly in fire preparedness and nutrition education. Future studies should involve multiple schools and longer follow-up periods to evaluate sustainability and scalability of VR-based interventions.

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