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A Review of the Effectiveness of Virtual and Augmented Reality Technologies in Physical Education

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Abstract

The integration of pedagogical practice with digital technology is revolutionizing physical education through the adoption of virtual reality (VR) and augmented reality (AR). Immersive technologies have been applied in various learning settings to increase motivation, engagement, and motor skill learning. Nevertheless, despite their increased application, there is a shortage of systematic reviews to analyze their effectiveness in physical education. The aim of this study is to synthesize existing empirical evidence on the use of VR/AR technologies in physical education, discussing their advantages and disadvantages, and identifying areas that have limited research. Literature review was undertaken systematically employing the Publish or Perish (PoP) software to search for pertinent research in Google Scholar. The parameters set were limited to peer-reviewed, 2020-2024 published journals using specific keywords related to VR/AR technologies in physical education and sports training contexts.. The studies were chosen on the basis of empirical design, motor skill development focus, and game-based learning approaches. The final round included research carried out using commercial VR/AR software and locally developed interactive programs. The studies categorized studies according to intervention duration, technology, participants, and outcome measured. The review identified a succession of studies that had established the increases in motor capability, motivation, and interest achieved through VR/AR-enabled physical education. VR environments added to full-body motion

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control, response, and balance, and AR device-enhanced visualization and execution of motor skills. Game-based VR/AR applications proved most effective among all categories of applications in maximizing learner interest and learning retention. Nonetheless, pertinent limitations were described, such as accessibility barriers, equipment cost, and transfer in reliability of motor skills in a virtual environment to actual use. In addition, the majority used quasi-experimental studies, with which it is challenging to evaluate cause-and-effect. Comparative research between AR effectiveness and VR does not exist. VR and AR technology offer exciting possibilities for extension of physical education in the areas of heightened motivation and motor skills acquisition. However, broader use of the technologies is limited by expense and logistical considerations. Studies should address how to surmount these, boil instructional design down to its essence, and clarify the long-term impact of VR/AR on physical education.

Keywords: Virtual Reality, Augmented Reality, Physical Education, Immersive Technologies, Learning Outcomes, Student Engagement

1. INTRODUCTION

The educational process, which is actively developing, does not remain on the sidelines of innovation implementation. In particular, the emergence of new technologies has led to the modernization of physical education at various levels of education. This is related both to the digitalization of the educational process and to the improvement of access to technology for its participants. The speed of emergence of digital technologies significantly exceeds the speed of their testing and research on their effectiveness in the field of physical education. A problem arises when only the advantages and possibilities of certain technologies are postulated, without substantiating their significance for the qualitative transformation of the physical education process. Another issue arises when a certain technology is proposed solely for the sake of diversifying physical education, without considering the effects that may be observed. The mechanical implementation of individual technologies in the physical education process does not allow for their effective use. The prompt practical testing of innovations in physical education determines the possibilities for its further optimization. There is also a need for periodic generalization of practical experience in using innovations in physical education, which allows for identifying general directions for its improvement through the combination of advantages from different technological groups.

Recently, there has been an increased interest in the use of virtual reality in the physical education process, driven by improved accessibility of these technologies for participants in the educational process. The rapid development of this field necessitates the generalization of practical experience regarding the use of virtual and augmented reality in physical education.

1.1 Research Objective.

To review the effectiveness of using gaming virtual and augmented reality technologies in physical education.

2.0 Literature Review

Technologies of virtual (VR) and augmented (AR) reality are currently being actively implemented in the educational process at both the school and higher education levels (Ariffin et al., 2022; Feng, 2020). Current research focuses exclusively on presenting potential and establishing real advantages of VR/AR technologies for learning (Bores-García et al., 2024; Calabuig-Moreno et al., 2020). These technologies are characterized by interactivity and attractive design. This contributes to increased engagement and motivation for learning (Awaluddin et al., 2024; Feng et al., 2022). Initially, virtual and augmented reality developed actively in the entertainment industry. This made it possible to increase player engagement and make both traditional and digital gaming more interactive, bringing it closer to real-life actions. In particular, players now had to move more (Bazylchuk et al., 2024; Lytvynova, 2022).

The game-based format of content presentation is a key feature of VR/AR technologies proposed for use in physical education. This can be achieved through the creation of special scenarios, competitive interactivity, and creativity in movement (Gulich, 2024; Kolovelonis et al., 2023). Reports indicate that the game-based method is

one of the most in-demand in the field of physical education. Its use with various age groups allows for greater motivation and engagement of participants, fosters creativity, and optimizes motor activity (Pryshlyak et al., 2024; Fidirko et al., 2021).

It is worth noting that VR/AR technology in teaching sports games has proven effective at an empirical level. Researchers have developed a program for using VR to simultaneously improve sports skills and develop motor abilities in school-aged children (He, 2024; Mladenova, 2022). It has been noted that the game-based format of using VR/AR technologies in physical education and sports training enhances both theoretical knowledge and practical skills. It is recommended to focus on the gamification of physical education with VR/AR technologies as a promising path for its modernization (Klochko et al., 2020; Satishkumar et al., 2024). Today, three distinct directions for their use can be identified.

of VR/AR technologies in future practical activities (Darmawan et al., 2023). At the same time, the use of VR/AR technology creates a synergistic effect in the development of future specialists' informational, innovative, and health-preserving competencies (Klochko et al., 2020). These advantages are based on both the results of practical research and recent reviews on specific issues related to the implementation and use of VR/AR technologies in physical education for different groups. However, in recent times, the accessibility and modification of VR/AR technology have improved. Nevertheless, no specific reviews have been found regarding the practical effectiveness of skill development in physical education through the use of gaming VR/AR technologies.

The research was conducted within the framework of the initiative topic of the Department of Track and Field Athletics at Kharkiv State Academy of Physical Culture, State Registration Number: 0119U103785, “Features of Spatiotemporal Characteristics of Sports (Track and Field) and Everyday Motor Activities.”

2. METHOD AND MATERIALS

To achieve the research objective, theoretical methods of pedagogical research were applied. A search was conducted using PoP ver. 8 software (Harzing, Germany). The search was performed in Google Scholar. The choice of this database was determined by its extensive coverage of scientific information across various research fields and the ability to access full materials. Despite the ambiguity of search algorithms, in general, the results are mostly similar to those obtained from searches in other scientific databases. Additionally, Google Scholar provides access to "gray literature," which, in our opinion, may contain valuable practical material relevant to the research topic.

Search queries were executed considering the features of PoP and were tested sequentially. The selection process was finalized when the maximum number of results was obtained for each query. The search was limited to the years 2020-2024. The queries followed the following structure and keywords:

1. TI = virtual reality physical education + KW = sport game;
2. TI = VR physical education + KW = sport game;
3. TI = augmented reality physical education + KW = sport game;
4. TI = AR physical education + KW = sport game.

The search structure is illustrated in **Figure 1.**

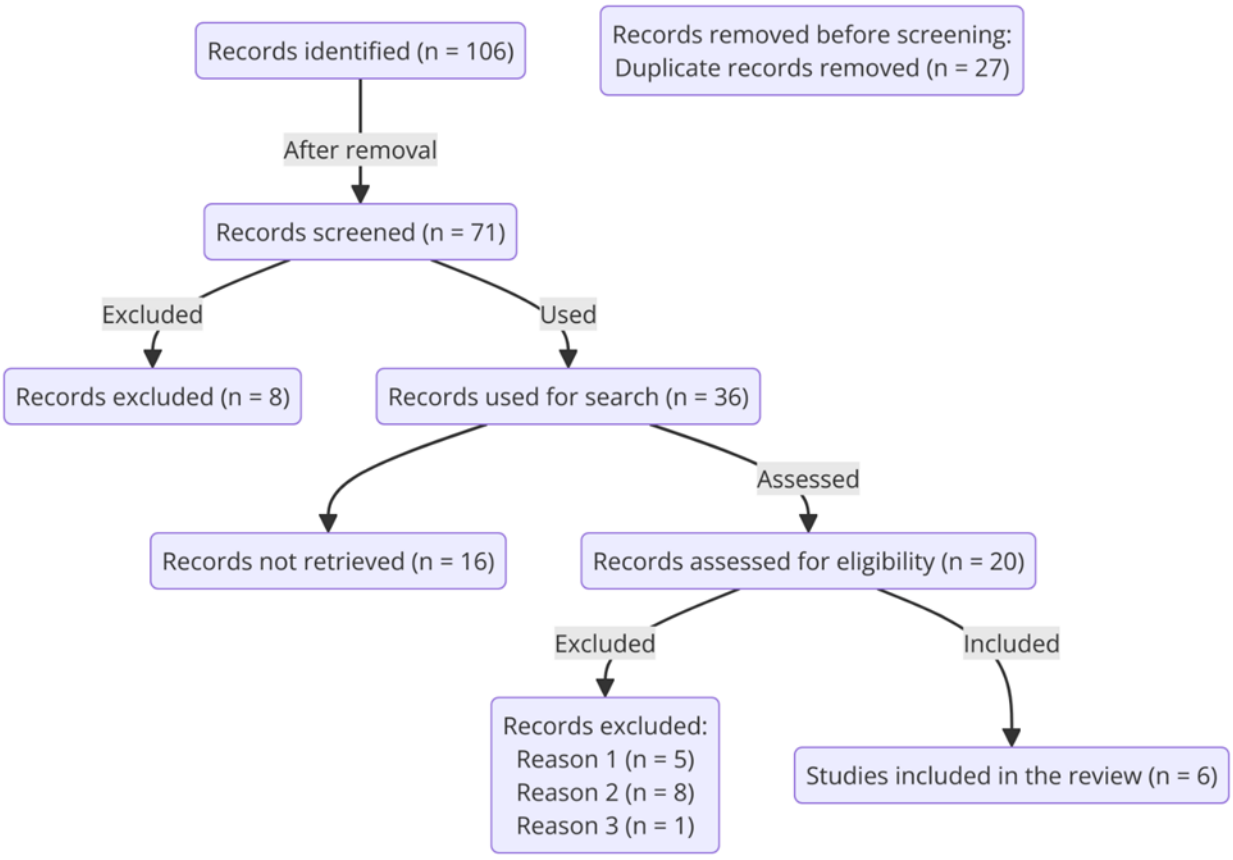

Figure 1*: Literature search protocol*

3. RESULTS AND DISCUSSION

The presentation of research results will consist of two parts. First, the results of the analysis of studies included in the review will be presented. Next, an analysis of the publications that were excluded will be provided. This is necessary to determine the direction of using the gaming format of VR/AR technologies to address the issue of youth engagement in physical exercise.

The presentation of research results will consist of two parts. First, the results of the analysis of studies included in the review. Next, an analysis of the data from the excluded publications will be presented. This is due to the need to determine the direction of using the gaming format of VR/AR technologies to address the issue of youth engagement in physical exercise.

Table 1 presents the results obtained by researchers from the selected publications included in the review.

Table 1:

Results of the studies included in the review

Author, Year	Participants	Technology	Intervention Features	Results	Conclusions
Utamayasa, I. G. D., & Mardhika, R. (2024)	34 students aged 10-12, divided into an experimental group and a control group	VR Metaverse	40 sessions using specially developed software ensuring full-body movement	Improvement in motor control compared to the control group, enhanced motor	VR can facilitate motor skill development in children in physical education

			engagement, focused on locomotor movements; motion control via sensors	skills	
Omarov, N., et al. (2024)	60 students, randomly assigned to an experimental group and a control group	AR Game-based learning (GBL)	Motion capture model using PoseNet based on the game *Subway Surfer*, conducted over six months	Differences between the two groups in motion testing and physical activity, as well as motivation, with higher scores in the experimental group	Significant advantages of AR in functional movement analysis, as well as motivation, which increases engagement in physical education
Chang, K. E., et al. (2020)	52 eighth-grade students, divided into an experimental group and a control group	AR PEdclass	Students must scan learning materials in books, with the app providing augmented reality (AR) visuals of hand movement skills and exercises. The screen displays 3D model animations of characters demonstrating exercise techniques. Sessions lasted 90 minutes per day.	Compared to learning through video materials, students in the experimental group showed better visualization and memorization of movement skills	Video instruction alone is not sufficient for interactive instruction, as it does not stimulate movement learning. AR integration with 3D models can help improve motor skills, allowing students to transfer movements from 3D character models into reading materials
Pratama, B. A., Sucipto, S., & Hanief, Y. N. (2022)	74 students aged 9-10, divided into an experimental group and a control group	Mobile AR application	A six-month intervention; AR research applications (35 min. per extracurricular session) conducted in field conditions	Improved movement accuracy in motor tests and better manipulation of objects among the experimental group	Using interactive media adapted to mobile AR applications helps develop basic movement skills in primary school students aged 9-10
Fernández-Vázquez, D., et al. (2024)	75 students aged 12-14, divided into control and experimental groups: PTS (n = 14); PTS+GAM (n = 32); PTS+GAM+VR (n = 29)	VR based on video games for Xbox One and devices such as Kinect, Nintendo Switch, and Oculus Quest 2	Six weeks of training with two sessions per week (50 min. each). The GAM program was developed specifically for the training group, considering the features of the	Significant improvement in movement test scores in the VR and GAM+VR groups, particularly in strength, balance, and coordination	GAM combined with VR enhances motor skill development and improves agility, reaction time, and eye tracking

			Avatar 2 fitness game. The VR group had additional exercises in Kinect Sports Xbox		
Bae, M. H. (2023)	90 students aged 5-6, divided into an experimental group and a control group	VR Educational book	An 8-week program with 40 sessions. Movement instructions were given through video demonstrations integrated into the VR application, with exercises displayed as 3D animations. The application was connected to Xbox and Kinect to track movement. The program included physical education tasks such as running, skiing, soccer, and dancing.	The experimental group showed improved basic motor skills, endurance, flexibility, and physical fitness, especially among boys and children with special needs	Physical education programs using VR are effective for developing movement skills in middle school

It has been demonstrated that despite significant interest in the use of VR/AR technologies in the process of physical education, a small number of recent studies are related to the practical demonstration of their effectiveness. Only two studies were associated with the use of existing VR/AR technologies in their modern understanding (Fernández-Vázquez et al., 2024; Pratama et al., 2022). Four studies presented original developments based on the metaverse, 3D modeling, and gamification through the use of VR/AR technologies (Chang et al., 2020; Pratama et al., 2022; Omarov et al., 2024; Utamayasa & Mardhika, 2024). One study compared gamified physical education with the use of VR technologies (Fernández-Vázquez et al., 2024). Another study introduced mobile applications as an AR intervention (Pratama et al., 2022). Overall, as expected, the primary teaching method in physical education using VR/AR technologies is the game-based approach.

All studies reported improvements in motor skills or the quality of motor learning as a result of using VR/AR technologies. However, only two studies reported changes in the testing of specific motor characteristics (Fernández-Vázquez et al., 2024; Pratama et al., 2022). Other studies contained information about changes in physical fitness levels or assessments of motor activity based on scoring systems. In general, the authors found no contradictions in the obtained data and pointed to the improvement of motor skills as one of the key advantages of using VR/AR technologies (Kong & Zhang, 2023; Kuleva, 2024; Mohamed Sayed Abd El Salam, 2020; Moreno-Guerrero et al., 2020).

Another study was analyzed but not included in the review due to the lack of information about the VR technology design developed in the Unity3D environment (Dong & Sha, 2024). However, it is noteworthy as it contains valuable information about modeling physical education environments incorporating VR technologies. The authors also reported improvements in students' physical preparedness based on test result comparisons between two groups before and after the intervention.

It is important to note that all analyzed studies had a quasi-experimental design, which is explained by the challenges of conducting randomized studies involving schoolchildren. One study did not report the duration of the intervention sessions, whereas in other studies, the session length corresponded to a standard school lesson (Omarov et al., 2024). An exception was a 90-minute training session using 3D modeling (Chang et al., 2020).

The analyzed studies are indicative of contemporary perspectives on the application of VR/AR technologies in physical education. It has been demonstrated that the predominant format of modified learning using VR/AR technologies is game based. This reinforces the understanding of how educational programs can be modified to be more effective (Astakhov & Yeremiya, 2021; Bazylevych, 2023). The interactivity and attractiveness of movement-based games are associated with increased engagement and motivation. According to most authors, these characteristics are linked to the improvement of motor skills (Sembat, 2024).

However, the use of VR/AR technologies should not be equated with the gamification of learning, as their design may differ and be tailored to specific target audiences (Lee & Lee, 2021; Singh & Awasthi, 2024; Wang, 2021). Surprisingly, there was no practical use of exergames in the context of VR/AR technology development. Additionally, none of the studies compared the effectiveness of VR and AR technologies. However, it is noted that VR enables the creation of immersive environments that significantly enhance participant engagement (Meng, 2021). Meanwhile, the extent to which skills developed in a virtual environment can be effectively transferred to real-world movements remains unclear. The analyzed studies do not establish a direct link between these two concepts. In most cases, VR/AR technologies are viewed as a means of presenting educational content in a game-based format, primarily as an engagement factor aimed at fostering achievement motivation among learners, rather than as a replacement for traditional methods of motor learning (Shi, 2024).

Thus, at present, the use of VR/AR technologies in physical education is associated with their integration into the traditional format

Young people prefer entertainment with minimal physical movement but focused on a gaming format. Video games remain popular, and interest in VR/AR-based entertainment is growing (Moreno-Guerrero et al., 2020). It would be a mistake to ignore the potential of using the gaming format of VR/AR technologies to increase youth engagement in physical education. This is especially important for organizing free time with a health-oriented focus. It has been established that VR/AR technologies generate interest among schoolchildren and students regarding their use in physical education (Meng, 2021; Satishkumar et al., 2024). The effects of using VR/AR gaming technologies in school physical education have been observed, including increased exercise time and physical activity levels, particularly during leisure time (Liang et al., 2023). Students reported greater engagement in motor learning using VR technologies (Darmawan et al., 2023). Meanwhile, middle school students experienced increased motivation for physical activity and improved well-being (Lee & Lee, 2021). It can be expected that VR/AR technologies applied in physical education will enhance interest in performing physical exercises regardless of how they are implemented.

The advantages outlined do not exclude limitations, particularly concerning the integration of VR/AR technologies as a fully-fledged component of the physical education process. It has been found that the implementation of VR/AR technologies occurs in two ways:

1. the development of original technologies.
2. the use of commercial equipment (Gulich, 2024; Mladenova, 2022).

The development of original technologies does not imply their rapid mass adoption. Moreover, there is a need to create guidelines for using such technologies (Singh & Awasthi, 2024; Utamayasa & Mardhika, 2024). The use of commercial equipment also cannot be widespread, especially for independent learning, due to its high cost (Lee & Lee, 2021). Thus, VR/AR technologies in physical education should still be associated with classroom-based learning. Exceptions may include 3D models of educational materials and mobile applications. However, in such a format, the advantages of the game-based method in motor learning will not be fully

realized. Limited access to VR/AR tools may negatively impact the learning process, especially in large classroom settings (Chang et al., 2020). Naturally, specially equipped spaces are required for using stationary equipment, adding financial constraints to the adoption of VR/AR technologies (Bae, 2023).

The study conducted achieved its goal but also raised several questions that need to be addressed in determining the feasibility of implementing VR/AR technologies in physical education:

- How can the motor density of a lesson be ensured with a limited number of VR/AR tools?
- Which approach (VR or AR) is more effective for physical education objectives?
- How can the transfer of developed motor skills in a VR environment to real-world movements be ensured?

Addressing these questions will provide a more comprehensive understanding of the potential applications of VR/AR technologies in physical education

4. CONCLUSION

This study focused on examining recent practical experiences in the application of VR/AR technologies in physical education. Despite the widely discussed potential benefits of these technologies for motor learning, only a limited number of scientific reports were found on their practical implementation.

The main advantages of VR/AR technologies for physical education include:

- No age restrictions for their use,
- Effectiveness in developing fundamental motor skills,
- Increased engagement and motivation for physical exercise.

The findings emphasize the critical role of the game-based method in the integration of VR/AR technologies into physical education, including its full gamification. Despite the growing availability of VR/AR technologies, significant limitations remain regarding their widespread accessibility, preventing their broad implementation in physical education across different groups. This suggests that further research should focus on studying the characteristics of specific VR/AR technologies and their potential applications in physical education for children of different age groups.

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