

The Effectiveness of Educational Game-Based Physical Education Learning on the Development of Elementary School Students' Physical Literacy: A Quasi-Experimental Study

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Abstract

Background physical literacy is a fundamental concept in modern physical education, encompassing physical, cognitive, affective, and social competencies. Despite its recognized significance, conventional teacher-centered methodologies in Indonesian elementary schools often do not foster holistic physical literacy in students. The purpose of this study was to examine the effectiveness of educational game-based physical education in fostering physical literacy development among elementary school students, as contrasted with traditional teaching approaches. Approach: A quasi-experimental pre-test post-test control group design was used with 60 third-grade elementary school students (aged 8-9 years) in East Kalimantan, Indonesia. Participants were randomly allocated to either an experimental group ($n = 30$) receiving educational game-based training or a control group ($n=30$) receiving traditional teaching methods. The 12-week intervention was implemented through collaborative teaching between university students and school educators. Primary objectives included physical literacy knowledge, learning intentions, and basic motor skills, as assessed by a validated instrument demonstrating strong reliability ($\alpha > 0.80$). Results: Significant inter-group differences were observed after the intervention for all assessed variables. The experimental group showed significant improvement in physical literacy scores (78.4 ± 6.9 vs. 62.1 ± 8.4 , $p = 0.001$, Cohen's $d = 2.16$), learning motivation (67.8 ± 5.6 vs. 54.3 ± 7.1 , $p < 0.001$, Cohen's $d = 2.10$), and motor skills (12.8 ± 1.4 vs. 9.7 ± 1.9 , $p = 0.002$, Cohen's $d = 1.86$). Conclusion The implementation of game-based physical education significantly improved the development of physical literacy of elementary school students compared to traditional methods, thus supporting the integration of game-based pedagogy in elementary physical education in Indonesia.

Keywords: Gameeducational; motor skills; physical education; physical literacy; student motivation

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Introduction

Physical literacy has emerged as a significant paradigm shift in modern physical education, substantially altering educators' perceptions of movement education. The International Physical Literacy Association defines physical literacy as "the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for lifelong engagement in physical activity." (Edwards et al., 2017; Santoso et al., 2022; Mahardhika et al., 2024) This comprehensive approach goes beyond conventional skill acquisition models by incorporating cognitive, emotional, psychomotor, and social elements into an integrated framework for sustained physical activity participation. (Cairney et al., 2019).

Recent meta-analytic findings highlight the importance of physical literacy in addressing global sedentary lifestyle patterns and encouraging sustained engagement in physical activity. (Belanger et al., 2018) have established that physical literacy components are significant predictors of physical activity levels in various populations, with the magnitude of the effect varying from moderate to large ($d = 0.42 - 0.78$) (Caldwell et al., 2020) This study identified a significant correlation between physical literacy scores and health indicators in school-aged children, underscoring the importance of this concept for public health programs.

These findings are particularly pressing, as World Health Organization data shows that 81% of adolescents worldwide do not achieve recommended physical activity standards. (Guthold et al., 2020). This global reality offers an important framework for examining how similar but often more complex challenges manifest themselves in the context of physical education in Indonesia. The educational landscape in Indonesia presents unique challenges for the advancement of physical literacy. Conventional physical education methods in Indonesian elementary schools primarily focus on teacher-led skills instruction, often neglecting cognitive and affective learning.

According to (Hartono et al., 2023) A recent evaluation revealed a worrying gap in knowledge and understanding of physical activity among Indonesian children aged 8-12, with only 32% demonstrating sufficient understanding of basic movement concepts. (Priadana et al., 2021). According to (Infallible (2022) Studies show that physical education instructors in Indonesia allocate only 15% of their teaching time to cognitive learning objectives, far below international standards. Modern educational theory increasingly recognizes game-based learning as an effective pedagogical method to address this limitation.

The social constructivist perspective, based on Vygotsky's theory, asserts that play facilitates an authentic environment for collaborative knowledge creation through peer interactions and supported learning experiences. (Opstoel et al., 2020) This theoretical framework is consistent with self-determination theory, which states that effectively developed educational games fulfill students' fundamental psychological needs for autonomy, competence, and relatedness, thereby enhancing intrinsic motivation. (Ryan & Deci, 2020). Empirical evidence from various global situations strengthens this theoretical statement.

A recent systematic review by (Li et al. (2024). This study reviewed 42 experimental trials and concluded that game-based physical education programs had moderate to substantial effects on student enjoyment ($g = 0.68$), especially for elementary school-aged

children. ((Roure et al., 2024)A meta-analysis of 28 experiments showed that physical education using gamification significantly improved situational interest ($d = 0.74$) and learning outcomes ($d = 0.56$) compared to conventional teaching. Despite this, there is still a significant gap in understanding the effectiveness of game-based learning for the holistic advancement of physical literacy, especially in the Southeast Asian context.

Although current research often focuses on single outcomes such as motor skills or motivation, there is little research exploring comprehensive interventions that consider the multifaceted nature of physical literacy.(Cornish et al., 2020; Liu & Chen, 2021). In addition, most research on game-based learning comes from developed western countries, which limits its application to diverse cultural and educational environments such as Indonesia.(Hermawan & Pratama, 2022)This study investigates the effectiveness of a comprehensive educational game-based physical education intervention on physical literacy development among elementary school children in Indonesia, thus addressing the existing research gap.

We investigated whether the collaborative implementation of strategically designed educational games would yield better outcomes than traditional teaching methods in the cognitive, emotional, and psychomotor domains. Based on the theoretical framework and empirical evidence, we hypothesized that students engaged in educational game-based learning would demonstrate significantly superior progress in (1) physical literacy knowledge, which includes understanding movement concepts, health benefits, and safety principles; (2) learning motivation, which includes enjoyment, self-efficacy, effort, and social connections; and (3) fundamental motor skills, including locomotor, manipulative, and stability skills, compared to students who participated in traditional teacher-directed instruction.

Method

This study used a quasi-experimental pre-test post-test control group design to assess the relative effectiveness of educational game-based training compared to traditional physical education methods. This design was chosen to facilitate causal inference while addressing the practical limitations inherent in school-based research. Randomization was implemented at the classroom level to reduce contamination between experimental conditions while maintaining ecological validity. The study was conducted at SDN 003 Sangatta Utara, a public elementary school in East Kutai Regency, East Kalimantan, Indonesia, during the 2024 academic semester.

This school was selected because of its commitment to supporting educational research efforts and its characteristics that are representative of elementary schools in Indonesia. 60 third-grade students, aged 8-9 years, participated in this study. Inclusion criteria included (1) consistent enrollment in third-grade, (2) no physical limitations that hinder participation in the physical education program, (3) parental consent for involvement, and (4) student assent. Exclusion criteria included (1) chronic absence of more than 20% of sessions, (2) physical limitations that are proven to hinder movement, and (3) withdrawal of consent. Participants

were randomized based on intact class groups into an experimental group (n=30) or a control group (n=30).

The experimental group consisted of 16 males (53.3%) and 14 females (46.7%), with a mean age of 8.73 ± 0.45 years. The control group consisted of 15 males (50.0%) and 15 females (50.0%), with a mean age of 8.67 ± 0.48 years. Chi-square analysis showed no significant change in gender distribution between groups ($\chi^2 = 0.067$, $p = 0.796$), and an independent t-test showed no age difference ($t = 0.530$, $p = 0.598$). The experimental intervention consisted of 24 organized physical education sessions (2 sessions per week, each lasting 70 minutes) conducted over 12 weeks. The sessions were conducted jointly by physical education students and class instructors, following a comprehensive lesson plan.

This strategy includes 24 unique educational games aimed at integrating elements of physical literacy across four sequential phases: Phase 1 (weeks 1-3): Fundamental Movement Literacy, activities centered on fundamental movement patterns, sport knowledge, and safety awareness. Examples include "sports mystery box" (recognizing sports through movement demonstrations) and "moving storytelling relay" (integrating locomotor skills with narrative comprehension). Phase 2 (weeks 4-6): Coordination and Balance Development, activities focusing on spatial awareness, balance, and coordination, while integrating instruction about health and nutrition.

Featured games include "smart bridge" (a balance challenge integrated with safety questions) and "healthy treasure hunt" (a dexterity course highlighting nutritional choices). Phase 3 (weeks 7-9) implements game-based skills modified sports activities combining strategic understanding with basic motor skills. Examples include "educational mini-tournaments" (table tennis integrated with math) and "smart kids league" (volleyball incorporating cognitive challenges). Phase 4 (weeks 10-12) integration and assessment of culminating activities summarizes cross-disciplinary learning through student-created games, skill demonstrations, and reflective assessments.

Participants in the control group received conventional physical education instruction in accordance with the National Curriculum recommendations. Sessions focused on conventional teacher-led activities such as warm-up exercises, skill demonstrations, practical exercises, and cool-down activities. Instruction focused largely on physical skill development, with little incorporation of cognitive or affective learning objectives. The 20-item instrument assessed cognitive understanding of physical activity concepts, including knowledge of exercise, health benefits, safety principles, and movement theory.

The assessment consisted of 15 multiple-choice questions (1 point each) and 5 short-answer questions (1 point each), resulting in a score ranging from 0 to 100. Content validity was confirmed through evaluation by physical education faculty experts. Internal consistency reliability was excellent (Cronbach's $\alpha = 0.847$). The 20-item self-report instrument evaluated motivation to engage in physical education on a 4-point Likert scale (1 = strongly disagree, 4 = strongly agree). The instrument assessed four elements of motivation: enjoyment (5 items), self-efficacy (5 items), effort/perseverance (5 items), and social connections (5 items). Total scores ranged between 20 and 80, with higher scores indicating increased motivation. The questionnaire had excellent internal consistency (Cronbach's $\alpha = 0.923$).

Motor competence was assessed using four standardized skill tests (1) 15-meter sprint (speed), (2) standing long jump (lower body strength), (3) tennis ball throw (upper body coordination), and (4) ball catching (eye-hand coordination). Each skill was evaluated using a 4-point rubric (1 = below expectations, 4 = exceeds expectations) according to technique and performance standards. Total scores varied between 4 and 16. Inter-rater reliability exceeded 0.85 for all evaluations. Data collection occurred during standardized physical education sessions to enhance ecological validity. Baseline testing was conducted the week before the start of the intervention, and posttesting was conducted one week after the intervention ended.

Research assistants received training in the evaluation protocol and remained blinded to group allocation during data collection. Data analysis followed intention-to-treat guidelines using SPSS version 25.0. Descriptive statistics included means, standard deviations, and frequency distributions for all variables. Normality was checked using the Shapiro-Wilk test, while homogeneity of variance was assessed using Levene's test. The primary analysis used paired-samples t-tests to assess within-group changes from pretest to posttest, and independent-samples t-tests to evaluate between-group differences on posttest and on improvement scores. Effect sizes were calculated using Cohen's d with aggregate standard deviations. The significance level was set at 0.05 for all statistical analyses.

Results

All continuous variables demonstrated normal distribution (Shapiro-Wilk $p > 0.05$) and homogeneity of variance (Levene's test $p > 0.05$), thus validating the assumptions for parametric analysis. Initial comparisons revealed no significant differences between groups in physical literacy knowledge ($t = 0.215$, $p = 0.830$), learning intention ($t = -0.326$, $p = 0.746$), or basic motor skills ($t = 0.667$, $p = 0.507$), thus confirming the success of randomization. Table 1 presents descriptive statistics and between-group comparisons for physical literacy knowledge scores. Groups demonstrated substantial improvement from pre-test to post-test, with the degree of change varying widely.

Table 1. Results of the physical literacy knowledge test

Group	Pretest M(SD)	Posttest M(SD)	Gain Score M(SD)	t in group	p-value	Cohen's d
Experimental	52.3(8.7)	78.4(6.9)	26.1(7.2)	19.85	<0.001	3.62
Control	51.8(9.2)	62.1(8.4)	10.3(5.8)	9.73	<0.001	1.78
Comparison between groups	$t = 0.215$, $p = 0.830$	$t = 8.146$, $p < 0.001$	$t = 9.284$, $p < 0.001$	-	-	$d = 2.39$

The experimental group achieved an average improvement of 26.1 points (a 49.9% increase), significantly exceeding the control group's improvement of 10.3 points (a 19.9% increase). The between-group effect size ($d = 2.39$) indicates substantial practical significance. Table 2 displays the learning motivation results across the experimental

conditions. The experimental group demonstrated significantly greater motivational improvement compared to the control group.

Table 2. Results of the learning motivation questionnaire

Group	Pretest M(SD)	Posttest M (SD)	Gain Score M (SD)	t in group	p-value	Cohen's d
Experimental	48.6(7.3)	67.8(5.6)	19.2(6.1)	17.24	<0.001	3.15
Control	49.2(6.8)	54.3(7.1)	5.1(4.2)	6.65	<0.001	1.21
Comparison between groups	t = -0.326, p = 0.746	t = 8.152, p < 0.001	t = 10.185, p < 0.001	-	-	d = 2.62

The experimental group's mean improvement of 19.2 points (a 39.5% increase) significantly exceeded the control group's improvement of 5.1 points (a 10.4% increase), resulting in a very large between-group effect size ($d = 2.62$). Table 3 summarizes the results of the basic motor skills assessment, which showed greater improvement in the experimental condition.

Table 3. Results of basic motor skills assessment

Group	Prates M (SD)	Posttest M (SD)	Gain Score M (SD)	t in group	p-value	Cohen's d
Experimental	8.4(1.6)	12.8(1.4)	4.4(1.8)	13.39	<0.001	2.44
Control	8.1(1.8)	9.7(1.9)	1.6(1.4)	6.26	<0.001	1.14
Comparison between groups	t = 0.667, p = 0.507	t = 6.937, p < 0.001	t = 6.652, p < 0.001	-	-	d = 1.71

The 4.4-point (52.4%) increase in the experimental group substantially exceeded the 1.6-point (19.8%) increase in the control group, resulting in a large between-group effect size ($d = 1.71$). Figure 1 illustrates the distribution of post-intervention achievement levels, which shows marked differences between groups in performance categories.

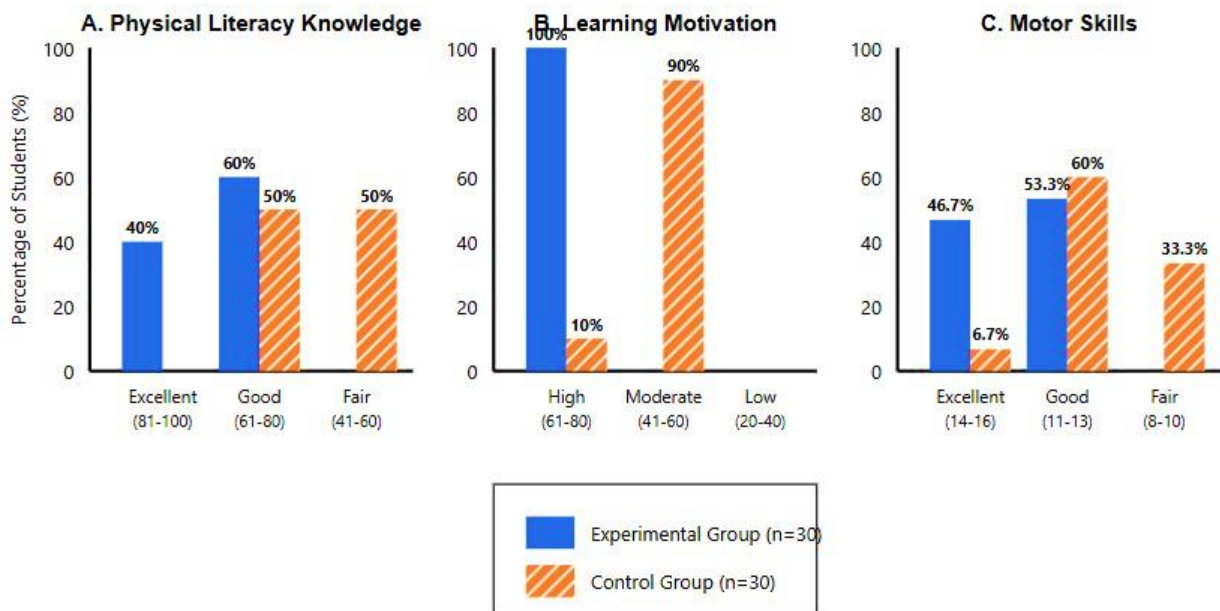


Figure 1. Distribution of post-intervention achievement levels by group

Chi-square analysis confirmed significant differences between groups in the distribution of achievement for physical literacy knowledge ($\chi^2 = 18.462$, $p < 0.001$), learning motivation ($\chi^2 = 45.714$, $p < 0.001$), and motor skills ($\chi^2 = 12.857$, $p < 0.001$). Table 4 presents the correlation matrix between post-test variables by group, which shows stronger associations in the experimental condition.

Table 4. Pearson correlation between post-test variables

Variables	Experimental Group			Control Group		
	PL	Mot	MS	PL	Mot	MS
Physical Literacy (PL)	1	.712***	.634***	1	.659***	.548**
Motivation (Mot)		1	.567**		1	.478**
Motor Skills (MS)			1			1

** $p < .01$, *** $p < .001$

The experimental group showed stronger intercorrelations between physical literacy components, indicating more integrated development across domains. Table 5 presents improvement scores disaggregated by gender, indicating consistent intervention effects across subgroups.

Table 5. Achievement scores by gender and group

Variables	Experimental Group			Control Group			P interaction
	Male M(SD)	Female M(SD)	P	Male M(SD)	Female M(SD)	P	
Physical Literacy	26.9(7.5)	25.1(6.9)	0.490	10.7(6.1)	9.9(5.6)	0.712	0.874

Variables	Experimental Group		Control Group			p interaction	
Motivation	19.8(6.4)	18.4(5.8)	0.534	5.3(4.5)	4.9(3.9)	0.789	0.792
Motor Skills	4.6(1.9)	4.1(1.6)	0.438	1.7(1.5)	1.5(1.3)	0.694	0.681

No significant gender \times treatment interactions were found, indicating comparable intervention effectiveness across gender subgroups.

Discussion

This study presents persuasive evidence of the transformative potential of game-based physical education in improving physical literacy among elementary school students. The intervention produced very large effect sizes across all assessed domains—cognitive ($d = 2.39$), affective ($d = 2.62$), and psychomotor ($d = 1.71$), significantly exceeding the results of standard educational interventions and challenging established beliefs about physical education pedagogy. Our findings strongly support social constructivist learning theory, which describes how game-based contexts foster active knowledge creation through significant social engagement.

The improvement in the experimental group's performance is in accordance with Vygotsky's concept of the zone of proximal development, because educational games facilitate structured learning experiences that allow students to go beyond their independent abilities.(Opstoel et al., 2020).The cooperative aspect of games facilitates peer learning and distributed cognition, which are recognized as essential for deep learning in modern educational theory.(Quennerstedt, 2019). The significant increase in motivation ($d = 2.62$) provides strong empirical validation for self-determination theory in the context of physical education.

Our instructional games systematically meet students' fundamental psychological needs of autonomy through choice and freedom of action in play, competence through increasing levels of difficulty and successful experiences, and connectedness through collaborative team activities (Ryan & Deci, 2020).These findings complement other studies by showing that effectively designed educational games can produce motivational effects that go beyond those typically seen in physical activity interventions.(Vasconcellos et al., 2020). The effect sizes we found significantly exceeded the effect sizes recorded in recent meta-analyses of game-based learning therapies.(Li et al., 2024).

Previous research identified a moderate impact on enjoyment outcomes ($g = 0.68$), whereas the motivational effect we found was of a much more significant magnitude.(Roure et al., 2024).Previous research also documented a moderate impact on learning outcomes ($d = 0.56$), in contrast to our cognitive domain effect of $d = 2.39$. Several reasons may explain this improvement. First, the holistic design of our intervention integrated multiple domains of physical literacy rather than focusing on a single outcome. Previous studies often focused on single-domain interventions, which may limit synergistic benefits across multiple dimensions of learning.(Young et al., 2020)

Our 12-week duration exceeded the duration of conventional interventions, facilitating better skill consolidation and habit formation. The collaborative teaching paradigm, which leverages the enthusiasm of university students combined with the pedagogical experience of classroom teachers, may have improved the quality of implementation beyond standard school-based treatments. However, our results differ from many previous studies in Indonesia that have shown more moderate effects (Hermawan & Pratama, 2022). The study identified small to moderate impacts ($d = 0.35 - 0.58$) of game-based physical education on motor skills.

This discrepancy may reflect variations in intervention design, as their studies used traditional games without intentionally incorporating cognitive and affective learning objectives. Our organized educational games with explicit physical literacy elements appear to be more effective than casual game-based methods. The breadth of reported impacts undermines core assumptions about physical education instruction in Indonesian classrooms. Conventional teacher-centered methods, while good for classroom management, appear to be far less effective in fostering comprehensive physical literacy.

Our findings suggest that the additional planning and resources required for game-based learning yield commensurate gains in student learning outcomes. The finding that integrated cognitive and affective learning enhances, rather than hinders, motor skill development challenges common concerns about "academic improvement" in physical education. (Kirk, 2019). The strong correlation between physical literacy components in the experimental group ($r = 0.567 - 0.712$) compared to the moderate correlation in the control group ($r = 0.478 - 0.659$) indicates that game-based learning encourages more cohesive growth.

This integration is in line with modern physical literacy theory, which highlights the interrelationships between the physical, cognitive, affective, and social domains. (Cairney et al., 2019). Conventional methods that address these topics in isolation can inadvertently limit students' overall development. Our findings illustrate the universal relevance of game-based learning methods, emphasizing the need for contextual adaptability. The educational game integrates Indonesian cultural features and local contexts, likely enhancing relevance and engagement for students. This cultural responsiveness may partly explain our improved results compared to studies using unmodified, Western-designed programs. (Suherman et al., 2019).

A collaborative teaching model involving students and classroom teachers provides a sustainable method for educational innovation in resource-constrained settings. This partnership strategy reduces common implementation barriers such as training, motivation, and educator support, while also increasing local capacity for sustainable program delivery. (Maksum, 2022). These findings challenge reductionist approaches in physical education research and support a comprehensive interpretation of physical literacy. (Whitehead, 2019) Our findings strengthen self-determination theory by demonstrating that educational games can foster an optimal motivational environment that goes beyond conventional autonomy-supportive teaching methods.

The organized yet engaging characteristics of instructional games seem to be particularly adept at balancing challenge and skill while maintaining intrinsic

motivation.(Ntoumanis et al., 2021)We present evidence on the cultural transferability of game-based learning principles, emphasizing the need for contextual adaptability. These findings inform discussions about universal versus culturally specific pedagogical methodologies in physical education.(Suherman et al., 2019).

Sconclusion

This study offers compelling empirical evidence that game-based physical education results in higher physical literacy outcomes compared to traditional training among Indonesian elementary school students. The significant effectiveness of the intervention in the cognitive, emotional, and psychomotor domains illustrates the transformative power of well-structured game-based pedagogy. These findings challenge the conventional, teacher-centered methodology prevalent in physical education in Indonesia and advocate for important pedagogical reforms that emphasize active, integrated, and meaningful learning experiences. A collaborative teaching model involving students and classroom instructors provides a sustainable approach to introducing new techniques and enhancing local capabilities. As the Indonesian education system modernizes, evidence-based methodologies such as game-based learning can foster the development of physically literate individuals ready to engage in lifelong physical activity. Future studies should investigate the long-term sustainability, scalability across contexts, and optimal implementation tactics to enhance the effectiveness of game-based physical education in promoting children's holistic development.

Author's Statement

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