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Advancing virtual learning spaces in Ukraine's educational institutions

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Abstract In the era of innovative societal development, virtual reality technologies are becoming an integral tool in the educational process. This article aims to analyse the potential of immersive technologies in implementing virtual learning environments in educational institutions in Ukraine. It has been found that immersive technologies are rapidly evolving from being an innovation to a practical and widely used range of tools. The study established that their implementation into the educational policy paradigm is seen as a promising necessity and a factor in intensifying the quality of education. The essence of the phenomenon of immersive technologies has been specified, with their components distinguished, including objective reality, virtual reality, and augmented reality. The specifics of involving immersive technologies in the educational process in Ukrainian educational institutions have been highlighted. An experiment was conducted involving virtual reality technologies in the professional educational environment of future fire safety specialists through the VR programme FLAIM Systems. During the study of the peculiarities of virtual reality technologies in educational modelling, the priority advantages and associated risks of their integration were highlighted. It was found that the potential of immersive technologies stimulates the optimisation of understanding complex concepts and significantly expands the toolkit of future industry specialists. It was determined that engaging visualisations and the experience of using virtual reality technologies offer an intuitive approach to rather abstract concepts that are difficult to reproduce within the framework of classical pedagogical technologies. It has been substantiated that using virtual reality technologies in the educational and management process has significant advantages over the traditional methodology of educational processes, as it actively engages the sensory system and emotional sphere. It has been proven that virtual reality (VR programmes) has significant potential to positively impact the quality of education in educational institutions in Ukraine.

Keywords: virtual reality, augmented reality, pedagogy, modelling, modernisation of education, immersive technologies

1. Introduction

Recently, immersive technologies have been gaining popularity as components of innovative pedagogical technologies, including vocational education. The most popular immersive technologies include augmented reality (AR) and virtual reality (VR) technologies. These technologies create prerequisites for effective interaction, modelling, and forecasting in a three-dimensional space. While augmented reality is created using an ordinary smartphone, virtual reality requires a headset and glasses. Immersive technologies are identified as integrating virtual content into the physical environment, creating conditions for effective interaction. At the same time, the user perceives the virtual components as an integral part of their experience. The range of immersive technologies encompasses a variety of programmes and tools that allow for integration, immersion, or interaction with simulated environments and objects.

Today, several mobile applications using augmented reality and dedicated VR devices have already been developed and are available for use. For the successful implementation of high-quality education, it is deemed necessary not only to develop and intensively introduce a range of educational technologies involving the potential of virtual reality but also to ensure the technical infrastructure required for the implementation of immersive tools, the optimisation of the digital environment of educational institutions, and the enhancement of digital literacy among educators. The critical aspect of the topic under study is exploring the potential of immersive technologies in Ukraine's educational environment.

Several contemporary researchers have addressed the issue of implementing virtual reality technologies in the educational sphere. In particular, Hamilton et al. argue that immersion in virtual reality is an appropriate universal learning tool (Hamilton et al., 2021). The researchers conducted a systematic review of studies on quantitative learning outcomes and experimental design, highlighting the significant prospective potential of the technologies under study.

Members of the modern scientific community, Kuhail and Sayary, have analysed the practical experience of immersive learning (Kuhail & ElSayary, 2022). The researchers believe the modern education system should be based on the synergy of traditional and immersive preventive technologies. The authors present the effectiveness of such synergy, emphasising recent achievements of certain experimental studies and pilot projects. Makransky and Petersen assert that the effectiveness of the cognitive-affective model of immersive learning is necessary to develop educational programmes successfully (Makransky & Petersen, 2021).

A representative of the modern scientific community, Chen, conducted an analysis of the practical experience of optimising the paradigm of management innovations in terms of converging basic traditional principles and the latest immersive technology tools (Chen, 2022; Sikorska, 2023). Authors like Lee Hodgson have studied the concepts of optimising education through immersive virtual reality and non-immersive virtual reality in the learning environment, arguing that the improvement of virtual reality technologies contributes to modernisation in the field of management, which is related to the intensification of scientific and technological advancements (Lee et al., 2020; Bakhmat et al., 2023).

The associated risks and challenges have been explored in the works of Liu et al., where the researchers analysed essential solutions in the context of the concept under study. The authors pay special attention to problematic issues concerning the exploration of the relationships between immersive technologies and academic achievements and scientific motivation, thus providing insight into the integration of immersive tools into the existing education system (Liu et al., 2022).

The issue of virtual technologies in education is also a subject of interest for other scholars (Li et al., 2023; Pellas et al., 2020; Han, 2020; Liu et al., 2020). Overall, researchers have proven the significant potential of virtual reality in the context of the outlined issue. However, at the same time, there is a need for further research on associated risks and challenges to improve the use of this tactic in a safe context, as the issue of transforming approaches to ensuring the safety of the virtual reality technology application process remains underexplored.

The article aims to analyse the potential of using immersive technologies to implement a virtual learning environment in Ukrainian educational institutions.

2. Methods

The foundation of the methodological and theoretical basis was a systemic approach and generally accepted concepts of complexity and dialectics. The systemic concept, in particular, created the prerequisites for practical analysis of the studied phenomenon as a systemic entity in its interconnections.

Within the study's framework, an experimental method was used, which involved virtual reality technologies in the professional educational environment of future fire safety specialists. Through the VR programme FLAIM Systems, a scenario for fire prevention was modelled. The FLAIM Trainer allowed the recreation of the stress and uncertainty of real situations, conveying visual sequences and tactile sensations. The system simulates behaviour by heating the user with a thermal vest, recreating the experience of acting in scenarios with different fire source locations.

The study sample consisted of 150 learners with varying experience and knowledge. The sample was selected randomly, as the students were chosen from a single educational institution with access to the necessary technologies and resources. The sample was divided into two groups: the metaspace (75 learners) and the traditional virtual environment (75 learners). The traditional virtual environment was purely digital and did not include real-world elements. The metaspace included virtual and natural elements, such as physical objects and real-time feedback. Students in both groups completed tasks and underwent assessments to measure their knowledge acquisition, engagement, and satisfaction with the learning process.

During the experiment, the time spent in the virtual reality environment was assessed, along with performance indicators (accuracy, reaction time, task completion time) for specific tasks or scenarios in the simulation, as well as physiological data (e.g., heart rate, skin conductance) to measure levels of arousal or stress, and user experience indicators (e.g., presence, engagement, satisfaction) using questionnaires or surveys. After the training, the knowledge gained during preparation for emergencies in the event of a forest fire was analysed through pre- and post-training assessments, as well as the ability to transfer skills to real scenarios related to emergency preparedness during forest fires.

3. Results and Discussion

The effectiveness of implementing innovative technology into the educational environment is determined, first and foremost, by its targeted use in synergy with the traditional educational process requirements and the formation of new educational content in particular. The use of immersive technologies, which involves the active engagement of virtual training opportunities in the educational system, should be based on research findings regarding the impact of these technologies on the quality and effectiveness of the educational process (Sanabria, 2017). The specific features of immersive technologies are seen in the presence of a sense of personal presence, multisensory experiences, and the variable possibility of interactive and social interaction, which significantly influence the dynamics of learning outcomes in synergy.

Virtual reality allows for a unique experience synthesised with successful learning strategies, particularly modelling, visualisation, and practical learning. The educational environment of virtual reality technologies includes a vibrant multimedia

and informational context that creates a system of unique interactivity. It should be noted that this context can be successfully adapted to individual learning styles. Virtual and augmented reality technologies optimise learning conditions, ensuring immersion in a multimodal environment enriched with sensory features.

Visualisation and cognitive interest, formed based on engagement and attention-focusing effects, allow VR technologies to be singled out as a separate category of tools for improving the educational and management environment, which are closely interrelated. Undoubtedly, the range of modern immersive technologies can significantly impact the effectiveness of the educational and training processes due to the possibilities of simulating various emotional states, engaging attention and interest in educational material, and the ability to experience the learning process personally. The effectiveness of the outcome of the outlined process is determined by the fundamental requirements underlying the design of educational and management content. Immersive technologies have significant potential in modernising education, making learning more interactive, interesting, and engaging (Zhu et al., 2015).

Among the critical qualitative characteristics of implemented virtual reality technologies in an immersive environment, it is necessary to highlight the effect of immersion, immersive visual and auditory experiences, creativity stimulation, and prompt decision-making optimisation (Perey et al., 2011; Iatsyshyn, 2022). Their interactivity and ability to create realistic situations allow for a more profound and more engaged experience of the educational material. VR technologies form several effective tools that contribute to practical generalisation, study, visual assimilation, spatial awareness of issues, intensification of cognitive activity, critical thinking, and creativity (Arifin et al., 2018).

In the experiment involving virtual reality technology for preventing and managing forest fires, the product of the Australian startup FLAIM Systems was used, which is currently positioned as a successful functional example of virtual reality programmes for practical, targeted purposes. The company's main product is the FLAIM Trainer, a virtual reality firefighting training system. It provides a safe and cost-effective way to replicate the stress and uncertainty of real situations to prepare professionals for the challenge better. The FLAIM Trainer not only conveys visual elements but also tactile sensations. The system simulates behaviour by heating the user with a thermal vest, recreating the experience of acting in scenarios with different fire source locations. The Trainer tracks real-time training data, including task completion speed, air and water usage, stress levels, trainee movements and attention, and object interaction. The VR realistically depicts all the fire, smoke, water, extinguisher foam, and heat, thanks to a special thermal suit that can heat the firefighter depending on their proximity to the virtual fire.

Additionally, a virtual reality programme was employed, which engaged a classroom (a facility within the complex was used, enabling the implementation of a 360° digital projection). The proposed innovative form of education becomes accessible thanks to high-speed internet, a network maintained at the necessary quality level, ensuring a stable streaming process. By creating a character, students observe their actions during a fire, understanding the importance of measures to prevent similar situations. It was established that by transcending the boundaries of traditional educational methods through 3D modelling and virtual reality, learners in the educational process intensify the development of critical thinking, imagination, and stress resistance. Students realised several essential truths and dispelled several myths. In particular, they clarified that forest fires are not solely caused by human negligence. Lightning or a summer drought in the forest are situations where human influence is not a factor in the ignition, but the fire can flare up and spread rapidly.

By combining virtual reality technology with the theory of embodied cognition, the experiment aimed to create a more effective and impactful training experience for professional response (Slater & Sanchez-Vives, 2016). The research suggests that cognition is not confined to the brain but is also influenced by the body and its interaction with the environment. The theory of embodied cognition is applied in various fields, such as psychology, neuroscience, and robotics. It explains how physical actions and experiences can significantly affect cognitive processes such as perception, attention, and memory.

The average values of the learning coefficient in the experimental and control groups were determined by the formula (1):

$$KN1 = A1/N1 \qquad (1)$$

where KN1 is the learning coefficient; A1 is the qualitative indicator of learning outcomes; N1 is the maximum possible number of points for the result of qualitative training.

The results of the assessment at all levels are shown in Table 1.

Table 1 Evaluation of results of implementing an interactive educational environment based on immersive technologies (by the Learning Coefficient).

Assessment criteria	Control group	Experimental group
Level of knowledge before the training	0,65	0,63
Level of knowledge after the training	0,69	0,74
Ability to transfer skills to real-life scenarios before the training	0,41	0,40
Ability to transfer skills to real-life scenarios after the training	0,49	0,58

The research convincingly demonstrates that using virtual reality technologies in the educational process has significant advantages over traditional methodological processes, as it actively engages the sensory system and emotional sphere. Specifically, the knowledge gained during preparation for emergencies in the event of a forest fire increased by 17% in the experimental group, while in the control group, it increased by only 6%. The ability to transfer skills to real scenarios related to emergency preparedness during forest fires increased by 45% in the experimental group. In contrast, it increased by only 19% in the control group. The experiment highlighted the necessity of critical thinking skills, a comprehensive view of the situation, and prompt decision-making. It is evident that the potential of immersive technologies stimulates the optimisation of understanding complex concepts and significantly expands the toolkit of the modern industry professional (Figure 1, 2, 3, 4).

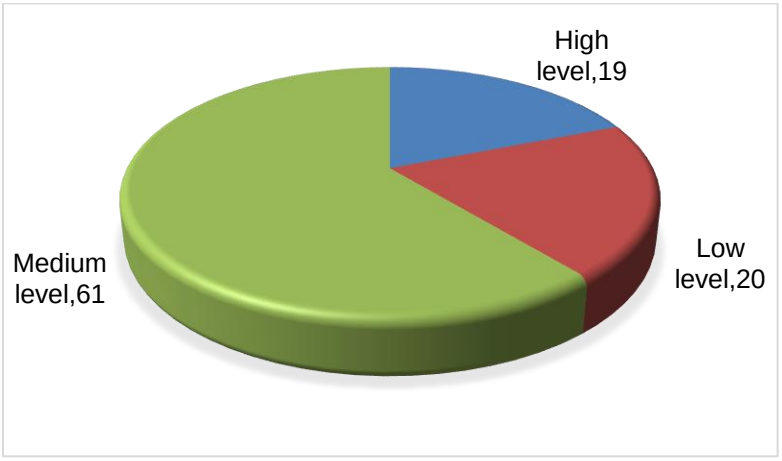

Figure 1 Dynamics of Knowledge Level Indicator in the Experimental Group before the experiment, number of students in %.

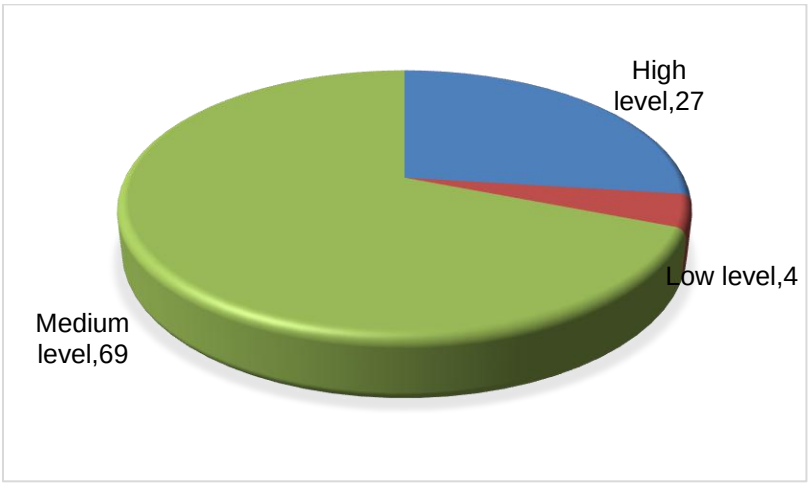

Figure 2 Dynamics of Knowledge Level Indicator in the Experimental Group after the experiment, number of students in %.

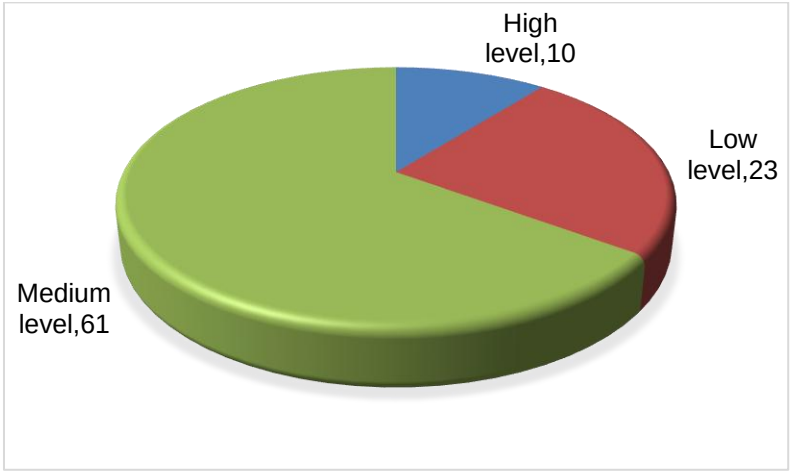

Figure 3 Dynamics of Transferability of Skills to Real Professional Scenarios before the experiment, the number of students.

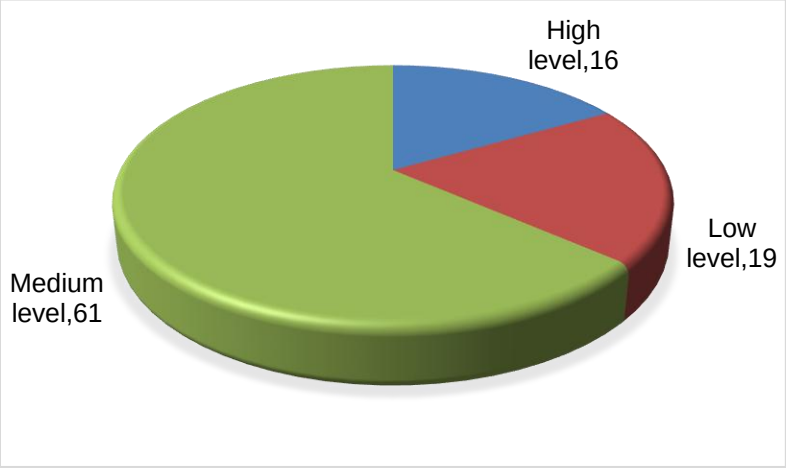

Figure 4 Dynamics of Transferability of Skills to Real Professional Scenarios after the experiment, the number of students.

When studying immersive technologies' applications in preventing and managing forest fires in a virtual environment, the advantages of their application were identified. These include visualising abstract and complex concepts, stimulating active interaction in virtual objects and environments, developing creativity and problem-oriented thinking, and acquiring realistic experiences important for understanding specific concepts and processes.

Despite several positive aspects related to the application of immersive technologies, their use is accompanied by several risks, drawbacks, and challenges. Among these, the high cost and limited accessibility of the necessary technical equipment should be highlighted. Most virtual reality technologies are expensive, especially in financial constraints and structured budgeting conditions. Additionally, implementing virtual reality technologies into the educational and management environment requires professionals to possess the necessary skills and appropriate training to use these technologies in practice.

Another risk is the potential disconnection from reality, as virtual reality technologies can focus attention on virtual scenarios, distracting from real-life situations. Prolonged use of immersive technologies can lead to health deterioration in discomfort, impaired vision, and memory retention issues. The active implementation of virtual reality technologies could lead to an overreliance on digital tools for education and management activities, which could negatively impact the development of other skills and social abilities. Furthermore, considering the rapid development of immersive technologies, it currently seems challenging to define standards and criteria for using these technologies in educational and management processes.

As results of the research position the phenomenon of immersive technologies as an innovative and promising element within the system for effectively implementing the concept of innovative practice-oriented education. As indicated by the findings of contemporary scholars (Klingenberg et al., 2020; Papanastasiou et al., 2019; Kubitskyi et al., 2022), one of the most effective means for optimising education is the active use of modern virtual reality technology tools. Considering the conclusions of Tang et al. regarding the concept of preventive training and educational systems based on virtual reality technologies, the priority and primary importance of user experience in the field of virtual reality in education will belong to augmented reality applications (Tang et al., 2022). Meanwhile, certain researchers, particularly Semerikov et al., emphasise addressing associated challenges and risks. The findings of Semerikov correlate with the conclusions of the experiment conducted in this study, as pedagogical methods involving virtual reality enable the educational process to gain practical value and align with the demands of modern society (Semerikov et al., 2021).

Marougkas et al. highlight specific prerequisites for an effective educational paradigm based on an integrated approach, focusing on the necessity of having an adequate resource base and the readiness of the teaching staff for innovations (Marougkas et al., 2024). Additionally, Erturk and Reynolds; Cheng propose utilising the potential of VR tools as training technologies within professional education, revealing their functionality in enhancing the practical significance of the educational process (Erturk & Reynolds, 2020; Cheng, 2022; Shkola et al., 2022). Some authors (Seufert et al., 2022; Coban et al., 2022; Enyedy & Yoon, 2021) position monitoring as essential in implementing optimal measures for integrating immersive technologies. Several studies have been conducted by scientists on the use of immersive learning in mixed reality to improve education, with the results indicating that the consequences include rethinking the tools of the learning environment with self-directed mobile learning, as well as the prioritisation of the tactile-sensory capabilities of virtual reality for innovative pedagogical technologies.

Despite numerous positive aspects and outcomes of implementing immersive technologies, their use is accompanied by various risks, drawbacks, and challenges.

Among these, the high cost and limited accessibility of the necessary technical tools stand out. The majority of virtual reality technologies are quite expensive, particularly under financial constraints and during socio-economic crises. Moreover,

implementing virtual reality technologies in educational and management environments requires specialists to possess the necessary skills and adequate training for using these technologies in practice.

A specific risk is the disruption of connection with reality, as virtual reality technologies may focus attention on virtual scenarios, distracting users from real-life situations. Prolonged use of immersive technologies may lead to health issues, such as discomfort, vision deterioration, and memory impairment. There is also the potential risk that active implementation of virtual reality technologies may cause excessive reliance on digital tools for learning and management, negatively impacting the development of other skills and social competencies. Additionally, given the rapid development of immersive technologies, establishing standards and criteria for their use in educational and managerial processes appears to be a challenge.

Nevertheless, implementing technologies with enhanced visualisation of content and visual models actively encourages the development of spatial imagination and intensifies understanding of complex issues. It facilitates content assimilation through visual representation, supports the creation of virtual spaces for unresolved problems, and reproduces real-life situations.

Despite significant scientific achievements in virtual reality, the issue of its large-scale practical adaptation to the realities of the Ukrainian educational system still needs to be solved. Modelling modern educational content with immersion in virtual reality leads to better results in intensifying professional self-awareness, as the immersive environment with a sense of real presence results in higher engagement and motivation and deeper cognitive processing of educational material. Educational virtual reality applications have significant potential that is unavailable with traditional educational technologies.

4. Conclusions

During the research, it was found that immersive technologies are rapidly evolving from being an innovation to becoming a practical and widely used range of tools. It has been established that their implementation into the paradigm of educational policy is seen as a promising necessity and a factor in intensifying the quality of education. Through the specification of the essence of the phenomenon of immersive technologies, their components were distinguished, particularly objective reality, virtual reality, and augmented reality.

The study provides an example of the application of virtual reality technologies in modelling a scenario to prevent a forest fire in a specific area using a virtual reality programme (VR programme) in a professional educational environment. The peculiarities of virtual reality technologies in educational modelling were studied, and the advantages and risks of their integration were highlighted. It is evident that the potential of immersive technologies stimulates the optimisation of understanding complex concepts and significantly expands the toolkit of modern pedagogical technologies.

Through the VR programme FLAIM Systems, a scenario was modelled to prevent a forest fire, focusing primarily on the prerequisites, factors, and consequences of forest fires. The FLAIM Trainer enabled the recreation of the stress and uncertainty of real situations, conveying the visual and tactile aspects. As a result of the experiment, the dynamics of the knowledge acquired during preparation for emergencies in the event of a forest fire were analysed, as well as the possibility of transferring skills to real scenarios related to professional training. In light of the experiment, certain limitations of the study are due to the limited sample size. As a result, the variability of specific indicators, such as the relationship between two or more variables and predicting future outcomes, could not be fully accounted for during the experiment, which warrants verification in future studies.

Thus, the use of immersive technologies in the learning process significantly expands the toolkit of modern education. Virtual reality technologies allow the projection of a virtual environment and the development of an interaction scenario with visual interactive material, which contributes to improving the effectiveness of the educational process.

Ethical Considerations

We confirm that we have obtained all consents required by applicable law for the publication of any personal data of the research participants. We agree to provide multidisciplinary reviews with copies of the consent or evidence that such consent was obtained if requested.

Conflict of Interest

The authors declare no conflicts of interest.

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