Integrating augmented reality into physical education: a comparative study on traditional and technology-assisted learning approaches

Integración de la realidad aumentada en la educación física: un estudio comparativo sobre métodos de aprendizaje tradicional y asistido por tecnología

Authors

Rifqi Festiawan[1,2]
Wawan Sundawan Suherman[1]
Tri Ani Hastuti[1]
Eko Sumanto[2]
Idah Tresnowati[3]
Gilang Nuari Panggraita[3]
Syahrir[4]
Taufik Rahman[5]
Eko Prabowo[6]
Muchtar Hendra Hasibuan[6]

[1]Universitas Negeri Yogyakarta (Indonesia)
[2]Universitas Jenderal Soedirman (Indonesia)
[3]Universitas Muhammadiyah Pekajang Pekalongan (Indonesia)
[4]Universitas Werisar (Indonesia)
[5]STKIP PGRI Sumenep (Indonesia)
[6]Universitas Negeri Jakarta (Indonesia)

Corresponding author:
Rifqi Festiawan
rifqifestiawan.2024@student.uny.ac.id
rifqi.festiawan@unsoed.ac.id

How to cite in APA

Festiawan, R., Suherman, W. S., Hastuti, T. A., Sumanto, E., Tresnowati, I., Panggraita, G. N., ... Hasibuan, M. H. . (2025). Integrating augmented reality into physical education: a comparative study on traditional and technology-assisted learning approaches. *Retos*, *69*, 873–883. https://doi.org/10.47197/retos.v69.114639

Abstract

Introduction: The use of technology in physical education is increasingly recognized for its potential to enhance student engagement and learning outcomes. Augmented Reality (AR) offers immersive and interactive learning experiences that may improve cognitive, affective, and psychomotor development.
Objective: This study aimed to analyze the impact of AR-based learning on cognitive understanding, motivation, and motor skill performance among junior high school students.
Methodology: A true experimental Pretest-Posttest Control Group Design was used with 64 students (M = 14.0 years, SD = 1.2), selected through cluster random sampling. Participants were divided into an experimental group (AR-based learning) and a control group (traditional learning). Learning outcomes were assessed using validated cognitive tests, the Physical Education Learning Motivation Questionnaire (PE-LMQ), and standardized psychomotor skill assessments.
Discussion: Results showed that students in the AR group experienced significantly greater improvements across all domains. Cognitive scores increased by 23.7 points versus 12.5 in the control group ($t = 6.375$, $p < 0.001$). Affective improvements were observed in motivation (+0.9 vs. +0.6), engagement (+0.8 vs. +0.5), and attitude (+0.7 vs. +0.4), all statistically significant ($p < 0.01$). Psychomotor improvements included better dribbling (-2.2 sec vs. -1.1 sec), passing and receiving (+2.5 vs. +1.3), and shooting accuracy (+23.8% vs. +13.1%), with $p < 0.001$.
Conclusion: AR-based learning proved more effective than traditional methods in enhancing comprehension, motivation, and motor skills. Its integration into physical education curricula is recommended to support innovative and impactful learning.

Keywords

Augmented reality; physical education; cognitive learning; affective learning; psychomotor skills; educational technology.

Resumen

Introducción: El uso de la tecnología en la educación física es cada vez más reconocido por su potencial para mejorar la participación estudiantil y los resultados de aprendizaje. La Realidad Aumentada (RA) ofrece experiencias de aprendizaje inmersivas e interactivas que pueden mejorar el desarrollo cognitivo, afectivo y psicomotor.
Objetivo: Este estudio tuvo como objetivo analizar el impacto del aprendizaje basado en RA sobre la comprensión cognitiva, la motivación y el rendimiento de habilidades motoras en estudiantes de secundaria.
Metodología: Se utilizó un diseño experimental verdadero con pretest-postest y grupo de control, con la participación de 64 estudiantes (M = 14,0 años, DE = 1,2), seleccionados mediante muestreo aleatorio por conglomerados. Los participantes se dividieron en un grupo experimental (aprendizaje basado en RA) y un grupo de control (aprendizaje tradicional). Los resultados de aprendizaje se evaluaron mediante pruebas cognitivas validadas, el Cuestionario de Motivación para el Aprendizaje de la Educación Física (PE-LMQ) y evaluaciones estandarizadas de habilidades psicomotoras.
Discusión: Los resultados mostraron que los estudiantes del grupo RA experimentaron mejoras significativamente mayores en todos los dominios. Las puntuaciones cognitivas aumentaron 23,7 puntos frente a 12,5 en el grupo de control ($t = 6,375$, $p < 0,001$). Las mejoras afectivas incluyeron la motivación (+0,9 vs. +0,6), la participación (+0,8 vs. +0,5) y la actitud (+0,7 vs. +0,4), todas estadísticamente significativas ($p < 0,01$). Las mejoras psicomotoras incluyeron mejor manejo del balón (-2,2 seg vs. -1,1 seg), pases y recepciones (+2,5 vs. +1,3) y precisión en los tiros (+23,8% vs. +13,1%), con $p < 0,001$.
Conclusión: El aprendizaje basado en RA demostró ser más eficaz que los métodos tradicionales para mejorar la comprensión, la motivación y las habilidades motoras. Se recomienda su integración en el currículo de educación física para fomentar un aprendizaje innovador y significativo.

Palabras clave

Realidad aumentada; educación física; aprendizaje cognitivo; aprendizaje afectivo; habilidades psicomotoras; tecnología educativa.

Introduction

Physical education plays a crucial role in enhancing students' motor skills, understanding of sports concepts, and motivation to participate in physical activities (Habyarimana et al., 2022; Khudolii et al., 2020; Umar et al., 2023). However, traditional teaching methods in physical education often face challenges such as limited visualization of biomechanical concepts, lack of instant feedback on students' skills, and low student engagement in the learning process (Julianti et al., 2024). With the advancement of digital technology, augmented reality has emerged as an innovation that can address these issues by providing a more interactive and digitally enhanced learning experience (Festiawan et al., 2024).

Augmented reality is a technology that superimposes digital elements, including images, audio, and 3D models, onto the physical environment using devices like smartphones, tablets, and AR-enabled glasses (Ciloglu & Ustun, 2023; Georgios Lampropoulos et al., 2022; Olim, 2024; Wenk et al., 2023). Unlike virtual reality, which creates a fully immersive digital environment, augmented reality enhances the real world by integrating digital elements that users can interact with in real time (Volioti et al., 2022; Yousef, 2021). Augmented reality has been widely applied in various fields, including healthcare, engineering, retail, and education (Alzahrani, 2020; Cevahir et al., 2022; Omarov, 2024; Orji, 2023). In the educational sector, augmented reality is used to enhance student engagement, facilitate interactive learning, and provide immersive experiences that improve comprehension of complex concepts (Avila-Garzon et al., 2021; Majeed & ALRikabi, 2022).

The integration of augmented reality in physical education offers opportunities for students to visualize sports techniques, gain a better understanding of biomechanics, and increase learning motivation through a technology-based approach (Liang, 2023). However, while some studies have explored the use of augmented reality in education, few have compared the effectiveness of traditional and augmented reality-based learning methods in the context of physical education (Zhang, 2023). Therefore, this study aims to explore the impact of augmented reality-based learning on students' learning outcomes compared to traditional teaching methods in physical education.

Despite the benefits of physical education for students' physical and cognitive development, several challenges in traditional teaching methods remain significant obstacles. Students often struggle to understand abstract principles of biomechanics and game strategies because theory-based learning does not provide direct experience in connecting concepts with actual movement (MacEachern et al., 2022; Sgro et al., 2019; Yudanto, 2022). Demonstration methods performed by teachers are often insufficient in providing a clear picture of specific sports techniques, particularly in sports requiring complex coordination (Casey, 2024; Zulbahri, 2024). Additionally, many students show low interest in physical education classes due to a lack of diverse teaching methods that could enhance their engagement (Aliriad, 2024; Kogoya et al., 2023). Traditional methods also fail to provide real-time feedback on students' technical performance, making the correction process slower and less effective (Cañabate et al., 2023; O'Brien, 2023; Salcines-Talledo et al., 2024).

With the emergence of augmented reality technology, various challenges in physical education can be addressed through innovative approaches. Augmented reality can help students visualize sports techniques directly, provide step-by-step guidance, and offer instant feedback on their performance (Nelson et al., 2022; Urban et al., 2022). This technology can also boost learning motivation by offering a more interactive and immersive experience compared to traditional methods (Cevahir et al., 2022; Zhao et al., 2022). Several previous studies have demonstrated that augmented reality enhances student learning outcomes. For example, (Baabdullah et al., 2022; Hidayat et al., 2021; Tuli et al., 2022)found that using augmented reality in sports skill learning improved students' conceptual understanding and motivation. (Dakeev, 2021; Majeed & ALRikabi, 2022) reported that augmented reality in physical education enhanced students' motor coordination and spatial awareness. Similarly, (Lin et al., 2023; Shen et al., 2022) indicated that augmented reality-based learning is more effective than conventional methods in developing technical sports skills. However, a research gap remains in comprehensively understanding how augmented reality-based methods compare to traditional teaching methods in physical education. Thus, this study is highly relevant in filling that gap by conducting a direct comparison between these two learning approaches.

The novelty of this study lies in several aspects. First, this study contributes by offering a direct comparison between augmented reality and traditional methods, complementing earlier studies that have explored the benefits of augmented reality, sometimes including comparative elements. Second, it offers a comprehensive assessment of learning outcomes, including conceptual understanding, motor skills, and student motivation. Third, by employing a mixed-methods approach, this study integrates both quantitative and qualitative data, providing a more holistic perspective on the impact of augmented reality in physical education. Consequently, this research contributes not only to the theoretical development of physical education and educational technology but also provides practical recommendations for educators in designing more effective and engaging teaching methods for students.

Physical education faces various challenges in traditional teaching methods, such as difficulties in visualizing concepts, low student motivation, and lack of instant feedback. Augmented reality technology presents a potential solution to these challenges by introducing a more interactive and digital reality-based approach to learning. However, limited research has directly compared the effectiveness of augmented reality with traditional teaching methods in physical education. Therefore, this study aims to investigate the differences in student learning outcomes between these approaches and provide new insights into the field of technology-enhanced physical education.

Method

This research utilizes a true experimental design with a Pretest-Posttest Control Group approach to evaluate the effectiveness of augmented reality-based learning compared to conventional teaching methods in physical education. The main goal is to examine the influence of augmented reality on students' learning outcomes, encompassing cognitive, affective, and psychomotor domains.

Participants

The research population consisted of all students in grades VII, VIII, and IX at Junior High School 8 Purwokerto, totaling 953 students across 27 classes, with each grade consisting of 9 classes. A representative sample was selected using cluster random sampling, in which entire classes were randomly chosen rather than individual students. This approach ensured an unbiased selection process, involving students from 2 classes (n = 64, age = 14.0 ± 1.2 years, height = 157.5 ± 7.0 cm, weight = 47.3 ± 9.0 kg). Each selected class consisted of 32 students. The two selected classes were then randomly assigned to either the control group or the experimental group, ensuring that all students within each class remained together during the intervention. The sampling technique enhanced the study's validity by maintaining natural classroom settings, allowing for a realistic evaluation of learning interventions.

Procedure

Students were randomly allocated into two groups using cluster random sampling: the experimental group, which engaged in augmented reality-based learning, and the control group, which received traditional physical education instruction. Before the intervention, both groups completed a pretest (O1) to assess their initial levels of learning outcomes in terms of cognitive, affective, and psychomotor aspects. The experimental group was then introduced to augmented reality-enhanced lessons (X), incorporating interactive visuals and real-time feedback to enhance their learning experience. Meanwhile, the control group continued with traditional teaching methods (C), relying on direct instruction and physical demonstrations. After completing the intervention phase, both groups undertook a posttest (O2) to evaluate changes in the learning outcomes.

Table 1. Research Design

Group	Assignment	Pretest	Treatment	Posttest
Experimental	Cluster Random	O1	Augmented Reality (X)	O2
Control	Cluster Random	O1	Traditional Learning (C)	O2

Description:
O1 : Pretest assessment of learning outcomes (cognitive, affective, psychomotor)
O2 : Posttest assessment of learning outcomes (cognitive, affective, psychomotor)
X : Augmented Reality-enhanced physical education learning
C : Traditional learning methods (direct instruction and physical demonstration)

Instrument

To comprehensively assess learning outcomes, this study evaluates three key aspects: cognitive, affective, and psychomotor domains. The cognitive aspect was measured using a multiple-choice test designed to assess students' understanding of physical education topics, including biomechanics, sports rules, and game strategies. The test was validated to ensure its accuracy in evaluating conceptual knowledge (Validity: 0.890; Reliability: 0.915). The affective aspect was examined using the Physical Education Learning Motivation Questionnaire (PE-LMQ), which measures students' motivation, engagement, and attitudes towards physical education (Validity: 0.871; Reliability: 0.912). Meanwhile, the psychomotor aspect was evaluated through skill performance assessments based on standardized rubrics, measuring students' execution of motor skills, coordination, and overall physical performance (Validity: 0.902; Reliability: 0.927).

Data analysis

Before conducting hypothesis testing, prerequisite tests were carried out to verify data validity. The Shapiro-Wilk test was applied to assess normality, with a significance value ($p > 0.05$) indicating that the data followed a normal distribution. Levene's test was used to evaluate homogeneity, ensuring equal variance across groups ($p > 0.05$). Once these assumptions were met, the Paired Sample T-Test was employed to examine differences in pretest and posttest scores within each group, while the Independent T-Test was utilized to compare the experimental and control groups. These statistical analyses aimed to determine the extent to which augmented reality-based learning impacted students' cognitive, affective, and psychomotor learning outcomes in comparison to conventional teaching methods. This methodological framework ensures a robust comparison between instructional approaches and provides empirical evidence supporting the effectiveness of augmented reality as an innovative tool in physical education.

Results

Description of the Augmented Reality Integration in the Intervention

The augmented reality (AR) technology used in this study was implemented via a mobile-based application designed specifically for physical education. The AR platform allowed students to scan visual markers placed in the gym or on the mat, triggering animated 3D models demonstrating correct execution of floor gymnastics techniques such as forward roll and handstand. The system provided step-by-step visual guidance accompanied by voice-over instructions. Through real-time feedback mechanisms, students received cues for body alignment, balance, and movement flow. By enabling students to compare their movements with the ideal digital demonstration, AR supported both cognitive understanding and psychomotor improvement in floor gymnastics.

Figure 1. Detail of Augmented Reality Media

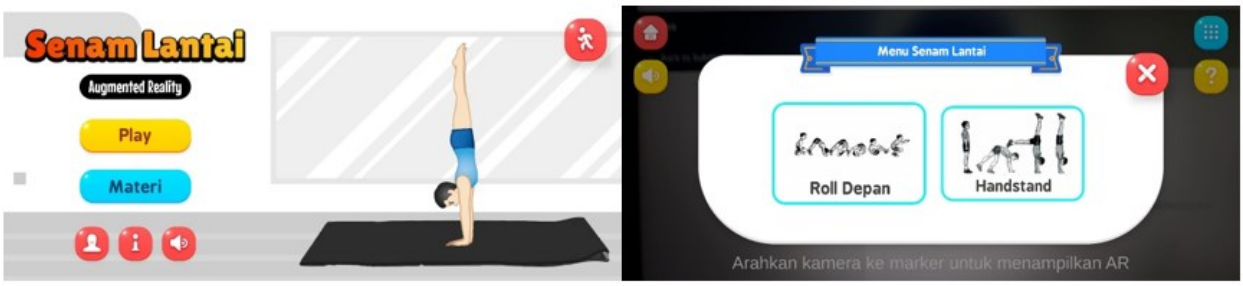


Table 2. Intervention Program Using Augmented Reality

Session	Learning Objectives	Augmented Reality Activities	Conventional Physical Activities
Forward Roll	Understand and perform the correct technique of a forward roll.	Scan AR marker to display 3D model of forward roll.	Practice forward rolls on the mat in pairs.

	Identify key body positions during the roll.	Step-by-step instructions with voice and visual cues. Real-time feedback on head, back, and hand position.	Peer support and physical guidance from the teacher.
Handstand	Perform a basic handstand with balance support. Combine forward roll and handstand in a sequence.	3D AR model of handstand posture and balance technique. Animated sequence of forward roll + handstand. Real-time feedback on posture and timing.	Practice handstand with wall support. Combine movements in small groups for routine demonstration.

The data obtained in this study is the value of students' learning outcome, with the following data description:

Cognitive Aspects of Physical Education Learning

Table 3 illustrates the impact of different instructional methods on the cognitive aspects of physical education learning. The data indicate that the experimental group, which used augmented reality, exhibited a significantly higher improvement (23.7 points) compared to the control group, which relied on traditional methods (12.5 points). This suggests that augmented reality plays a crucial role in enhancing students' understanding of physical education concepts. The notable increase in the posttest scores of the experimental group (86.2) compared to the control group (75.6) further supports the effectiveness of augmented reality in reinforcing cognitive learning. Additionally, the wider range of posttest scores in the experimental group, with a maximum score of 97, indicates that students exposed to augmented reality achieved higher levels of conceptual mastery. These findings highlight the potential of integrating technology-driven learning tools in physical education to improve students' comprehension of physical education material. The results also suggest that incorporating interactive and immersive experiences can lead to better engagement and retention of knowledge, making learning more effective and impactful.

Table 3. Cognitive Aspects Data of Physical Education Learning

Group	Pretest (Mean ± SD)	Pretest Min	Pretest Max	Posttest (Mean ± SD)	Posttest Min	Posttest Max	Improvement
Experimental (Augmented Reality)	62.5 ± 7.8	50	75	86.2 ± 6.9	72	97	+23.7
Control (Traditional Method)	63.1 ± 8.1	49	78	75.6 ± 7.3	60	88	+12.5

Affective Aspect in Physical Education Learning

Table 4 presents the affective aspect data in physical education learning, comparing the experimental and control groups. The experimental group, which used augmented reality, showed greater improvements across all three affective components: motivation (+0.9), engagement (+0.8), and attitude (+0.7), compared to the control group, which demonstrated lower improvements (+0.6, +0.5, and +0.4, respectively). The most notable increase was in student engagement, where the experimental group improved from 3.9 in the pretest to 4.7 in the posttest, surpassing the control group's posttest score of 4.3. The higher posttest scores and maximum values in the experimental group further suggest that augmented reality fosters a more engaging and motivating learning experience in physical education. These findings emphasize the potential of technology-driven learning approaches to enhance students' affective involvement, leading to a more positive attitude and higher participation in physical education activities.

Table 4. Affective Aspect Data in Physical Education Learning

Component	Group	Pretest (Mean ± SD)	Pretest Min	Pretest Max	Posttest (Mean ± SD)	Posttest Min	Posttest Max	Improvement
Motivation	Experimental (Augmented Reality)	3.7 ± 0.5	3.0	4.5	4.6 ± 0.4	4.0	5.0	+0.9
	Control (Traditional Method)	3.6 ± 0.6	2.8	4.4	4.2 ± 0.5	3.5	4.8	+0.6
Engagement	Experimental (Augmented Reality)	3.9 ± 0.4	3.2	4.6	4.7 ± 0.3	4.2	5.0	+0.8
	Control (Traditional Method)	3.8 ± 0.5	3.0	4.5	4.3 ± 0.4	3.7	4.9	+0.5
Attitude	Experimental (Augmented Reality)	3.8 ± 0.5	3.1	4.5	4.5 ± 0.4	3.9	5.0	+0.7
	Control (Traditional Method)	3.7 ± 0.5	3.0	4.3	4.1 ± 0.4	3.5	4.7	+0.4

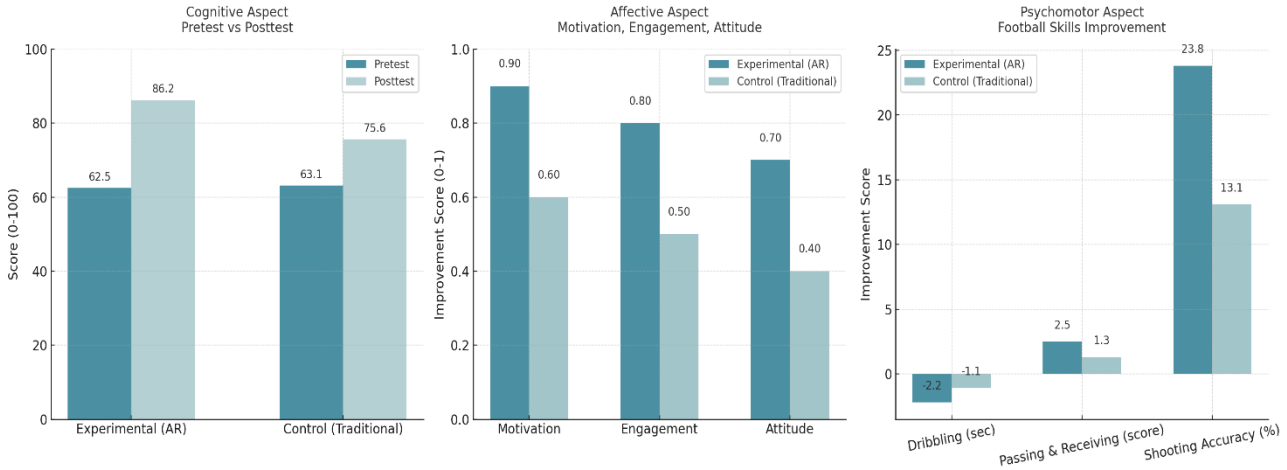
Psychomotor Aspect Data in Physical Education Learning

The descriptive analysis of football skill performance, as presented in Table 5, shows that the experimental group (Augmented Reality-based learning) experienced greater improvements across all three measured skills: dribbling, passing & receiving, and shooting accuracy, compared to the control group (Traditional Method). In the dribbling test, the experimental group improved from 10.5 ± 1.2 seconds to 8.3 ± 0.9 seconds, a -2.2 second reduction, while the control group showed a smaller improvement of -1.1 seconds. In the passing & receiving test, the experimental group increased its performance by +2.5 points, reaching 8.7 ± 1.0, whereas the control group improved by only +1.3 points. The shooting accuracy test recorded the most significant difference, with the experimental group improving by +23.8% (54.7% to 78.5%), compared to a +13.1% improvement in the control group. The minimum and maximum values also indicate that the experimental group had a broader range of skill enhancement, with higher maximum scores in all categories. This suggests that Augmented Reality-based training provided a more effective and engaging learning experience, leading to better skill execution, improved motor control, and enhanced overall football performance compared to traditional training methods.

Table 5. Psychomotor Aspect Data in Physical Education Learning

Football Skill Component	Group	Pretest (Mean ± SD)	Min	Max	Posttest (Mean ± SD)	Min	Max	Δ Improvement
Dribbling Test (sec)	Experimental	10.5 ± 1.2	9.1	12.7	8.3 ± 0.9	7.0	9.8	-2.2 sec
	Control	10.6 ± 1.3	9.3	13.0	9.5 ± 1.1	8.2	11.2	-1.1 sec
Passing & Receiving (score)	Experimental	6.2 ± 1.1	4.5	7.8	8.7 ± 1.0	6.9	10.1	+2.5 points
	Control	6.1 ± 1.2	4.4	7.7	7.4 ± 1.1	5.9	8.9	+1.3 points
Shooting Accuracy (%)	Experimental	54.7 ± 8.4	42.0	68.5	78.5 ± 7.2	65.2	89.1	+23.8%
	Control	55.1 ± 8.1	43.3	67.9	68.2 ± 7.5	56.1	78.4	+13.1%

Figure 2. Comparison of Experimental and Control Group Data



Normality and Homogeneity Test for Cognitive, Affective, and Psychomotor Aspects

The Shapiro-Wilk test was conducted to determine whether the pretest and posttest data for all three aspects (cognitive, affective, and psychomotor) were normally distributed.

Table 6. Normality Test Results for Cognitive, Affective, and Psychomotor Aspects

Aspect	Group	Pretest Sig.	Posttest Sig.
Cognitive	Experimental	0.081	0.067
	Control	0.094	0.078
Affective	Experimental	0.073	0.065
	Control	0.085	0.071
Psychomotor	Experimental	0.092	0.058
	Control	0.096	0.062

Levene's test was conducted to determine whether the variances between the experimental and control groups were homogeneous.

Table 7. Homogeneity Test Results for Cognitive, Affective, and Psychomotor Aspects

Aspect	F-value	Sig.
Cognitive	1.425	0.237
Affective	0.872	0.354
Psychomotor	1.672	0.209

The Shapiro-Wilk test results indicate that all aspects (cognitive, affective, and psychomotor) in both the experimental and control groups are normally distributed ($p > 0.05$). This allows for the use of parametric statistical tests, such as Paired Sample T-Test and Independent T-Test. Additionally, the Levene's test results show homogeneous variances between groups ($p > 0.05$), ensuring the validity of comparative analysis. With both assumptions met, statistical comparisons between augmented reality-based learning and traditional methods can be conducted accurately and reliably, providing a strong basis for analyzing learning outcome improvements.

Hypothesis Testing Results

The results of the Paired Sample T-Test show that both the experimental and control groups experienced significant improvements across cognitive, affective, and psychomotor aspects after the intervention ($p < 0.05$). However, the experimental group demonstrated greater progress, with a higher mean difference in all aspects compared to the control group. This indicates that augmented reality-based learning had a stronger impact on enhancing students' knowledge, motivation, and motor skills than traditional teaching methods.

Table 8. Paired Sample T-Test Results

Aspect	Group	Mean Difference (Post-Pre)	t-value	df	Sig. (p-value)
Cognitive	Experimental	20.3	12.423	31	0.000
	Control	10.4	8.672	31	0.002
Affective	Experimental	0.8	9.238	31	0.000
	Control	0.4	6.849	31	0.004
Psychomotor	Experimental	1.8	10.129	31	0.000
	Control	1.0	7.921	31	0.003

The Independent T-Test results provide strong evidence that the experimental group achieved significantly higher posttest scores compared to the control group ($p < 0.05$). This indicates that augmented reality-based learning proves to be more effective than conventional teaching methods in enhancing students' academic performance. The significant differences between groups provide strong empirical evidence that integrating digital technology into physical education enhances conceptual understanding, student engagement, and skill execution more effectively than traditional instruction.

Table 9. Independent t-test

Aspect	t-value	df	Sig. (p-value)	Mean Difference (Exp - Ctrl)
Cognitive	6.375	62	0.000	10.4
Affective	4.829	62	0.000	0.4
Psychomotor	5.921	62	0.000	0.8

Discussion

The results of this study reveal that learning facilitated by augmented reality (AR) significantly improves students' cognitive, affective, and psychomotor learning outcomes in physical education compared to conventional teaching approaches. Students in the experimental group, who participated in AR-supported lessons, showed greater progress in all measured areas. These findings highlight the potential of AR integration in physical education to enhance learning effectiveness, engagement, and interactivity.

In the cognitive aspect, AR has been shown to improve students' understanding of complex concepts by providing interactive and visual representations. (Wang, 2023) found that AR enhances conceptual comprehension in sports education by enabling students to visualize biomechanical movements in real time. (Cevahir et al., 2022) also reported that students using AR displayed better knowledge retention and problem-solving skills compared to those taught using conventional methods. In this study, the cognitive scores of the experimental group improved significantly (+23.7 points) compared to the control group (+12.5 points), reinforcing the effectiveness of AR in enhancing cognitive learning outcomes.

In terms of the affective aspect, AR has been widely recognized for its ability to increase student motivation and engagement. (Dengel et al., 2022; G Lampropoulos, 2025) highlighted that AR-based learning fosters a more immersive and interactive environment, leading to higher levels of student participation and positive attitudes toward physical education. Similarly, (Anuar et al., 2021) found that AR interventions in physical education increased students' enthusiasm and willingness to engage in learning activities. The results of this study support these findings, showing greater improvements in motivation (+0.9 vs. +0.6), engagement (+0.8 vs. +0.5), and attitude (+0.7 vs. +0.4) in the experimental group compared to the control group. This suggests that AR not only facilitates learning but also enhances students' emotional connection to the subject matter.

From a psychomotor perspective, AR offers significant advantages in improving motor skills by providing real-time feedback and step-by-step guidance. (Wenk et al., 2023) demonstrated that AR-based learning improves movement execution and skill acquisition by allowing students to practice techniques interactively. (Widyaningsih, 2023)further emphasized that AR enables students to refine their motor coordination through augmented simulations, which are more effective than traditional demonstration-based learning. In this study, the experimental group showed notable improvements in dribbling (-2.2 sec vs. -1.1 sec), passing and receiving (+2.5 points vs. +1.3 points), and shooting accuracy (+23.8% vs. +13.1%), confirming the role of AR in enhancing psychomotor skills.

The key strength of this study lies in its direct comparative analysis between AR-based and traditional methods, assessing cognitive, affective, and psychomotor aspects comprehensively. The true experimental Pretest-Posttest Control Group Design ensures high reliability and validity, and the integration of a mixed-methods approach provides a holistic perspective on AR's impact. However, limitations such as the relatively small sample size and short-term assessment period should be considered in future research. Longitudinal studies and broader participant demographics could further validate these findings.

The results of this study suggest that AR has a transformative potential in physical education by improving students' cognitive understanding, increasing motivation and engagement, and enhancing psychomotor skill development. Educators and policymakers should consider integrating AR technology into curricula to maximize learning effectiveness. Overall, this research reinforces the growing body of evidence supporting the use of AR in education and highlights its potential to revolutionize physical education through interactive, engaging, and effective learning experiences.

Conclusions

This study concludes that augmented reality-based learning significantly improves cognitive, affective, and psychomotor learning outcomes in physical education compared to traditional teaching methods. The integration of AR enhances students' understanding of complex concepts, increases motivation and engagement, and facilitates better skill acquisition through real-time feedback and interactive learning. The empirical evidence provided in this study highlights AR's superiority over conventional methods, reinforcing its role as an effective technological tool in physical education. Future research should focus on long-term impacts and the broader application of AR across different sports disciplines and age groups. Educators and policymakers should consider implementing AR-based learning strategies to optimize the teaching and learning experience in physical education.

Future research should explore the integration of AR with emerging technologies like AI and wearables to enhance personalization and immersion. Studies on its use in inclusive education and long-term

impact are also needed. Additionally, cross-cultural research can help validate AR's effectiveness and support the development of standardized implementation guidelines in physical education.

References

Aliriad, H. (2024). Improvement of Motor Skills and Motivation to Learn Physical Education Through the Use of Traditional Games. Physical Education Theory and Methodology, 24(1), 32–40. https://doi.org/10.17309/tmfv.2024.1.04

Alzahrani, N. M. (2020). Augmented reality: A systematic review of its benefits and challenges in e-learning contexts. In Applied Sciences (Switzerland) (Vol. 10, Issue 16). https://doi.org/10.3390/app10165660

Anuar, S., Nizar, N., & Ismail, M. A. (2021). The Impact of Using Augmented Reality as Teaching Material on Students' Motivation. Asian Journal of Vocational Education and Humanities, 2(1), 1–8. https://doi.org/10.53797/ajvah.v2i1.1.2021

Avila-Garzon, C., Bacca-Acosta, J., Kinshuk, , Duarte, J., & Betancourt, J. (2021). Augmented Reality in Education: An Overview of Twenty-Five Years of Research. Contemporary Educational Technology, 13(3), ep302. https://doi.org/10.30935/cedtech/10865

Baabdullah, A. M., Alsulaimani, A. A., Allamnakhrah, A., Alalwan, A. A., Dwivedi, Y. K., & Rana, N. P. (2022). Usage of augmented reality (AR) and development of e-learning outcomes: An empirical evaluation of students' e-learning experience. Computers and Education, 177. https://doi.org/10.1016/j.compedu.2021.104383

Cañabate, D., Bubnys, R., Hernández, E., & Colomer, J. (2023). A rubric for pre-service teachers to evaluate meaningful physical education. Frontiers in Education, 8. https://doi.org/10.3389/feduc.2023.1324349

Casey, A. (2024). Applying Models-based Practice in Physical Education. In Applying Models-based Practice in Physical Education. https://doi.org/10.4324/9780429347078

Cevahir, H., Özdemir, M., & Baturay, M. H. (2022). The Effect of Animation-Based Worked Examples Supported with Augmented Reality on the Academic Achievement, Attitude and Motivation of Students towards Learning Programming. Participatory Educational Research, 9(3), 226–247. https://doi.org/10.17275/per.22.63.9.3

Ciloglu, T., & Ustun, A. B. (2023). The Effects of Mobile AR-based Biology Learning Experience on Students' Motivation, Self-Efficacy, and Attitudes in Online Learning. Journal of Science Education and Technology, 32(3), 309–337. https://doi.org/10.1007/s10956-023-10030-7

Dakeev, U. (2021). Augmented Reality Computer-aided Design Education (ARCADE) Tool to Improve Student Motivation, Engagement, and Spatial Cognition. In ASEE Annual Conference and Exposition, Conference Proceedings. https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85124501948&origin=inward

Dengel, A., Iqbal, M. Z., Grafe, S., & Mangina, E. (2022). A Review on Augmented Reality Authoring Toolkits for Education. Frontiers in Virtual Reality, 3(April), 1–15. https://doi.org/10.3389/frvir.2022.798032

Festiawan, R., Sumanto, E., Febriani, A. R., Permadi, A. A., Arifin, Z., Utomo, A. W., Nugroho, W. A., & Pratama, K. W. (2024). The Hybrid Learning System With Project Based Learning: Can It Increase Creative Thinking Skill and Learning Motivation in Physical Education Learning? Retos, 56, 1009–1015. https://doi.org/10.47197/retos.v56.105047

Habyarimana, J. de D., Tugirumukiza, E., & Zhou, K. (2022). Physical Education and Sports: A Backbone of the Entire Community in the Twenty-First Century. International Journal of Environmental Research and Public Health, 19(12). https://doi.org/10.3390/ijerph19127296

Hidayat, H., Sukmawarti, S., & Suwanto, S. (2021). The application of augmented reality in elementary school education. Research, Society and Development, 10(3), e14910312823. https://doi.org/10.33448/rsd-v10i3.12823

Julianti, R. R., Suherman, A. ., Ma'mun, A., Budiana, D., Sari, E. F. N. ., Ridwan, M., & Rifqi. (2024). Implementación de un enfoque psicosocial intencional a través de juegos populares y deportes tradi-cionales en estudiantes de educación primaria (Implementation of intentionally structured

psychosocial through folk games and traditional sports in elementary school students). *Retos*, *60*, 810–815. https://doi.org/10.47197/retos.v60.108208

Khudolii, O., Kapkan, O., Harkusha, S., Marchenko, S., & Veremeenko, V. (2020). Motor skills development: Optimization of teaching boys aged 15 press headstand and handstand. Teoria Ta Metodika Fizicnogo Vihovanna, 20(1), 42–48. https://doi.org/10.17309/tmfv.2020.1.06

Kogoya, T., Mutohir, C., Pramono, M., Kristiyanto, A., Putro, B. N., Ali, S. K. S., Karakauki, M., Sukarmin, Y., Sutapa, P., Festiawan, R., Pratama, K. W., Permadi, A. A., Sonjaya, A. R., & Trisnadi, R. A. (2023). Developing the Value of Peace in Sport, Health, and Physical Education Lecture through Traditional Games. International Journal of Human Movement and Sports Sciences, 11(2), 268–275. https://doi.org/10.13189/saj.2023.110202

Lampropoulos, G. (2025). Combining Artificial Intelligence with Augmented Reality and Virtual Reality in Education: Current Trends and Future Perspectives. In Multimodal Technologies and Interaction (Vol. 9, Issue 2). https://doi.org/10.3390/mti9020011

Lampropoulos, Georgios, Keramopoulos, E., Diamantaras, K., & Evangelidis, G. (2022). Augmented Reality and Gamification in Education: A Systematic Literature Review of Research, Applications, and Empirical Studies. Applied Sciences (Switzerland), 12(13). https://doi.org/10.3390/app12136809

Liang, L. (2023). The Effectiveness of Augmented Reality in Physical Sustainable Education on Learning Behaviour and Motivation. Sustainability (Switzerland), 15(6). https://doi.org/10.3390/su15065062

Lin, X. F., Wong, S. Y., Zhou, W., Shen, W., Li, W., & Tsai, C. C. (2023). Undergraduate Students' Profiles of Cognitive Load in Augmented Reality–Assisted Science Learning and Their Relation to Science Learning Self-efficacy and Behavior Patterns. International Journal of Science and Mathematics Education, 0123456789. https://doi.org/10.1007/s10763-023-10376-9

MacEachern, S., Forkert, N. D., Lemay, J. F., & Dewey, D. (2022). Physical Activity Participation and Barriers for Children and Adolescents with Disabilities. International Journal of Disability, Development and Education, 69(1), 204–216. https://doi.org/10.1080/1034912X.2021.1952939

Majeed, B. H., & ALRikabi, H. T. S. (2022). Effect of Augmented Reality Technology on Spatial Intelligence among High School Students. International Journal of Emerging Technologies in Learning, 17(24), 131–143. https://doi.org/10.3991/ijet.v17i24.35977

Nelson, S., Darni, R., & Haris, F. (2022). Development Augmented Reality (AR) Learning Media for Pencak Silat Course at Faculty of Sports and Science Universitas Negeri Padang. Educational Administration: Theory and Practice, 28(1), 37–46. https://doi.org/10.17762/kuey.v28i01.322

O'Brien, W. (2023). Motor competence assessment in physical education–convergent validity between fundamental movement skills and functional movement assessments in adolescence. Physical Education and Sport Pedagogy, 28(3), 306–319. https://doi.org/10.1080/17408989.2021.1990241

Olim, S. C. (2024). Periodic fable discovery: an augmented reality serious game to introduce and motivate young children towards chemistry. Multimedia Tools and Applications, 83(17), 52593–52619. https://doi.org/10.1007/s11042-023-17526-9

Omarov, N. (2024). Applying an augmented reality game-based learning environment in physical education classes to enhance sports motivation. Retos, 60, 269–278. https://doi.org/10.47197/retos.v60.109170

Orji, J. U. (2023). Augmented Reality and Machine Learning in Health: A Systematic Review. In ACM International Conference Proceeding Series (pp. 59–67). https://doi.org/10.1145/3603421.3603430

Salcines-Talledo, I., González-Fernández, N., Manrique-Arribas, J. C., & Picos, A. P. (2024). Evaluation of Competences in the Final Degree Projects or Final Master's Degree Project in the Initial Training of Physical Education Teachers. Design and validation of a questionnaire. Retos, 55, 353–362. https://doi.org/10.47197/RETOS.V55.103996

Sgro, F., Quinto, A., Platania, F., & Lipoma, M. (2019). Assessing the impact of a physical education project based on games approach on the actual motor competence of primary school children. Journal of Physical Education and Sport, 19(3), 781–786. https://doi.org/10.7752/jpes.2019.s3111

Shen, S., Xu, K., Sotiriadis, M., & Wang, Y. (2022). Exploring the factors influencing the adoption and usage of Augmented Reality and Virtual Reality applications in tourism education within the context

of COVID-19 pandemic. Journal of Hospitality, Leisure, Sport and Tourism Education, 30(January), 100373. https://doi.org/10.1016/j.jhlste.2022.100373

Tuli, N., Singh, G., Mantri, A., & Sharma, S. (2022). Augmented reality learning environment to aid engineering students in performing practical laboratory experiments in electronics engineering. Smart Learning Environments, 9(1), 1–20. https://doi.org/10.1186/s40561-022-00207-9

Umar, Ockta, Y., & Mardesia, P. (2023). A Correlational Study: Pedagogical and professional competence of physical education teachers in relation to the implementation of the Merdeka curriculum. Journal of Physical Education and Sport, 23(12), 3325–3331. https://doi.org/10.7752/jpes.2023.12380

Urban, H., Pelikan, G., & Schranz, C. (2022). Augmented Reality in AEC Education: A Case Study. Buildings, 12(4). https://doi.org/10.3390/buildings12040391

Volioti, C., Keramopoulos, E., Sapounidis, T., Melisidis, K., Zafeiropoulou, M., Sotiriou, C., & Spiridis, V. (2022). Using Augmented Reality in K-12 Education: An Indicative Platform for Teaching Physics. Information (Switzerland), 13(7). https://doi.org/10.3390/info13070336

Wang, T. (2023). Augmented Reality in Sports Event Videos: A Qualitative Study on Viewer Experience. In Proceedings of the Annual Hawaii International Conference on System Sciences (Vol. 2023, pp. 4109–4118). https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85149928211&origin=inward

Wenk, N., Penalver-Andres, J., Buetler, K. A., Nef, T., Müri, R. M., & Marchal-Crespo, L. (2023). Effect of immersive visualization technologies on cognitive load, motivation, usability, and embodiment. Virtual Reality, 27(1), 307–331. https://doi.org/10.1007/s10055-021-00565-8

Widyaningsih, H. (2023). Physical Education Learning Design with Augmented Reality for Special Needs Students. International Journal of Human Movement and Sports Sciences, 11(5), 1070–1078. https://doi.org/10.13189/saj.2023.110515

Yousef, A. M. F. (2021). Augmented reality assisted learning achievement, motivation, and creativity for children of low-grade in primary school. Journal of Computer Assisted Learning, 37(4), 966–977. https://doi.org/10.1111/jcal.12536

Yudanto. (2022). The effect of game experience learning model and fundamental movement skills on psychosocial skills in youth soccer players. Journal of Physical Education and Sport, 22(5), 1227–1233. https://doi.org/10.7752/jpes.2022.05154

Zhang, J. (2023). Augmented Reality in Sports and Physical Education. In Springer Handbooks (pp. 355–368). https://doi.org/10.1007/978-3-030-67822-7_14

Zhao, X., Liu, M., & Liu, Y. (2022). The Influence of Different Learning Strategies on Pupils' Learning Motivation: Is Augmented Reality Multimedia Learning Consistent With Traditional Text Learning? Frontiers in Psychology, 13(February). https://doi.org/10.3389/fpsyg.2022.810345

Zulbahri, Z. (2024). Physical education learning outcomes of senior high school students based on gender and intellectual intelligence review. Retos, 60, 362–369. https://doi.org/10.47197/retos.v60.108990

Authors' and translators' details:

Rifqi Festiawan	rifqifestiawan.2024@student.uny.ac.id	Autor/a
Wawan Sundawan Suherman	wansuherman@uny.ac.id	Autor/a
Tri Ani Hastuti	tri_anihastuti@uny.ac.id	Autor/a
Eko Sumanto	eko.sumanto@unsoed.ac.id	Autor/a
Idah Tresnowati	idahumpp88@gmail.com	Autor/a
Gilang Nuari Panggraita	panggraita@umpp.ac.id	Autor/a
Syahrir Syahrir	syahrirsanti87@gmail.com	Autor/a
Taufik Rahman	opick_conk@stkippgrisumenep.ac.id	Autor/a
Eko Prabowo	ekoprabowo@unj.ac.id	Autor/a
Muchtar Hendra Hasibuan	mhendra@unj.ac.id	Autor/a