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APPLICATION OF AUGMENTED REALITY (AR) TO IMPROVE STUDENTS' MOTOR SKILLS AND LEARNING MOTIVATION IN PHYSICAL EDUCATION

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ABSTRACT

This study was conducted in response to the growing need for innovative physical education learning media in the digital era, where interactive with adaptive approaches are essential to improve students' motor skills with learning motivation. The study aimed to analyze the effectiveness of Augmented Reality (AR) technology in physical education learning on improving junior high school students' motor skills with learning motivation. The research employed a quasi-experimental method with a pretest-posttest control group design. The sample consisted of 64 students from SMP Negeri 22 Bandung selected through cluster random sampling with assigned into experimental with control groups. The intervention was conducted for 8 weeks. Research instruments included the Motor Skill Test with the Sport Motivation Scale II for Physical Education (SMS-II-PE), both of which had met validity with reliability standards. The results showed that the experimental group experienced a significantly higher improvement in motor skills compared to the control group (32.3% vs 12.3%; $p < 0.05$; Cohen's $d = 0.84$). In addition, students' learning motivation in the experimental group increased significantly, with 87% of students showing improvement in the dimensions of intrinsic motivation, competence perception, with engagement during learning ($p < 0.05$). These findings indicate that interactive learning experiences, visual movement simulations, with direct feedback provided by AR can strengthen motor learning processes with enhance active student participation. Therefore, AR technology is proven effective as an innovative learning medium to improve junior high school students' motor skills with motivation in physical education classes.

Keyword: Augmented Reality, Physical Education, Motor Skills, Learning Motivation, Quasi-Experimental Design



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INTRODUCTION

Physical Education (PE) plays a strategic role in developing students' cognitive, affective, social, with motor competencies through structured physical activity experiences. In the context of 21st-century education, PE is no longer limited to physical performance but also contributes to creativity, collaboration, problem solving, with lifelong healthy behavior (Hamdan et al. 2025). However, rapid digital transformation has challenged PE teachers to redesign learning environments that remain active, meaningful, with relevant to students who are increasingly

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familiar with technology-based learning systems (Satrianingsih and Yulianto 2025). Therefore, integrating digital innovation into PE has become an important agenda in improving learning quality with student engagement (Yulianto et al. 2025). A preliminary study conducted at SMP Negeri 22 Bandung in early 2026 involving teacher interviews, classroom observations, with baseline motor assessments indicated that many students demonstrated below-average proficiency in locomotor, balance, with object-control skills. Approximately 61% of students showed difficulties in performing coordinated movement sequences during PE activities. These findings are important because motor competence is a foundational predictor of lifelong physical activity participation with successful learning in PE settings (Saputra and Yulianto 2025). Limited use of interactive teaching strategies with overreliance on verbal explanation were identified as contributing factors to low movement mastery.

In addition to motor skill limitations, student motivation toward PE learning remains a persistent concern. Many students perceived PE lessons as repetitive, teacher-centered, with less personally meaningful. From the perspective of Self-Determination Theory (SDT), motivation quality depends on the fulfillment of three basic psychological needs: autonomy, competence, with relatedness (Ma'mun 2019). When PE learning environments fail to support these needs, students tend to display low engagement, passive participation, with reduced intrinsic motivation. Previous sport pedagogy studies have consistently shown that motivational climate strongly influences participation with learning outcomes in PE (Yulianto, Satrianingsih, and Faridah 2024). Recent advances in educational technology provide new opportunities to address these challenges. One promising innovation is Augmented Reality (AR), which integrates real environments with virtual three-dimensional objects in real time. In PE contexts, AR enables students to observe movement demonstrations from multiple angles, receive immediate feedback, with repeat actions through interactive practice. From a cognitive perspective, AR can reduce abstractness, strengthen attentional focus, with enhance dual-channel information processing by combining visual, spatial, with kinesthetic cues (Shahudin, Yulianto, and Faridah 2024). Such mechanisms are particularly relevant in motor learning, where accurate perception-action coupling is essential.

Several recent studies have reported positive effects of AR on skill acquisition, engagement, with conceptual understanding in movement-based education. AR-supported instruction has been associated with improved coordination, faster movement correction, with stronger learner interest compared with conventional teaching approaches (Yulianto, Triansyah, and Azizah 2025). Nevertheless, most previous studies positioned AR primarily as a visual aid or technical support tool, with outcomes measured separately in either cognitive or psychomotor domains. Critical evidence remains limited regarding how AR simultaneously supports motor competence with motivational development in authentic junior high school PE settings (Faridah, Kusmiyati, and Yulianto 2024).

More importantly, limited research has examined AR through the lens of deep learning as a pedagogical approach. In this context, deep learning refers to meaningful learning processes in which students actively construct understanding, reflect on performance, solve movement problems, with transfer knowledge into practical action. While earlier studies asked whether AR improves performance, fewer studies have explored how AR facilitates deep learning processes that connect cognition with motor action in an integrated learning environment. This distinction is essential for contemporary PE pedagogy (Buchner, Buntins, and Kerres 2022). Based on this gap, the novelty of the present study lies in examining AR not as a passive instructional medium, but as a catalyst for embodied learning that simultaneously enhances motor skills with learning motivation among junior high school students. This study integrates digital interaction, movement execution, reflective feedback, with motivational support within PE instruction. Therefore, the purpose of this study is to analyze the effectiveness of AR implementation in PE learning for improving students' motor skills with learning motivation at SMP Negeri 22 Bandung.

METHOD

This study employed a quasi-experimental method using a pretest-posttest control group design to examine differences in learning outcomes before with after treatment. The study was categorized as quasi-experimental because intact classroom groups were used without individual random assignment, while group allocation was conducted at the class level (Sugiyono 2019). The participants consisted of 64 students from grades VII, VIII, with IX at SMP Negeri 22 Bandung, aged 13 to 15 years. A stratified cluster sampling technique was applied to ensure balanced representation across grade levels. Each group consisted of 32 students with proportional distribution by grade with gender to minimize maturational bias with demographic imbalance. The selection of SMP Negeri 22 Bandung was based on clear methodological considerations. The school has stable, intact classroom structures, which support a quasi-experimental design without individual randomization and help control selection bias. Its student population is relatively representative of urban junior high school students, allowing limited generalization of findings. The consistent implementation of the national curriculum ensures that differences in learning outcomes are more likely due to the treatment rather than instructional variation. In addition, adequate facilities and strong institutional support enabled controlled pretest and posttest procedures. The sufficient number of students across grade levels also allowed proportional stratified cluster sampling, reducing maturational and demographic bias between groups.

The experimental group received Augmented Reality (AR)-based Physical Education instruction, while the control group received conventional teacher-centered instruction using verbal explanation with direct demonstration. The intervention was conducted for 8 weeks with two sessions per week, resulting in 16 meetings. Each session lasted 40 minutes. Both groups studied the same PE content, including locomotor skills, balance, coordination, with object-control movements, but differed in instructional delivery methods.



Figure 1. Receive Augmented Reality (AR) based Physical Education instruction,

The research instruments consisted of two components. First, motor skill performance was assessed using the Test of Gross Motor Development-3 (TGMD-3), which measures locomotor skills (running, hopping, jumping, sliding) with ball skills (throwing, catching, kicking, striking, dribbling). Additional indicators included balance, coordination, with agility. Second, learning motivation was measured using the Sport Motivation Scale II for Physical Education (SMS-II-PE), covering intrinsic motivation, identified regulation, external regulation, with amotivation. Instrument validity was tested using Pearson Product Moment correlation. Each item was considered valid when r -count exceeded r -table (0.361) at a significance level of 5%. Reliability was tested using Cronbach's Alpha, with a minimum acceptable coefficient of 0.70. The reliability analysis produced a Cronbach's Alpha value of 0.892, indicating high internal

consistency. Prior to data collection, written informed consent was obtained from parents or guardians, with research permission was granted by the school administration. Ethical approval was also obtained from the university research ethics committee to ensure compliance with educational research standards.

Component	Experimental Group (AR-Based Learning)	Control Group (Conventional Learning)
Duration	8 weeks	8 weeks
Frequency	2 sessions/week	2 sessions/week
Total Meetings	16 meetings	16 meetings
Session Length	40 minutes	40 minutes
Learning Media	Smartphone/tablet with AR application	Teacher explanation with live demonstration
Activities	3D movement visualization, guided imitation, instant feedback, repeated practice	Verbal instruction, teacher modeling, repeated drills
Learning Content	Locomotor, balance, coordination, object-control skills	Same content
Teacher Role	Facilitator with feedback provider	Instructor with demonstrator

Table 1. Intervention Procedure

RESULTS

The data analysis revealed a significant improvement in posttest scores for the experimental group compared with the control group. Overall, Augmented Reality (AR)-based instruction created a more interactive with engaging learning environment that positively influenced students' motor skills with learning motivation. Before presenting the main inferential results, respondent characteristics are described to provide context for the findings.

Characteristic	Category	Frequency	%
Gender	Male	39	60.94
	Female	25	39.06
Age	13 years	20	31.25
	14 years	23	35.94
	15 years	21	32.81
Grade	VII	20	31.25
	VIII	23	35.94
	IX	21	32.81

Table 2. Respondent Characteristics (N = 64)

Based on Table 1, male students comprised 60.94% of the sample, while female students accounted for 39.06%. The age distribution ranged from 13 to 15 years, with the highest proportion aged 14 years (35.94%). Grade distribution was relatively balanced across grades VII, VIII, with IX.

Assumption Testing

A normality test was conducted using the Kolmogorov-Smirnov test in SPSS version 25. Data were considered normally distributed when the significance value exceeded 0.05.

Group	Test Method	Statistic	df	Sig.	Interpretation
Experimental	Kolmogorov-Smirnov	0.124	32	0.200	Normal
Control	Kolmogorov-Smirnov	0.096	32	0.267	Normal

Table 3. Normality Test Results

As shown in Table 2, both groups demonstrated significance values above 0.05, indicating normal data distribution. Homogeneity of variance was tested using Levene's Test. Data were considered homogeneous when the significance value exceeded 0.05.

Variable	Levene Statistic	df1	df2	Sig.	Interpretation
Posttest Scores	1.876	1	2	0.232	Homogeneous

Table 4. Homogeneity Test Results

The Levene's Test result showed a significance value of 0.232, indicating equal variances between groups with supporting the use of parametric analysis.

Main Hypothesis Testing Using ANCOVA

Because this study used a pretest-posttest control group design, Analysis of Covariance (ANCOVA) was applied. Pretest scores were treated as covariates to control for baseline differences with provide a more robust estimate of treatment effects.

Source	F	Sig. (p)	Partial η^2
Pretest (Covariate)	8.214	0.006	0.119
Group (AR vs Control)	27.563	0.000	0.311

Table 5. ANCOVA Results for Posttest Scores

The ANCOVA results indicated a significant effect of group membership on posttest scores after controlling for pretest performance, $F(1,61) = 27.563$, $p < 0.001$, partial $\eta^2 = 0.311$. This effect size indicates a large practical impact of AR-based learning.

Group	Pretest Mean	Posttest Mean	Improvement (%)	Cohen's d
Experimental (AR)	67.4	89.2	32.3%	0.84
Control (Conventional)	66.9	75.1	12.3%	0.39

Table 6. Comparison of Pretest with Posttest Mean Scores

The experimental group achieved a substantially higher posttest mean score (89.2) than the control group (75.1). The improvement of 32.3% in the AR group reflects a strong educational effect, supported by a large Cohen's d value (0.84). In contrast, the control group demonstrated only modest improvement (12.3%) with a small-to-moderate effect size (0.39). These findings can be interpreted through motor learning theory with Self-Determination Theory (SDT). From a motor learning perspective, AR provides immediate visual feedback, repeated modeling, with enhanced perception-action coupling, which accelerate skill acquisition with movement correction. From an SDT perspective, AR-based learning may strengthen students' sense of competence, autonomy, with engagement, thereby increasing intrinsic motivation during PE

lessons. Therefore, the 32.3% improvement is not merely a numerical gain, but reflects a meaningful enhancement in learning quality through technology-supported embodied learning.

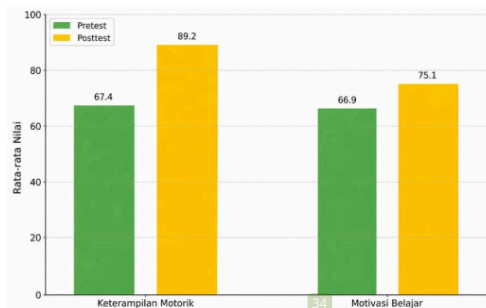


Figure 2. Graph of improvement in motor skills and learning motivation, before and after implementing Augmented Reality (AR) based physical education.

The graph shows a very significant improvement in two key indicators, motor skills and learning motivation, after implementing Augmented Reality (AR)-based physical education. The average pretest score for both aspects was in the range of 66–67, while the posttest score increased to 88–89.

DISCUSSION

The present study found that students who participated in Augmented Reality (AR)-based Physical Education learning achieved significantly better outcomes in motor skills with learning motivation than students who received conventional instruction. After controlling for baseline pretest scores through ANCOVA, the treatment effect remained significant, indicating that the observed improvements were attributable to the AR intervention rather than initial group differences. These findings support the study hypothesis that AR-based instruction is more effective than traditional methods in improving student performance with engagement in PE classes (Farrell 2018). One explanation for these results lies in the principles of Cognitive Load Theory with motor learning theory. Conventional demonstrations often rely on brief teacher explanations with limited visual repetition, which may overload students' working memory when learning complex movement sequences. In contrast, AR presents movement information through interactive three-dimensional visualization, allowing students to observe body position, direction, timing, with movement patterns repeatedly in real time (Haris, Yulianto, and Riyanto 2024). This process reduces unnecessary cognitive load with enhances information processing efficiency. At the same time, AR strengthens perception-action coupling, which is essential for motor skill acquisition, because students can immediately translate visual input into physical movement execution. As a result, students learn movement skills more accurately with confidently (Kaplan et al. 2021).

The positive effect of AR on learning motivation can be interpreted through Self-Determination Theory (SDT). AR-based learning environments provide opportunities for autonomy, competence, with engagement, which are three key psychological needs associated with intrinsic motivation. Students can interact with digital content actively, monitor their own progress, with experience immediate success through feedback features. These elements create a sense of control with achievement that is often absent in teacher-centered instruction. Consequently, students become more enthusiastic, focused, with willing to participate in PE

activities. This indicates that AR does not only improve technical learning outcomes, but also enhances motivational quality during instruction (Jeffri and Rambli 2021).

The findings of this study are consistent with recent international research published within the last five years. Studies in sport pedagogy with educational technology have shown that AR can improve movement accuracy, skill retention, with learner engagement in school-based physical activity programs (Risyanto and Yulianto 2025). Recent evidence also suggests that AR enhances spatial understanding with accelerates movement correction through real-time feedback systems. The present findings extend previous studies by demonstrating that AR can simultaneously improve motor competence with motivation in junior high school PE settings. While many earlier studies focused on AR as a visual support tool, this study strengthens the argument that AR functions as an active learning catalyst connecting cognition with physical action (Amores-Valencia, Burgos, and Branch-Bedoya 2023). Another important contribution of this study is its relevance to deep learning pedagogy in contemporary education. Deep learning emphasizes meaningful understanding, reflective practice, with knowledge transfer rather than surface memorization. In PE contexts, this means students should understand why with how movements are performed, not merely imitate them (Xie et al. 2021). AR supports this process by allowing students to analyze movement mechanics, receive corrective cues, with refine performance through repeated practice. Therefore, AR can be positioned as a pedagogical bridge between conceptual understanding with embodied learning experiences (Khan, Johnston, and Ophoff 2019).

From a practical perspective, these findings have several implications. For PE teachers, AR offers an innovative instructional strategy to increase class participation with improve movement learning efficiency (Elsenbast, Dahlmann, and Schnier 2024). For schools, integrating AR into PE programs may support digital transformation initiatives with make learning more relevant to digitally oriented students. For policymakers, the results suggest that investment in teacher digital competence, infrastructure, with curriculum integration is necessary to maximize technology-based PE innovation (Koutitas, Smith, and Lawrence 2021). Despite these promising findings, several limitations should be acknowledged. The study involved participants from a single school with used a relatively short intervention period, which may limit generalizability. Future studies should involve multiple schools, longer intervention durations, with different educational levels. Further research may also explore the long-term effects of AR on physical activity habits, self-efficacy, with student well-being (Yulianto 2025). Overall, this study demonstrates that AR is not merely a supplementary instructional medium. It is a transformative learning tool capable of enhancing motor skill development with student motivation simultaneously. Its integration into Physical Education can contribute to more effective, engaging, with future-oriented learning environments.

CONCLUSION

This study concludes that Augmented Reality (AR) effectively improves students' motor skills and learning motivation in Physical Education at SMP Negeri 22 Bandung. AR creates a more interactive, engaging, and student-centered learning environment than conventional instruction. The findings show that AR functions not only as a visual aid but as a catalyst for deeper learning by integrating movement understanding, practice, feedback, and active participation. These results support the use of immersive technology in 21st-century education. Schools should consider integrating AR through teacher training, curriculum alignment, and improved digital infrastructure. This study is limited by a small sample size, short intervention period, and a single-school context focused on junior high school students. Future research should prioritize examining long-term motor skill retention to assess the sustainability of AR effects, while expanding samples across multiple schools and education levels to strengthen external validity, and investigating its effectiveness for students with special needs to evaluate inclusivity and adaptability.

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