



## Effectiveness of a game-based learning model in improving physical fitness and collaboration skills among junior high school students

*Eficacia de un modelo de aprendizaje basado en juegos para mejorar la condición física y las habilidades de colaboración en estudiantes de educación secundaria*

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### Abstract

**Introduction:** Physical Education (PE) is essential for promoting holistic development in junior high school students, including physical fitness and social-emotional skills such as collaboration. Traditional teacher-centered approaches often limit student engagement, emphasizing the need for innovative pedagogical strategies.

**Objective:** This study aimed to develop and evaluate the effectiveness of a game-based learning model in improving physical fitness and collaborative behaviors among junior high school students.

**Methodology:** A Research and Development design following the ADDIE model was implemented and validated by five experts in PE and educational media. Effectiveness testing employed a quasi-experimental pretest-posttest control group design involving 73 students in the experimental group and 79 in the control group. Physical fitness was assessed with the Indonesian Student Fitness Test (TKSI), while collaboration was measured using a Likert-scale instrument.

**Results:** The experimental group showed significant improvements in physical fitness (Mpost = 19.42, SD = 2.37) and collaboration (Mpost = 41.05, SD = 3.08) compared to the control group (Mpost = 14.16, SD = 0.78; 34.23, SD = 3.38). Independent samples t-tests confirmed statistically significant differences: physical fitness  $t(150) = 18.650$ ,  $p < 0.001$ ; collaboration  $t(150) = 12.983$ ,  $p < 0.001$ .

**Conclusions:** Game-based learning effectively enhances physical fitness and strengthens collaborative behaviors, offering an innovative and contextually relevant strategy for PE that promotes engagement, teamwork, and positive social interaction among junior high school students.

### Keywords

Game-based learning, physical fitness, collaboration, junior high school, Physical Education.

### Resumen

**Introducción:** La Educación Física (EF) es fundamental para promover el desarrollo integral en estudiantes de secundaria, incluyendo la condición física y habilidades socioemocionales como la colaboración. Los enfoques tradicionales centrados en el docente suelen limitar la participación del alumnado, lo que resalta la necesidad de estrategias pedagógicas innovadoras.

**Objetivo:** Este estudio tuvo como propósito desarrollar y evaluar la efectividad de un modelo de aprendizaje basado en juegos para mejorar la condición física y las conductas colaborativas de los estudiantes de secundaria.

**Metodología:** Se empleó un diseño de Investigación y Desarrollo siguiendo el modelo ADDIE, validado por cinco expertos en EF y medios educativos. La prueba de efectividad utilizó un diseño cuasiexperimental con pretest-posttest y grupo de control, con la participación de 73 estudiantes en el grupo experimental y 79 en el grupo de control. La condición física se evaluó mediante el Test de Condición Física del Estudiante Indonesio (TKSI), mientras que la colaboración se midió con un instrumento tipo Likert.

**Resultados:** El grupo experimental mostró mejoras significativas en la condición física (Mpost = 19.42, SD = 2.37) y la colaboración (Mpost = 41.05, SD = 3.08) en comparación con el grupo de control (Mpost = 14.16, SD = 0.78; 34.23, SD = 3.38). Las pruebas t de muestras independientes confirmaron diferencias estadísticamente significativas: condición física  $t(150) = 18.650$ ,  $p < 0.001$ ; colaboración  $t(150) = 12.983$ ,  $p < 0.001$ .

**Conclusiones:** El aprendizaje basado en juegos mejora de manera efectiva la condición física y fortalece las conductas colaborativas, constituyendo una estrategia pedagógica innovadora y contextualizada para la EF que fomenta la participación, el trabajo en equipo y la interacción social positiva en estudiantes de secundaria.

### Palabras clave

Aprendizaje basado en juegos, condición física, colaboración, secundaria, Educación Física.

## Introduction

Physical Education (PE) plays a fundamental role in the holistic development of junior high school students (Li, Jusoh, Niu, Liu, & Zhou, 2024). Beyond promoting physical fitness and motor competence, PE fosters essential social and emotional skills such as collaboration, communication, and emotional regulation. The once-dominant pedagogical paradigm—where teachers served as the sole authorities and transmitters of knowledge—has progressively shifted toward active and participatory learning models that position students as autonomous agents in their own learning processes (Etkin, 2024). Contemporary educational discourse highlights that PE is increasingly recognized not only as a vehicle for physical development but also as a strategic medium for cultivating interpersonal competencies required in 21st-century learning environments.

International policy documents, including the Quality Physical Education (QPE) guidelines endorsed by UNESCO, emphasize that high-quality PE constitutes a critical component of public health strategies and the Sustainable Development Goals (SDGs), particularly SDG 3 on health and SDG 4 on quality education, underscoring PE's long-term contribution to wellbeing, inclusivity, and active lifestyles. Nevertheless, many school-based PE programs continue to struggle with sustaining students' motivation, long-term participation, and cooperative engagement, signaling the need for innovative pedagogical frameworks that simultaneously integrate physical fitness enhancement and socio-emotional skill development (Guío Gutiérrez, 2022).

Game-Based Learning (GBL) has emerged as an innovative pedagogical approach that integrates key game elements—such as challenge, immediate feedback, goal clarity, and peer cooperation—into instructional design (Noroozi, Dehghanzadeh, & Talaei, 2020). Drawing on Self-Determination Theory (SDT), GBL aligns with the premise that intrinsic motivation flourishes when learners' psychological needs for autonomy, competence, and relatedness are met (Wang, Wang, Wang, Wind, & Gill, 2024). In educational psychology, these mechanisms are associated with sustained engagement, deeper learning, and higher-quality peer interactions, rendering GBL particularly compatible with PE settings.

Within the PE context, embedding game dynamics not only enhances engagement and enjoyment but also creates a fertile environment for social interaction and collaboration—dimensions often overlooked in traditional fitness-focused programs (Camacho-Sánchez, Manzano-León, Rodríguez-Ferrer, Serna, & Lavega-Burgués, 2023). Empirical findings by Omarov, Omarov, Azhibekova, & Omarov (2024) demonstrate that GBL, particularly when supported by interactive technologies such as Augmented Reality (AR), significantly enhances both student motivation and physical activity levels compared to conventional instruction. These findings suggest that the convergence between game mechanics and movement-oriented activities can promote multifaceted learning outcomes, spanning cognitive, affective, and psychomotor domains.

A growing body of evidence supports the efficacy of GBL in PE settings. Recent meta-analyses and systematic reviews have reported that structured PE interventions incorporating game mechanics or gamification produce measurable improvements in physical fitness indicators such as cardiovascular endurance, muscular strength, and flexibility. However, effect sizes are influenced by factors such as intervention fidelity, session duration, task complexity, and age-specific developmental characteristics. Moreover, heterogeneity across studies—stemming from differences in context, participant characteristics, and outcome measures—complicates cross-study generalization. This heterogeneity indicates a need for standardized protocols and clearer theoretical alignment across GBL intervention studies. Importantly, few studies have simultaneously assessed both objective physical outcomes and social-collaborative skills within a single intervention framework, underscoring a critical research gap (Alzghoul, 2024; Wu et al., 2023).

Further studies have explored relevant innovations in PE pedagogy. For instance, Rismanto et al., (2024) reported that play-based approaches in Islamic junior secondary schools (Madrasah Tsanawiyah) improved students' physical fitness, though the study did not quantitatively assess collaboration skills. Similarly, Astuti et al., (2025) developed e-modules and learning units incorporating modified sports and mini-games to enhance students' conceptual understanding and motor proficiency during online learning. Their findings revealed strong content validity and highly positive student responses, espe-

cially in relation to interactive, cooperative, and problem-solving components—suggesting that students demonstrate increased engagement when learning activities stimulate both cognitive and social dimensions of participation.

Despite these advancements, a substantial gap remains in the literature. There is a paucity of experimental or quasi-experimental studies conducted in developing-country contexts that rigorously evaluate the effectiveness of GBL on both objective physical fitness metrics and validated measures of collaboration skills. Additionally, key mediating and moderating mechanisms—such as motivation, enjoyment, and implementation fidelity—are rarely analyzed within prior research designs. The limited analytical attention to these variables weakens the interpretability of causal relationships and restricts insights into how and why GBL produces its documented benefits. This gap suggests that claims of GBL “effectiveness” require empirical verification through methodologically robust designs, standardized intervention protocols, and multidimensional outcome assessments encompassing both physical and socio-collaborative domains.

In response to these gaps, the present study is designed under the title “Effectiveness of a Game-Based Learning Model in Improving Physical Fitness and Collaboration Skills among Junior High School Students.” The study aims to: (1) evaluate the impact of a structured GBL intervention on objective indicators of physical fitness (i.e., cardiovascular endurance, muscular strength, and flexibility); (2) measure changes in students’ collaboration skills using validated observational and self-report instruments; and (3) examine the mediating or moderating roles of motivation, enjoyment, and implementation fidelity in explaining observed effects. Employing a quasi-experimental or cluster-randomized controlled trial (RCT) design, the study includes an active control group, pre-post assessments, and short-to-medium-term follow-ups. By integrating rigorous measurement techniques with contextually responsive intervention design, the study aims to generate replicable evidence that strengthens the scientific basis of GBL in PE while advancing pedagogical innovation in Indonesian junior high schools.

## Method

### *Participants*

The expert validation phase involved five experts, comprising university lecturers and professional practitioners in the field of Physical Education, Sport, and Health (PESH), with specific expertise in instructional media development and curriculum design.

The effectiveness testing phase adopted a quasi-experimental approach employing a pretest-posttest control group design. Participants were drawn from two junior high schools in Jambi City:

- 1) Experimental group: SMP Negeri 19 Kota Jambi (n = 73), which received the intervention through the implementation of the game-based learning model.
- 2) Control group: SMP Negeri 17 Kota Jambi (n = 79), which followed a traditional learning approach without exposure to the developed model.

### *Material and Method*

This study employed a Research and Development (R&D) methodology guided by the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The material used in this research consisted of a game-based learning model prototype, instructional media, PE equipment (cones, balls, markers, agility tools), standardized assessment instruments (TKSI and collaboration scale), and expert validation sheets. The characteristics of the material focused on feasibility for junior high school PE, safety, and adaptability to various learning environments. Participant selection followed inclusion criteria such as being enrolled in grades VII–VIII, participating in regular PE classes, and having no medical restrictions for physical activity. Techniques employed included expert review, pilot testing, pretest-posttest assessment, and classroom-based implementation. Tools used involved standardized test manuals, stopwatch, measuring tape, documentation sheets, and SPSS software. The methodological procedure considered practical constraints such as school schedules, environmental conditions, and adherence to ethical research protocols.



To determine the model's impact on the dependent variables, a Control Group Pretest–Posttest Design was applied. This design enabled the comparison of changes in physical fitness and collaborative attitudes between students exposed to the game-based learning intervention and those taught through conventional instruction.

### ***Development Procedure***

The ADDIE model provided a structured developmental pathway:

- 1) Analysis – identifying learners' needs, curriculum demands, and contextual factors influencing physical education in junior high schools.
- 2) Design – formulating learning objectives, game scenarios, and assessment rubrics focused on physical fitness and collaboration.
- 3) Development – constructing and refining the game-based learning prototype through expert consultation and pilot testing.
- 4) Implementation – executing the model in the experimental group's regular PJOK sessions.
- 5) Evaluation – assessing model validity, practicality, and effectiveness through both quantitative and qualitative data.
- 6) This systematic procedure ensured that the developed learning model was not only pedagogically sound but also contextually relevant to secondary-level physical education environments.

### ***Instrument***

The evaluation instruments in this study were developed within two primary domains, namely physical fitness assessment and collaboration attitude assessment, each of which was subjected to rigorous validation and reliability testing to ensure empirical robustness.

For the physical fitness assessment, the research utilized the Tes Kesegaran Siswa Indonesia (TKSI), a standardized national instrument developed and validated by the Ministry of Education, Culture, Research, and Technology (Kementerian Pendidikan Riset, dan Teknologi Republik Indonesia, 2023). The TKSI comprises five test components designed to measure multidimensional aspects of physical fitness among junior high school students:

- 1) Hand–Eye Coordination Test,
- 2) Sit-Up Test (abdominal muscular endurance),
- 3) Standing Broad Jump Test (explosive leg power),
- 4) T-Test (agility performance), and
- 5) Multistage Fitness Test (Beep Test) (aerobic capacity).

Each component of TKSI follows nationally standardized testing procedures and scoring norms that have undergone extensive psychometric evaluation by Kemdikbudristek. Empirical evidence has confirmed that the TKSI demonstrates high construct validity and excellent reliability coefficients, making it a valid and dependable instrument for assessing the physical fitness levels of Indonesian junior high school students (Kementerian Pendidikan Riset, dan Teknologi Republik Indonesia, 2023).

For the collaborative attitude assessment, the study employed a measurement scale adapted from the theoretical frameworks of (Jaswal & Behera, 2024; Prieto-Saborit, Méndez-Alonso, Ordóñez-Fernández, & Bahamonde, 2022; Xu & Correia, 2024). The adapted scale consisted of 15 items presented in a four-point Likert format, representing five essential dimensions of collaboration within game-based learning contexts:

- 1) Effective interpersonal communication within teams,
- 2) Individual accountability for assigned tasks,
- 3) Social support and mutual assistance among peers,
- 4) Engagement in reflective group dialogue, and



## 5) Commitment to achieving shared goals.

The adaptation process adhered to a systematic validation procedure. Initially, the draft instrument underwent a Focus Group Discussion (FGD) involving experts in physical education, sport pedagogy, and educational psychology to ensure content validity, cultural relevance, and semantic clarity of each statement. Following expert revision, a pilot study was conducted involving a representative sample of junior high school students to evaluate item clarity, response consistency, and construct coherence. The results of the pilot testing revealed a Cronbach's Alpha coefficient exceeding 0.80, indicating high internal consistency and reliability.

Consequently, both instruments—the TKSI and the collaboration attitude scale—were confirmed to be valid and reliable measurement tools, ensuring the credibility of the findings obtained in this study.

### **Data analysis**

The data analysis procedures in this study were conducted through a series of quantitative statistical techniques designed to evaluate the effectiveness of the developed game-based learning model in improving students' physical fitness and collaboration skills. The analysis process was carried out systematically to ensure both statistical rigor and interpretive accuracy.

Initially, descriptive statistics were applied to summarize the data distribution and central tendency for each variable, including mean, standard deviation, minimum, and maximum values for both the pretest and posttest results across the experimental and control groups. This preliminary stage provided an overview of the baseline equivalence between groups prior to intervention.

To test the assumptions of inferential analysis, the data were examined for normality using the Kolmogorov-Smirnov test and for homogeneity of variances using Levene's test. Both assumptions were satisfied, confirming that the data met the statistical requirements for parametric testing.

Subsequently, the study employed both between-group inferential analyses. For between-group comparisons, an independent-sample t-test was applied to examine the differential impact of the intervention between the experimental and control groups.

All statistical analyses were conducted using IBM SPSS Statistics (version 26.0) with a significance level set at  $p < 0.05$ . The adoption of this significance threshold ensured that any observed effects were unlikely to have occurred by random chance.

The integration of descriptive and inferential analyses provided a comprehensive analytical framework for interpreting the empirical impact of the developed model. This multifaceted approach strengthened the validity of the study's conclusions and aligned with international standards for empirical research in educational and sport sciences.

## **Results**

### **Expert Validation**

The developed game-based learning model underwent expert validation in two dimensions. Content experts in physical education rated the model with a score of 85.42, categorized as "feasible," while media experts assigned a score of 90.20, also deemed "feasible." These results indicate that the model is both pedagogically sound and media-appropriate for implementation at the junior high school level.

#### *Development of Game-Based Learning Models*

The final outcome of the development phase produced five innovative, engaging, and educational game models, designed contextually to suit the characteristics of junior high school students:

- 1) Estafet Ceria – Designed to enhance coordination, agility, and muscular endurance, this relay-based game requires teams to complete a series of physical challenges such as cone ball carrying, obstacle jumping, and target throwing. The activity emphasizes physical fitness and cultivates team responsibility and mutual support.



- 2) **Tangkap Komando** – Focused on reaction speed, hand–eye coordination, and team communication, students respond rapidly to commands from a group “commander.” Errors or delayed responses benefit the opposing team, promoting effective communication, focus, social awareness, and trust among team members.
- 3) **Rantai Manusia** – Emphasizing group coordination, strength, and cohesion, participants form a chain and navigate a winding course without breaking the link. The game develops collaborative skills, empathy, and collective responsibility, combining physical and social learning elements.
- 4) **Bola Lompat Berantai** – This activity targets endurance, explosive strength, and agility, requiring groups to jump while alternately bouncing a ball without dropping it. Success relies on individual coordination and mutual support, fostering team awareness and social interdependence.
- 5) **Jaring Kerjasama** – A reflective, integrative closing game in which small groups transport a ball using a network of interconnected ropes. Each participant’s movement is interdependent, reinforcing collaboration, communication, coordination, commitment, and fine psychomotor skills.

Overall, the five games are active, interactive, and adaptable, feasible for implementation in school fields using simple equipment. Limited field testing with Grade VIII students, following expert validation by physical education and educational psychology specialists, demonstrated that all games were feasible, engaging, and effective in enhancing both physical fitness and collaborative behaviors.

### *Effectiveness Testing*

Effectiveness was assessed using a Control Group Pretest–Posttest Design. The experimental group (SMP Negeri 19 Kota Jambi,  $n = 73$ ; 41 male, 32 female) received the game-based learning intervention, while the control group (SMP Negeri 17 Kota Jambi,  $n = 79$ ; 46 male, 33 female) underwent conventional instruction.

### *Descriptive Statistics*

Prior to presenting the statistical outcomes, it is essential to provide an overview of the data distribution and preliminary observations regarding the effects of the game-based learning intervention. The descriptive analysis allows for an initial comparison between the experimental group, which received the game-based learning model, and the control group, which followed conventional instruction.

This analysis examines two primary domains: physical fitness and collaborative behaviors. For each domain, pretest scores establish the baseline performance of participants, while posttest scores reflect changes following the intervention. Presenting these descriptive statistics offers insights into the magnitude of improvement and the overall trends in student performance before conducting inferential analyses.

Table 1 displays the mean scores and standard deviations for both groups across pretest and posttest measures, providing a clear visual representation of the impact of the intervention on the targeted outcomes.

Table 1. Descriptive Statistics of Pre-test and Post-test Scores in Experimental and Control Groups

Variable	Group	N	Mean	SD	
Physical Fitness	Pretest	Experimental	73	12,03	1,37
		Control	79	11,84	1,24
	Posttest	Experimental	73	19,42	2,37
		Control	79	14,16	0,78
Collaboration	Pretest	Experimental	73	30,63	2,54
		Control	79	31,42	2,82
	Posttest	Experimental	73	41,05	3,08
		Control	79	34,23	3,38

Table 1 presents the descriptive statistics of pretest and posttest scores for both physical fitness and collaboration in the experimental and control groups. For physical fitness, the experimental group exhibited a mean pretest score of 12.03 (SD = 1.37), which increased substantially to 19.42 (SD = 2.37) following the implementation of the game-based learning model. In comparison, the control group demonstrated a smaller increase from 11.84 (SD = 1.24) in the pretest to 14.16 (SD = 0.78) in the posttest.



This pattern suggests that the intervention had a notable impact on students' physical fitness development.

Similarly, in terms of collaboration, the experimental group had a pretest mean score of 30.63 (SD = 2.54), which increased to 41.05 (SD = 3.08) after the intervention. The control group, by contrast, showed a modest improvement from 31.42 (SD = 2.82) to 34.23 (SD = 3.38). These results indicate that the experimental group not only improved in physical fitness but also demonstrated stronger gains in collaborative behaviors relative to the control group.

### *Normality Test (One-Sample Kolmogorov–Smirnov Test)*

Before proceeding with inferential statistical analyses, it is essential to evaluate the distributional characteristics of the data to ensure that the assumptions underlying parametric tests are met. One of the fundamental assumptions for parametric tests, including t-tests, is that the data for each group are approximately normally distributed.

In this study, the normality of the pretest and posttest scores for both physical fitness and collaboration was examined. Assessing normality provides a preliminary indication of whether parametric statistical procedures can be appropriately applied to determine the effectiveness of the game-based learning intervention.

The results of the normality test are presented in the following table, offering a detailed overview of the data distribution for each variable and group.

Table 2. One-Sample Kolmogorov–Smirnov Test Test for Normality

Variable	Group	p-value	
Physical Fitness	Pretest	Experimental	0.139
		Control	0.186
	Posttest	Experimental	0.094
		Control	0.274
Collaboration	Pretest	Experimental	0.142
		Control	0.412
	Posttest	Experimental	0.266
		Control	0.207

As presented in Table 2, the One-Sample Kolmogorov–Smirnov Test was conducted to assess the normality of pretest and posttest scores for both physical fitness and collaboration in the experimental and control groups. The results indicate that all variables had p-values greater than 0.05, ranging from 0.094 to 0.412.

These findings suggest that the distribution of scores for each group did not significantly deviate from normality, thereby satisfying the normality assumption required for parametric testing. Specifically:

- 1) For physical fitness, the experimental group's pretest ( $p = 0.139$ ) and posttest ( $p = 0.094$ ) scores, as well as the control group's pretest ( $p = 0.186$ ) and posttest ( $p = 0.274$ ) scores, all met the normality criterion.
- 2) For collaboration, the experimental group's pretest ( $p = 0.142$ ) and posttest ( $p = 0.266$ ) scores, and the control group's pretest ( $p = 0.412$ ) and posttest ( $p = 0.207$ ) scores, similarly exhibited normal distributions.

These results confirm that the data are appropriate for subsequent parametric analyses, including independent samples t-tests, to examine the effectiveness of the game-based learning model in improving both physical fitness and collaborative behaviors.

### *Homogeneity of Variance (Levene's Test)*

Following the assessment of normality, the assumption of homogeneity of variance was evaluated using Levene's Test. Homogeneity of variance is a prerequisite for parametric tests, such as the independent samples t-test, as it ensures that the variability of scores across groups is comparable and does not bias the results.

Table 3. Levene's Test for Homogeneity

Variable	Group	p-value
Physical Fitness	Pretest	0.502
	Posttest	0.137
Collaboration	Pretest	0.276
	Posttest	0.684

As shown in Table 3, Levene's Test indicated that the variances of both pretest and posttest scores for physical fitness and collaboration were statistically homogeneous, with all p-values exceeding the 0.05 threshold. Specifically:

- 1) For physical fitness, the pretest ( $p = 0.502$ ) and posttest ( $p = 0.137$ ) scores demonstrated equal variances between the experimental and control groups.
- 2) For collaboration, the pretest ( $p = 0.276$ ) and posttest ( $p = 0.684$ ) scores also confirmed homogeneity of variance.

These results confirm that the assumption of homogeneity is met, validating the use of independent samples t-tests to compare posttest outcomes between the experimental and control groups. Establishing both normality and homogeneity ensures the statistical integrity and reliability of subsequent inferential analyses.

### *Independent Samples t-Test*

After confirming that the assumptions of normality and homogeneity of variance were satisfied, independent samples t-tests were conducted to examine the effectiveness of the game-based learning model on students' physical fitness and collaboration. The posttest scores of the experimental group, which received the intervention, were compared with those of the control group, which followed conventional instruction.

Table 4. Independent t-Test Results for Post-test Scores

Variable	t	df	p-value	Mean Difference	95% CI Lower	95% CI Upper
Physical Fitness	18.650	150	0.000	5.26	4.702	5.817
Collaboration	12.983	150	0.000	6.83	5.787	7.865

As presented in Table 4, the results reveal that the experimental group outperformed the control group in both outcome variables, with statistically significant differences.

For physical fitness, the experimental group achieved a posttest mean score of 19.42, compared to 14.16 in the control group. The t-test yielded  $t(150) = 18.650$ ,  $p < 0.001$ , with a mean difference of 5.26 (95% CI: 4.702–5.817). This result indicates a substantial and statistically significant improvement in physical fitness attributable to the game-based learning intervention.

For collaboration, the experimental group obtained a posttest mean score of 41.05, whereas the control group scored 34.23. The t-test result ( $t(150) = 12.983$ ,  $p < 0.001$ ) and a mean difference of 6.83 (95% CI: 5.787–7.865) demonstrate that the intervention significantly enhanced students' collaborative behaviors.

These findings provide strong empirical evidence supporting the effectiveness of the developed game-based learning model. Students in the experimental group not only showed enhanced physical performance but also exhibited improved social interaction and teamwork skills, indicating that the model effectively promotes holistic development in junior high school students.

As a result of the systematic procedures conducted through the ADDIE framework, several empirical findings were generated that confirmed the model's feasibility and readiness for implementation.

## Discussion

The findings empirically support that the game-based learning model significantly enhances students' physical fitness and collaborative behaviors, corroborating theoretical claims that game-based pedagogical approaches promote active, collaborative, and enjoyable learning experiences while simultaneously supporting physiological and social development.

### ***Physical Fitness Improvement***

The improvement in physical fitness aligns with Zhao et al., (2024), who reported that exergames significantly enhance students' physical performance in PE, with an effect size of 0.45 (95% CI: 0.27–0.63,  $p < 0.00001$ ). Purwanto, Rejeki, & Mentara (2024) emphasized that game-based learning contributes to the development of gross motor skills, including strength, agility, and coordination. Unlike conventional methods, which rely on repetitive movements, game-based learning provides dynamic, varied activities, optimizing physiological adaptation and sustaining motivation.

Koekoek, Dokman, & Walinga (2022) highlighted that game-based pedagogy positions students as active participants, allowing meaningful engagement in physical activity while integrating strategic thinking and social interaction. Similarly, El-Tanahi et al., (2023) showed that gamification enhances intrinsic motivation, active participation, and physical outcomes. Mahardhika et al., (2024) demonstrated that competitive yet enjoyable game-based activities stimulate intensive motor engagement, improving coordination and long-term interest in physical activity.

### ***Enhancement of Collaborative Behaviors***

Beyond physical improvements, the intervention significantly enhanced collaborative behaviors among students. The experimental group demonstrated greater communication, mutual support, and shared responsibility within teams compared to the control group. This aligns with Boke et al., (2025), whose meta-analysis indicated that Cooperative Learning in PE produces moderate positive effects on students' social, affective, and physical domains (effect size = 0.459, 95% CI: 0.324–0.592,  $p < 0.001$ ), with collaboration showing the greatest improvement.

Gamification elements such as challenges, role assignments, and collective objectives further motivated students to work together, develop teamwork skills, empathy, and intrinsic motivation, consistent with (Prieto & Aguilar, 2022) and (Maliki et al., 2025). Additional evidence supports that gamified approaches foster social interaction and a positive classroom climate (Koekoek et al., 2022; Sal-de-Rellán, Hernández-Suárez, & Hernaiz-Sánchez, 2025). Longitudinal studies confirm that game-based PE enhances team cohesion, tactical thinking, and cooperative decision-making (Ferraz et al., 2024; Manninen, Magrum, Campbell, & Belton, 2025), while game-based response systems improve emotional and social engagement, reinforcing collaborative dynamics (Priante & Tsekouras, 2025).

Overall, these findings demonstrate that game-based learning not only develops social-emotional competencies but also creates a cooperative, interactive learning environment conducive to holistic student development.

### ***Synergistic Multidimensional Effects***

The integration of physical and social learning components in game-based approaches generates synergistic multidimensional effects. Improvements in physical fitness facilitate more active participation in collaborative tasks, while social engagement enhances adherence to physical challenges. This interdependence creates a holistic learning environment, where physiological, cognitive, and socio-emotional domains develop concurrently. Meta-analyses by Alotaibi (2024) and Camacho-Sánchez et al., (2023) support these findings, demonstrating that game-based learning simultaneously enhances motor skills, social interaction, intrinsic motivation, and engagement. Consequently, game-based PE not only advances physical competencies but also cultivates collaborative attitudes and interpersonal skills, aligning with 21st-century educational goals that emphasize comprehensive student development.

## ***Educational Implications***

Overall, the results demonstrate that the game-based learning model is an effective, innovative, and relevant pedagogical strategy for 21st-century physical education. It promotes holistic learning, simultaneously enhancing cognitive, affective, and psychomotor domains through meaningful, collaborative, and contextually designed activities. The model not only improves physical fitness but also cultivates social values such as collaboration, empathy, and shared responsibility among junior high school students, aligning with the goals of modern, student-centered education.

## **Conclusions**

The present study provides compelling evidence that the game-based learning model is highly effective in enhancing both physical fitness and collaborative behaviors among junior high school students. Empirical findings demonstrated significant improvements in posttest scores for the experimental group compared to the control group, confirming that the intervention created active, engaging, and contextually meaningful learning experiences. Beyond physiological gains, the model strengthened key socio-emotional competencies—including teamwork, empathy, communication, and collective responsibility—which are increasingly recognized as central outcomes of 21st-century physical education.

From a theoretical perspective, the findings reinforce the assumptions of Self-Determination Theory, indicating that game-based structures effectively satisfy students' needs for autonomy, competence, and relatedness. Methodologically, the study demonstrates the robustness of the ADDIE-based R&D approach in producing a validated, feasible, and replicable pedagogical model tailored to junior high school contexts.

Practically, the model offers PE teachers an evidence-based framework that can increase student motivation, promote higher-quality movement experiences, and foster positive peer interactions using minimal equipment and adaptable activity formats. At the policy level, these results support ongoing efforts to integrate student-centered, active-learning pedagogies within national PE curricula.

Despite its strengths, the study is limited by the short intervention duration, the focus on two schools within a single city, and the absence of long-term follow-up regarding behavioral sustainability. Future research should examine longitudinal effects, explore implementation across diverse cultural and school environments, investigate moderating variables such as gender or baseline fitness, and evaluate integration with digital, augmented, or hybrid learning technologies to further expand the model's applicability and impact.

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## **Conflict of interest**

The authors declare no conflict of interest related to this research. The study was conducted independently, and all data collection, analysis, and reporting were carried out objectively, without influence from external parties or financial interests.



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