Development and validation of a quantum learning model based on traditional games to improve physical literacy in primary school students
Desarrollo y validación de un modelo de aprendizaje cuántico basado en juegos tradicionales para mejorar la alfabetización física en alumnos de primaria

Authors

Prayogi Nurfauzan [1]
Guntur [1]
Aris Fajar Pambudi [1]
Ade Gusti Ningsih [1]
Apriliana Nurulita Nur Fauzi [1]
Andika Triansyah [2]
Fatma Atik Mulyani [1]
St. Nur Almaidah RS. [1]
Atina [3]
Maria Magdalena Sri Wahyuni [3]
Arief Kuswidyanarko [1]
Irene Maria Wato [1]
Anna Mariyani [1]
Hidayatul Hikmah[1]
Amran [1]

[1] Universitas Negeri Yogyakarta (Indonesia)
[2] Universitas Pendidikan Indonesia (Indonesia)
[3] Universitas Sarjanawiyata Tamansiswa (Indonesia)

Corresponding author:
Prayogi Nurfauzan
prayoginurfauzann@gmail.com
prayoginurfauzan.2023@student.uny.ac.id

Abstract

Introduction: Physical literacy is fundamental to the holistic development of students. However, in Indonesia, its implementation at the primary school level remains limited due to teacher misconceptions, a lack of innovative pedagogical models, and low student engagement in physical activities.
Objective: This study aimed to design and evaluate the feasibility, practicality, and effectiveness of a Quantum Learning model incorporating traditional games to enhance physical literacy among primary school students. Methodology: A Research and Development (R&D) approach was employed, following the ADDIE model. Participants included fifth-grade students from six primary schools in the Paseh District, Bandung Regency. Two instructional design experts and two subject matter experts conducted the validation process. The effectiveness of the model was tested on 34 students from two schools. Data analysis involved Aiken's V, Cronbach's Alpha, paired sample t-tests, N-Gain scores, and the Mann–Whitney U test.
Results: The validation results demonstrated a high level of validity (V ≥ 0.894) and good instrument reliability (α > 0.80). The model's practicality achieved an average score of 94%. Effectiveness testing showed a significant improvement in physical literacy in the experimental group (p < 0.05) with an N-Gain of 0.53 (moderate category), exceeding that of the control group (0.30). Discussion: The integration of the Quantum Learning framework with culturally rooted traditional games fostered active, enjoyable, and contextually relevant Physical Education (PE) learning experiences aligned with students' developmental needs and the *Merdeka Belajar* (Freedom to Learn) policy.
Conclusions: The developed model proved feasible, practical, and effective in improving physical literacy and holds promise for broader adoption in culturally responsive physical education programs.

Keywords

Physical literacy; quantum learning; traditional games; Physical Education; primary school.

Resumen

Introducción: La alfabetización física es fundamental para el desarrollo integral de los estudiantes, pero en Indonesia su aplicación en las escuelas primarias sigue viéndose limitada por conceptos erróneos de los docentes, la falta de modelos innovadores y la escasa participación de los estudiantes en actividades físicas. Objetivo: El presente estudio tiene por objeto desarrollar y poner a prueba la viabilidad, la practicidad y la eficacia de un modelo tradicional de aprendizaje cuántico basado en juegos para mejorar la alfabetización física de los estudiantes de primaria. Metodología: Este estudio empleó un diseño de investigación y desarrollo (I+D) utilizando el modelo ADDIE. Los sujetos fueron alumnos de quinto curso de seis escuelas primarias del distrito de Paseh, en la regencia de Bandung. La validación fue realizada por dos expertos en diseño instruccional y dos expertos en la materia, mientras que las pruebas de eficacia se llevaron a cabo con 34 alumnos de dos escuelas. Los datos se analizaron utilizando la V de Aiken, el alfa de Cronbach, la prueba t para muestras emparejadas, el N-Gain y la prueba de Mann-Whitney. Resultados: Los resultados de la validación demostraron un alto nivel de validez (V ≥ 0,894) y una buena fiabilidad del instrumento (α > 0,80). La practicidad del modelo obtuvo una puntuación media del 94 %. Las pruebas de eficacia mostraron una mejora significativa en la alfabetización física en el grupo experimental (p < 0,05) con una ganancia N de 0,53 (categoría moderada), superando la del grupo de control (0,30). Discusión: La integración del modelo *Quantum Learning* y los juegos tradicionales creó de manera eficaz un aprendizaje de Educación Física (EF) activo, divertido y contextual, en línea con el desarrollo de los estudiantes, al tiempo que apoyó la política Merdeka Belajar.
Conclusiones: El modelo desarrollado demostró ser viable, práctico y eficaz para mejorar la alfabetización física, con potencial para una aplicación más amplia en la educación física basada en la cultura.

Palabras clave

Alfabetización física; aprendizaje cuántico; juegos tradicionales; Educación Física; escuela primaria

Introduction

Physical literacy (PL) has emerged as an important concept in 21st-century Education. It is defined as an individual's ability to participate confidently and competently in a wide range of physical activities, supported by motor skills, cognitive understanding, and a positive attitude toward physical activity (Nur et al., 2025). It is considered crucial for the comprehensive development of children, particularly at the primary school, as it supports not only physical growth but also cognitive and social development. Globally, educational institutions such as Physical and Health Education (PHE) in Canada and Sport Australia have prioritized physical literacy in their curricula. Indeed, physical literacy has become a primary goal in many developed countries as part of a strategic effort to address the growing issue of physical inactivity (Cairney et al., 2019). Physical literacy forms the foundation of quality Physical Education, which aims to develop physically competent, confident, and motivated individuals who can sustain an active lifestyle throughout their lives. However, in Indonesia, the concept and understanding of physical literacy remain limited. For example, the National Literacy Movement (NLM) does not prioritize physical literacy, instead focusing on literacy in reading, writing, numeracy, science, finance, digital literacy, cultural literacy, and civic literacy (Mayuni et al., 2020; Nuryana et al., 2020). Research trends also suggest that physical literacy development in Indonesia has not progressed as rapidly as in developed countries. This is evident from the limited number of studies in this field (Friskawati & Stephani, 2021) and the shortage of local contextually relevant research tailored to the context of Indonesian primary schools (Nur et al., 2025).

Teaching methods in Physical Education (PE) within Indonesian primary schools remain constrained by teacher-centered approaches, limited pedagogical innovation, and a lack of creative instructional strategies. These persistent challenges have contributed to the alarmingly low levels of physical literacy among students. One critical issue is the widespread misconception held by teachers, compounded by a significant gap in professional knowledge. Interviews conducted with PE teachers from the Sindangsari Cluster in Bandung (16 January 2023) revealed that the majority of teachers continue to perceive physical literacy narrowly , often equating it merely with the ability to identify body parts or as a vehicle for achieving athletic success, rather than embracing its comprehensive, multidimensional nature. In reality, physical literacy encompasses interconnected physical, cognitive, and affective domains, each of which plays a vital role in fostering lifelong engagement in physical activity and overall well-being. This situation indicates that physical literacy has not been prioritized in national physical Education policies, likely due to the lack of empirical research and academic discourse in this field. Secondly, the overall level of physical literacy among primary school students in Indonesia remains low, with the majority falling into the 'Beginner' and 'Developing' categories, particularly in the knowledge and understanding domains (Irmansyah et al., 2025). Thirdly, there are no standardized methods for assessing physical literacy among students or incorporating physical literacy into the primary school curriculum. Physical literacy is increasingly important, yet standardized assessment tools for evaluating students' physical literacy are still unavailable (Nur et al., 2025). This gap hinders educators and policymakers from developing physical Education programs aligned with developmental needs. Fourthly, there are pedagogical limitations in practice. Physical Education teachers in West Bandung Regency struggle to implement innovative or student-centered pedagogies. As a result, the learning process remains teacher-centered and does not take into account the natural ways in which primary school children want to play, move, and interact with their peers. Fifth, this problem is exacerbated by digitalization and sedentary lifestyles. Students are becoming more individualistic and less collaborative. Addiction to digital games is a major concern, contributing to increased screen time, reduced physical activity, and unhealthy lifestyle patterns. Collectively, these issues manifest at multiple levels, reinforcing the conclusion that the persistently low levels of physical literacy in Indonesian primary schools constitute a complex, systemic problem, rather than one attributable solely to individual student shortcomings.

One potential pedagogical alternative is Quantum Learning (QL). This model combines art, the natural potential of learners, and a dynamic learning environment to create a fun and meaningful learning atmosphere (Kristiyanto & Indriayu, 2020; Agustini et al., 2022). Rooted in Lozanov's suggestology, QL incorporates positive suggestions, games, colors, music, optimistic thinking, physical activities, and a comfortable emotional atmosphere. All these elements are designed to accelerate and deepen the learning process. QL also aligns with the principles of Freire and Lozanov, which emphasize the importance

of active interaction between teachers and students in uncovering their potential (Koroglu et al., 2022; Mclean, 2019). The philosophy of QL, 'bring their world into our world and bring our world into theirs,' encourages meaningful student engagement in the learning context. Its main principles include "everything speaks", "everything has a purpose", "experience before naming", "value every effort", and "if it is worth learning, it is worth celebrating". Numerous studies have demonstrated QL's effectiveness in enhancing learning motivation and critical thinking, with potential to strengthen physical literacy (Widana, 2020; Maulidi, 2022; Fauzan et al., 2024; Setiawan, 2023).

Traditional games are a significant part of Indonesia's cultural heritage, passed down across generations. Classified as verbal, imaginative, and physical activities, these games are appropriate for the developmental characteristics of primary school children (Marzuqi et al., 2022; Saefullah et al., 2024). In addition to enhancing gross and fine motor skills, traditional games contribute to the development of intellectual, social, and character competencies. They also play a role in preserving local cultural values (Mudzakir, 2020; Kurniawan, 2015; Maliki et al., 2024). Empirical studies have proven that traditional games can improve cardiorespiratory fitness, basic motor skills, social competence, and active student engagement (Kurniati, 2016; Muhaimin et al., 2024; Toff et al., 2024). The QL philosophy, which emphasizes a positive, participatory, and student-centered learning environment, is well aligned with the characteristics of traditional games (Sofyan & Murdianingsih, 2022). As they are enjoyable and physically active and encourage group interaction while being appropriate for children's developmental stages, traditional games serve as an ideal medium to support the QL approach. Combining these two elements produces a synergistic pedagogical approach. QL provides structure, philosophy, and motivational strategies, while traditional games offer meaningful activities that enrich students' physical, cognitive, social, and cultural development.

An analysis of conventional game-based pedagogical intervention models from 2020 to 2025 reveals that, although various approaches are applied in primary schools, many are limited in scope and depth. Previous research by Nur et al. (2025) and Susanti et al. (2023) developed a modified traditional game intervention model that successfully improved students' physical fitness. However, this model did not cover other dimensions of physical literacy, such as cognitive aspects, motivation, and understanding of movement concepts. Maliki et al. (2024), on the other hand, developed a traditional game-based in physical education learning model that encompasses various areas, including physical fitness, motor skills, social skills, and cultural preservation. However, the effectiveness of its implementation in the field or its integration into a comprehensive educational framework such as Quantum Learning has not been evaluated. These results confirm the effectiveness of traditional games as a medium for physical education interventions while emphasizing the critical need for more integrative, systematic, and pedagogically sound learning models to improve all aspects of physical literacy in a balanced manner.

A literature analysis over the past five years also reveals a significant gap in physical literacy development in Indonesia. Research in this field is currently limited and lagging behind that in developed countries. It tends to focus on measurement or instrument development without a comprehensive conceptual framework (Friskawati et al., 2021). It is characterized by an absence of contextually relevant studies designed to meet the needs of primary schools (Nur et al., 2025). The lack of standardized assessment frameworks and effective measurement tools has hindered the systematic integration of physical literacy interventions into the primary school curriculum. Research on traditional games demonstrates their positive impact on students' physical fitness and motor skills (Maliki et al., 2025). However, studies assessing their impact on multidimensional physical literacy, including the cognitive, emotional, and social dimensions, remain limited (Warman & Ristiani, 2023). Furthermore, there are no systematic studies that combine the concept of Quantum Learning with traditional games in the context of physical Education to enhance students' physical literacy. Nevertheless, students' physical literacy skills in Indonesia are inadequate, particularly with regard to knowledge and understanding (Friskawati, 2024; Priadana et al., 2021; Irmansyah et al., 2025). There are no comprehensive, context-based teaching strategies to help address these issues. Traditional games are effective in improving physical fitness, and Quantum Learning is recognized as an enjoyable, holistic approach to learning. While traditional games have been shown to improve physical fitness, their broader impact on physical literacy remains largely unexplored. Similarly, although Quantum Learning is known as an engaging and holistic pedagogy, it has not yet been strategically combined with traditional games to improve physical literacy in primary schools comprehensively.

This study aims to fill this gap through the development and validation of a Traditional Game-based Quantum Learning Model, which is specifically designed to improve the physical literacy of Indonesian primary school students holistically. The novelty of this study lies in four key aspects:

1. Pioneering Integration: It represents the first systematic integration of Quantum Learning principles with traditional games specifically designed for enhancing physical literacy in primary school students.

2. Contextualized Development: The model was developed and empirically validated within the unique social, cultural, and educational context of Indonesia, ensuring its contextual relevance and applicability.

3. Holistic Educational Approach: The program adopts a comprehensive framework, simultaneously targeting students' physical competence, intrinsic motivation, self-confidence, as well as their knowledge and understanding related to physical literacy.

4. Innovative Response to Digitalization: This model offers an innovative pedagogical solution to address the challenges of sedentary lifestyles and the adverse effects of excessive digital media use among children in contemporary primary school settings.

The lack of literature on the synergistic combination of Quantum Learning and traditional games in the context of physical Education in Indonesia provides a strong basis for the urgency of this study. The integration of these two approaches is capable of presenting an attractive, contextual, and holistic pedagogical model while also functioning as a solution to the complex challenges of physical literacy development in primary schools. In line with the problems, research gaps, and novelty identified, this study aims to develop a traditional game-based Quantum Learning model in PE learning to improve the physical literacy of primary school students.

In addition, the study evaluates the feasibility, practicality, and effectiveness of the model in enhancing students' physical competencies, motivation, self-confidence, and conceptual understanding within the elementary school context. This study offers a conceptual framework on how the interconnection between physical literacy components can be enhanced through a cultural and contextual pedagogical approach. Furthermore, this research contributes a conceptual model that integrates Quantum Learning and traditional games, verified through a Research and Development (R&D) methodology with rigorous validity testing, making it a methodological reference for physical Education research in similar contexts. Practically, the developed model provides an alternative learning approach for PE teachers, offering a more engaging, effective, and culturally appropriate student-centered approach.

Method

Research Design
This study used the research and development (R&D) method with the ADDIE (analyze, design, develop, implement, and evaluate) development model approach. The aim was to create a traditional game-based quantum learning model for Physical Education to improve the physical literacy of primary school students. Figure 1 shows the series of research stages.

Figure 1. ADDIE Research Flow
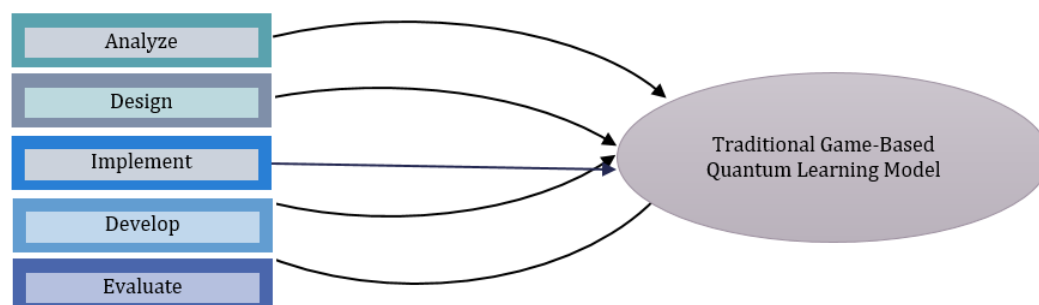
(Dick & Carey, 2015)

Research Subject

This study involved 34 Year 5 students from primary schools in the Paseh Subdistrict, Bandung Regency, West Java, Indonesia. The participants were selected through cluster random sampling from a total population of six public schools: SDN Sindangsari 01 to SDN Sindangsari 06. A random draw identified two schools for the implementation trial: SDN Sindangsari 03 and SDN Sindangsari 06.

Data collection

Data collection was conducted in multiple phases, following the stages of the ADDIE model:

- Phase 1 – Analysis: A comprehensive needs analysis was carried out through questionnaires, semi-structured interviews with Physical Education teachers, classroom observations, and an extensive review of relevant literature.

- Phase 2 – Design: Based on the findings from the analysis, learning models and supporting instructional tools were designed. These drafts were subsequently subjected to expert validation and refined through focus group discussions.

- Phase 3 – Development: The validated learning models, instruments, and instructional materials were finalized and prepared for field implementation.

- Phase 4 – Implementation: The developed product was implemented in two selected primary schools, followed by practicality and effectiveness trials in real classroom settings.

- Phase 5 – Evaluation: Data on the effectiveness of the model was collected through pre- and post-tests measuring

Instrument (suggestion: follow the same logic as the previous point)

This research instrument comprises a questionnaire, observation sheets, interview guides and physical literacy tests. The questionnaire is used to assess the model's validity by experts, and its practicality for learning, from the perspectives of teachers and students. Observations are conducted to record learning implementation, as well as teacher and student activities and model implementation in the field. Interviews were conducted to gather in-depth information about the implementation of physical education learning, as well as the school's equipment and facilities, and the obstacles encountered. Practice-based physical literacy tests were used to measure students' abilities before and after the intervention. Additionally, two instruments tested for validity and reliability were adopted for this study: the Perceived Physical Literacy Questionnaire (PPLQ) by Holler et al. (2023), which measures students' motivation and self-confidence with good construct validity and very high reliability (α = 0.882); and the Assessment of Physical Literacy – Physical Competence Domain (APL-PCD) by Permana et al. (2023), which measures physical competence with very high validity (1.017 for males and 0.937 for females) and high reliability. Both instruments have been adapted to the cultural context and characteristics of primary school students in Indonesia.

Data Analysis

Data analysis was conducted using descriptive and inferential quantitative methods. Model validity was analyzed using Aiken's V percentage of acceptability, based on the interpretation of Aiken's V values (Table 1). These values range from highly valid to invalid. Instrument reliability was tested using Cronbach's alpha method, with a minimum reliability criterion of 0.70 (see Table 2). The validity and reliability of each assessed aspect are classified according to the following table.

Table 1. Aiken's V Value Criteria

Aiken's V Value	Validity Category	Interpretation
0,00 – <0,20	Not Valid	The item does not have adequate content
0,20 – <0,40	Less Valid	Low content validity does not meet standards
0,40 – <0,60	Moderately Valid	Moderate content validity, but still requires
0,60 – <0,80	Valid	Good content validity and can be used
0,80 – 1,00	Highly Valid	Very high content validity and highly relevant

Table 2. Cronbach's Alpha Reliability Criteria

Cronbach's Alpha Value	Category	Interpretation
> 0,90	Very Good	The instrument has very high internal consistency
> 0,80 – 0,90	Good	The instrument has high internal consistency
> 0,70 – 0,80	Acceptable	The instrument has adequate internal consistency
0,50 – 0,70	Moderate	The instrument has sufficient internal consistency
< 0,50	Low	The instrument has low internal consistency and needs improvement

The practicality of the model was analyzed using field test data, which included the feasibility of learning and the activities of teachers and students, as well as their responses to the model. The practicality of the learning model was interpreted based on the percentage score range of the practicality test results.

The criteria for interpreting practicality are presented in Table 3 below.

Table 3. Criteria for Interpreting the Practicality of Learning Models

Score Range	Category	Description
90-100	Very Practical	The model can be used immediately without revision because all aspects of implementation are excellent
75-89	Practical	The model can be used with minor revisions for minor improvements
65-74	Sufficiently Practical	The model is suitable for use after moderate revisions to some parts
55-64	Less Practical	The model requires major revisions before it can be implemented optimally
0-54	Very Less Practical	The model is not suitable for use and needs to be completely redesigned

The effectiveness of the model was analyzed using a paired-sample t-test to determine whether there were any significant differences in students' physical literacy scores before and after the test. Additionally, learning outcome improvement was measured using N-gain scores, which were then categorized.

The criteria for grouping N-gain scores are shown in Table 4.

Table 4. Interpretation Criteria for N-gain Score

Limits	Category
G > 0.7	High
$0,3 \leq g \leq 0,7$	Moderate
G < 0,3	Low

Results

A needs analysis was conducted to evaluate the current condition of Physical Education instruction and to explore opportunities for integrating traditional, game-based teaching models in primary schools. Data were gathered through classroom observations, semi-structured interviews, and focus group discussions involving teachers, lecturers, and practitioners. The findings revealed that existing learning models were limited in scope and lacked variety, resulting in passive and unengaging learning experiences for students. These opportunities and challenges were subsequently examined through a SWOT analysis, the results of which are presented in Table 5.

Table 5. SWOT Analysis Results of the Development of a Traditional Game-Based Quantum Learning Model to Improve Physical Literacy in Primary School Students

Strength	Weakness
Provides an active and enjoyable learning experience for primary school students	Teacher's competence in designing innovative models is still limited
Supports physical, cognitive, and social-emotional development through physical literacy	Limited time management in implementing game-based learning
Increases student motivation, participation, and skills	Limited traditional game facilities and infrastructure in schools

Opportunity	Threat
In line with the Merdeka Belajar (Freedom of Learning) and Character Education policies	Technological developments reduce student interest in traditional activities
Increases student awareness of the importance of physical, mental, and cognitive health	Limited support for traditional games from schools and the government

Source: Research data, 2025

The results of the SWOT analysis indicate that the traditional game-based Quantum Learning model holds significant potential for enhancing the physical literacy of primary school students by offering an active, enjoyable, and holistic learning experience. Nevertheless, several challenges must be addressed, including issues related to teacher competence, time allocation, and limited school facilities. Although educational policy support appears favorable, the rapid advancement of technology and the persistent shortage of infrastructure remain notable barriers to the effective implementation of this model.

Learning Design Expert Feasibility Test Result

To ensure the quality and effectiveness of the developed product, feasibility testing of the traditional game-based Quantum Learning model was conducted by two learning design experts. The results of their evaluations, which assessed various aspects of the product's design and implementation, are summarized in Table 6.

Table 6. Results of the Feasibility Test of Learning Design Experts Using Aiken's V

No	Aspect	Expert 1	Expert 2	Aiken's V	Validity Interpretation
1	Introduction	4,0	3,7	0,95	Very High (V ≥ 0,9)
2	Theoretical Basis	3,5	3,8	0,88	High (0,8 ≤ V < 0,9)
3	Model Syntax	3,8	4,0	0,97	Very High (V ≥ 0,9)
4	Model Reaction Principles	3,8	3,8	0,93	Very High (V ≥ 0,9)
5	Model Social System	3,8	4,0	0,97	Very High (V ≥ 0,9)
6	Model Support System	3,4	3,6	0,83	High (0,8 ≤ V < 0,9)
7	Instructional & Accompanying Impacts	3,0	3,2	0,73	Moderate (V < 0,8)
8	Model Implementation	3,7	4,0	0,95	Very High (V ≥ 0,9)
9	Language	3,0	3,5	0,83	High (0,8 ≤ V < 0,9)

The content validity analysis, conducted using Aiken's V coefficient, demonstrated that the developed learning model generally met high validity criteria. Six out of nine assessed aspects (66.7%) achieved a V value of ≥ 0.9, indicating very high validity and strong expert agreement regarding their alignment with the intended construct. Notably, the syntactic aspect (V = 0.97) and the social system aspect (V = 0.97) recorded the highest validity scores, reflecting precise formulation in both the sequencing of learning stages and the structuring of social interactions within the model. The remaining three aspects obtained V values within the range of 0.8–0.9, which still fall within acceptable content validity standards. Collectively, these findings affirm the model's suitability for use as an effective instructional tool.

Subject Expert Feasibility Test Result

Product feasibility testing was also conducted by two Physical Education experts to assess the quality and appropriateness of the traditional game-based Quantum Learning model, as well as to provide recommendations for refining the draft. The results of their evaluations, covering multiple aspects of the product, are summarized in Table 7.

Table 7. Results of Material Expert Feasibility Test Using Aiken's V

No	Aspect	Expert 1	Expert 2	Aiken's V	Validity Interpretation
1	Introduction	4	3,7	0,95	Very High (V ≥ 0,9)
2	Theoretical Basis	3,7	4	0,95	Very High (V ≥ 0,9)
3	Model Syntax	3,6	3,4	0,83	High (0,8 ≤ V < 0,9)
4	Model Reaction Principles	3,8	3,6	0,90	Very High (V ≥ 0,9)
5	Model Social System	3,8	4	0,97	Very High (V ≥ 0,9)
6	Model Support System	3,8	4	0,97	Very High (V ≥ 0,9)
7	Instructional & Accompanying Impacts	3,7	4	0,95	Very High (V ≥ 0,9)
8	Model Implementation	3,7	4	0,95	Very High (V ≥ 0,9)
9	Language	4	3,5	0,92	Very High (V ≥ 0,9)

The results of the Aiken's V analysis indicate that the developed traditional game-based learning model has achieved strong content validity. Eight out of nine assessed aspects received V values of ≥ 0.90, reflecting a very high level of expert agreement regarding the relevance and adequacy of these components. The Model Syntax aspect obtained a V value of 0.83, which, while slightly lower than the others, still meets the established content validity standards. Overall, this analysis confirms that the model has attained satisfactory theoretical validity and is ready to proceed to the empirical testing phase. The consistently high expert consensus reinforces the model's appropriateness in representing a traditional

game-based Quantum Learning approach for enhancing physical literacy among primary school students.

Instrument reliability was tested using Cronbach's Alpha to assess internal consistency among items. The test results from the Content Expert and Learning Design Expert are presented in Table 8.

Table 8. Reliability Statistics of the Learning Model Feasibility Instrument

Reliability Statistics	Cronbach's Alpha	Interpretation	N of Items
Subject Expert	0. 861	Good Reliability	9
Learning Design Expert	0. 882	Good Reliability	9

The results of the reliability analysis of the instrument using Cronbach's Alpha by the Subject Matter Expert produced a coefficient of 0.861, indicating that the internal consistency of the instrument was in the good category ($\alpha > 0.80$) and exceeded the minimum threshold of 0.70. This finding confirms that the nine aspects measured in the instrument consistently reflect a single construct, namely the feasibility of the Quantum learning model based on traditional games. Furthermore, the results of the analysis conducted by the Learning Design Expert showed a Cronbach's Alpha value of 0.882, which is also in the good category ($\alpha > 0.80$). These results indicate that the instrument used has strong internal consistency in measuring the construct of the developed learning model.

Product Practicality Test Results

Product practicality testing was conducted by two Physical Education teachers at Paseh Subdistrict Elementary School, Bandung Regency, to assess the practicality and improve the quality of the product draft. The assessment results are presented in Table 9.

Table 9. Results of Teacher Practicality Assessment

No	Aspek	Teacher 1	Teacher 2	Score Average
1	The Traditional Game-Based Quantum Learning Model effectively facilitates students' understanding of physical education content	4	4	4
2	This model proves to be effective in enhancing students' acquisition of physical education skills	3	3	3
3	The model supports the development of students' creativity through engaging and contextualized learning activities	3	4	3,5
4	The teaching module aids in the effective delivery of physical education material in a structured and accessible manner	4	4	4
5	The student worksheets included in the module are clearly designed and easy for students to comprehend	4	4	4
6	The implementation of student worksheets is straightforward and practical within the classroom setting	4	4	4
7	Each stage of the model is systematically structured and feasible for implementation in the learning process	4	4	4
8	The teaching materials are presented in a clear and comprehensible manner, promoting ease of understanding	3	4	3,5
9	Teachers exhibit a high level of interest in implementing this learning model within their instructional practices	4	4	4
10	The attractiveness of the teaching materials is considered to be fairly high.	3	4	3,5
	Total	36	39	37,5
	Average	3,6	3,9	3,75

The results of the product practicality test (Table 9) revealed an average score of 3.75 (94%), indicating that the traditional game-based Quantum Learning model is highly practical and easy to implement within Physical Education instruction. The model proved effective in enhancing students' comprehension of learning material and supporting teachers through the provision of structured teaching modules and student worksheets, both of which received average scores of 4.0. The implementation stages likewise achieved high scores (4.0), reflecting the model's ease of application in classroom settings.

However, the teaching of students' physical skills received a score of 3.0, while the development of student creativity and the attractiveness of the teaching materials each obtained scores of 3.5, suggesting areas for further refinement. Teachers demonstrated strong enthusiasm for adopting the model, as indicated by a score of 4.0 for their interest in future use. Student responses were overwhelmingly positive, with affirmative feedback across all assessed areas, including material comprehension, technical

skill development, ease of using instructional materials, and learning motivation. In summary, the model has been shown to be both practical and effective in improving the physical literacy of primary school students, with specific recommendations for enhancing its capacity to foster creativity and improve the appeal of teaching materials.

Product Trial Results

The product trial involved 34 students as research participants to evaluate the model's effectiveness, practicality, and acceptability. The trial procedure consisted of pretest, treatment, and posttest stages, applied to both the experimental and control groups. The data collected included individual scores, group means, variances, and standard deviations. To ensure participant anonymity and maintain consistency in data presentation, each student was assigned an identification code beginning with the letter 'S', representing Student 1 to Student 34. A detailed summary of the pretest and posttest results is provided in Table 10.

Table 10. Comparison of Physical Literacy Scores between the Experimental and Control Groups in the Pretest and Posttest

No	Student Code	Pretest (Exp)	Pretest (Ctrl)	Posttest (Exp)	Posttest (Ctrl)
1	S 1	50	55	75	60
2	S 2	55	55	85	65
3	S 3	52	60	80	65
4	S 4	45	65	75	70
5	S 5	50	43	70	70
6	S 6	60	60	75	65
7	S 7	60	55	85	70
8	S 8	50	55	80	65
9	S 9	60	50	75	65
10	S 10	35	60	70	75
11	S 11	60	60	85	75
12	S 12	45	65	85	75
13	S 13	55	70	75	80
14	S 14	55	65	70	75
15	S 15	60	70	80	75
16	S 16	65	45	70	65
17	S 17	50	40	80	65
18	S 18	70	50	90	65
19	S 19	55	55	75	70
20	S 20	50	50	80	65
21	S 21	50	55	80	70
22	S 22	55	70	75	75
23	S 23	45	55	75	75
24	S 24	45	55	70	65
25	S 25	55	40	80	65
26	S 26	50	40	90	65
27	S 27	45	40	80	70
28	S 28	70	45	85	80
29	S 29	60	40	85	65
30	S 30	65	55	75	65
31	S 31	40	55	75	60
32	S 32	55	60	70	75
33	S 33	45	50	80	60
34	S 34	50	50	80	60
Total		1812	1838	2660	2330
Mean		53.29	54.06	78.24	68.53
Variance		62.80	78.35	32.18	31.66
Standard Deviation		10.23	10.37	4.01	4.06

Table 10 shows the comparison of the physical literacy scores of the experimental and control groups in the pretest and posttest. At the pretest stage, the experimental group achieved an average score of 53.29, which was slightly lower than that of the control group (54.06). The control group had a higher variance (78.35) than the experimental group (62.80), indicating a more varied distribution of initial scores. Following the intervention involving the Traditional Game-Based Quantum Learning Model, the experimental group's average posttest score increased significantly to 78.24; in contrast, the control group's average posttest score increased to only 68.53 after using Direct Instruction. The average increase in the experimental group was 24.95 points, which was greater than the 14.47-point increase seen in the control group. Posttest score variance decreased in both groups to 32.18 (experimental

group) and 31.66 (control group), reflecting a more homogeneous distribution of results after the intervention. The highest posttest score in the experimental group was 90, which was higher than the control group's highest score of 80. These findings suggest that the Traditional Game-Based Quantum Learning Model is more effective than Direct Instruction in improving the physical literacy of primary school students, as demonstrated by the significant increase in average scores and greater consistency of results.

Product Effectiveness Test Results

Following the implementation of the Traditional Game-Based Quantum Learning Model, its effectiveness in enhancing the physical literacy of primary school students was evaluated. Table 11 presents the descriptive statistics of the pretest and posttest results for both the experimental and control groups.

Table 11. Descriptive Test of Physical Literacy

Research Class	Treatment	N	Range	Min.	Max.	Mean		Std. Deviasi	Variansi	N-Gain
						Statistik	Std. Eror			
Control	Pretest	34	30	40	70	54,06	1,541	8,985	80,724	0,30
	Posttest	34	20	60	80	68,53	0,980	5,711	32,620	
Experiment	Pretest	34	35	35	70	53,29	1,379	8,044	64,699	0,53
	Posttest	34	20	70	90	78,24	0,987	5,758	33,155	

As shown in the table, the average physical literacy score in the experimental group increased substantially from 53.29 (pretest) to 78.24 (posttest), while the control group's score rose from 54.06 to 68.53. The N-Gain value for the experimental group was 0.53, indicating moderate effectiveness, which was notably higher than the control group's N-Gain of 0.30, classified as low effectiveness. These findings suggest that the Traditional Game-Based Quantum Learning Model was more effective in enhancing students' physical literacy compared to conventional instructional methods.

A prerequisite normality test was conducted using the Shapiro–Wilk test, as each group contained fewer than 50 participants. The results of the normality test for both the pretest and posttest data in the experimental and control groups are summarized in Table 15. The analysis revealed that the significance values for most of the data sets were below 0.05 (see Table 12), indicating that the data were not normally distributed. Consequently, further analysis was carried out using non-parametric statistical tests.

Table 12. Normality Test Result

Aspect	Research Class	Data	N	Shapiro Wilk		
				Statistic	df	Sig.
Physic Literacy	Experiment	Pretest	34	0,964	34	0,310
		Posttest	34	0,914	34	0,011
	Control	Pretest	34	0,936	34	0,046
		Posttest	34	0,887	34	0,002

Subsequently, the Wilcoxon test was employed to ascertain the discrepancy in physical literacy scores between the pretest and posttest in each paired class. The results of the Wilcoxon test are presented in Table 13.

Table 13. Wilcoxon Test Result

Aspect	Research Class	Data	N	Wilcoxon	
				Z	Asymp. Sig. (2 tailed)
Physic Literacy	Experiment	Pretest	34	-5,103[b]	0,000
		Posttest	34		
	Control	Pretest	34	-5,115[b]	0,000
		Posttest	34		

Table 13 indicates an Asymp. Sig. (2-tailed) value of 0.000 for both the experimental and control groups, indicating a significant difference between the pretest and posttest scores in both groups ($p < 0.05$). These results demonstrate that both conventional learning and the Traditional Game-Based Quantum Learning Model significantly improved students' physical literacy.

To examine the difference in effectiveness between the experimental and control groups, a Mann–Whitney U test was performed on the posttest scores. The results of this analysis are presented in Table 14.

Table 14. Mann Whitney Test Result

Aspect	Research Class	Mann Whitney	
		Z	Asymp. Sig. (2 tailed)
Physic Literacy	Experiment Kontrol	-5,380	0,000

Table 14 indicates an Asymp. Sig. (2-tailed) value of 0.000, indicating a significant difference between the experimental and control classes (p < 0.05). It confirms that the traditional game-based quantum learning model is more effective in improving students' physical literacy than conventional learning.

Discussion

This study involved the development and validation of a traditional game-based Quantum Learning model designed to enhance the physical literacy of primary school students. The findings demonstrated that the model was effective in improving multiple dimensions of physical literacy, including motivation, physical competence, knowledge and understanding, and daily physical activity behavior. The key outcome indicating the model's effectiveness was the higher physical literacy scores achieved by the experimental group compared to the control group, with an N-Gain value of 0.53 (moderate category) versus 0.30. The integration of traditional games within the Quantum Learning framework effectively fostered active student participation and strengthened holistic physical literacy outcomes.

These findings are strongly supported by established theoretical frameworks and previous research. Whitehead's (2010) concept of physical literacy, which highlights the holistic integration of physical, cognitive, and affective components, served as the conceptual foundation for this study. The results also reinforce the efficacy of the Quantum Learning approach, which emphasizes meaningful, contextualized, and engaging learning experiences that activate students' full potential (Mulasi et al., 2024; Nasution, 2023). The developed model proved successful in optimizing physical literacy through the educational application of enjoyable, culturally relevant traditional games.

Furthermore, the findings are consistent with prior research demonstrating that traditional games can significantly enhance students' motivation and participation in physical activities within the school setting (Oktarina et al., 2024; Toev et al., 2024; Azlan et al., 2021). Earlier studies similarly reported that incorporating local cultural activities positively influences students' physical capacity while strengthening social relationships (Chasciar et al., 2025). The use of traditional games in Physical Education not only promotes students' motor skills and physical fitness but also fosters cultural awareness (Fathihah, 2024; Budiman, 2024; Toivonen et al., 2024; Yusroni, 2024; Maliki et al., 2024).

While previous literature has noted limitations in game-based models for developing cognitive skills, often attributed to time constraints and classroom management challenges. This study successfully integrated cognitive stimulation within game activities through the systematic and structured implementation of Quantum Learning principles. As a result, these barriers were effectively minimized through the careful design of instructional strategies.

Improvement in Physical Fitness and Basic Motor Skills

This study provides compelling evidence that implementing a traditional game-based Quantum Learning model can significantly improve the physical fitness of primary school students. These results align with the findings of Muhaimin et al. (2024), who reported that traditional games such as Hadang and Bentengan positively influence various components of physical fitness, including sprint performance, pull-ups, sit-ups, vertical jumps, and short-distance running. Likewise, Ghozelin et al. (2023) and Mo et al. (2024) demonstrated that instructional programs incorporating traditional games are effective in reducing physical fatigue and enhancing students' concentration during academic activities. Furthermore, prior studies have emphasized the potential of traditional games as a medium for fostering fundamental motor skills (Fathihah, 2024; Ningsih et al., 2024). When adapted to align with principles of child development, these games have been shown to facilitate motor skill acquisition, promote higher levels of physical activity, and improve performance across a range of physical tasks.

Cognitive and socio-emotional stimulation

The learning model developed in this study impacted not only physical aspects but also significantly contributed to the cognitive and socio-emotional stimulation of students. The study observed improvements in problem-solving abilities, logic, and social and cultural understanding. These findings are supported by studies that highlight the educational and social value of traditional Indonesian games (Zulela & Iasha, 2024; Hasan & Husein, 2024; Wazuda & Subayani, 2024). Furthermore, several studies have identified games such as Gobak Sodor, Sundanese Manda, Congklak, and Dakon as stimulating students' cognitive abilities (Hasan & Husein, 2024; Apriyanda et al., 2024). Traditional games can develop children's social and emotional skills by encouraging meaningful interactions with peers and adults, including cooperation, communication, and conflict resolution (Johannes et al., 2024; Hasni et al., 2024; Ilmi et al., 2024).

Increased motivation and engagement of students

The learning model also led to notable improvements in students' motivation and engagement. The integration of traditional games into instructional activities has been shown to enrich students' learning experiences and enhance their intrinsic motivation (Mudzakir, 2020; To et al., 2024). The enjoyable, low-pressure, yet intellectually stimulating nature of traditional games plays a vital role in fostering a positive learning environment and encouraging students to participate more actively. These games function not only as recreational tools but also as effective pedagogical instruments that boost students' motivation, particularly within the context of physical education (Mulya, 2024; Nashir et al., 2024; Hasanah et al., 2024).

Overcoming Physical Literacy Gaps in Indonesia

Although numerous studies have demonstrated the benefits of traditional games, this research specifically addresses a gap in the literature concerning their impact on children's cognitive development within the framework of physical literacy. In this regard, the study offers a significant contribution to efforts aimed at improving the low levels of physical literacy in Indonesia, particularly in terms of students' knowledge and understanding (Irmansyah et al., 2025; Nur et al., 2025). The holistic, traditional game-based Quantum Learning model developed in this study has proven effective in strengthening these dimensions, offering a contextualized and culturally relevant approach to advancing physical literacy in Indonesian primary school.

Theoretical implications

The findings of this study are highly relevant to Quantum Learning Theory, which emphasizes holistic education through enjoyable and interactive experiences (Fauzan et al., 2024; Sofyan & Murdianingsih, 2022). Traditional games naturally embody the core principles of Quantum Learning, particularly the Experience and Celebrate elements within the TANDUR framework. This is evident in students' active participation and enjoyment during gameplay (Djuwita & Fakhri, 2019; Morejón Calixto et al., 2024; Warman & Ristiani, 2023). These games offer cognitively rich stimuli by combining strategic thinking, motor coordination, social interaction, and problem-solving which supporting the premise that the brain functions optimally when exposed to diverse, and simultaneous stimuli. As such, Quantum Learning presents an effective pedagogical approach for incorporating traditional games into physical education.

Moreover, the learning model is grounded in constructivist principles, both cognitive and social. From the perspective of cognitive constructivism (Piaget), students build knowledge structures through direct experience and the continuous adjustment of mental models during play (Kritt, 2022; Erawati & Adnyana, 2024). From the social constructivist lens (Vygotsky), traditional games foster collaborative learning, as students negotiate rules, develop shared strategies, and internalize social norms (Muniyappan & Sivakumar, 2018; Mishra, 2023; Ashar et al., 2024). The active engagement, problem-solving, and peer interaction required in these games render them ideal tools for constructivist learning environments.

These findings also align with Kolb's (1984) Experiential Learning Theory, which outlines the learning cycle through four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation (Anggraeni, 2017; Jones-Roberts & Bechtold, 2024). In this study, students directly engaged in gameplay, reflected on their experiences, formulated strategic insights, and applied them in subsequent rounds, enhancing their motivation, self-confidence, and both cognitive and socio-

emotional development. Furthermore, this model addresses the limitations of conventional physical education, which often neglects affective and cognitive domains (Nur et al., 2025).

Traditional games also nurture communities of practice where learners gradually acquire knowledge of rules, strategies, and social dynamics through active participation (Ignacio, 2022). The notion of legitimate peripheral participation is evident when new players begin by observing before fully engaging in play. These informal, culturally embedded learning contexts, conducted beyond the boundaries of the classroom which offer rich opportunities for contextualized and meaningful learning. Therefore, this model represents a powerful pedagogical strategy for holistically enhancing physical literacy through culturally relevant, experiential learning.

Critical analysis

The validity of this study's findings, in relation to existing theories and prior research, is supported by several key factors. First, the selection of contextual and culturally relevant traditional games has been shown to enhance students' emotional engagement and intrinsic motivation (Ashar et al., 2024; Trajkovik et al., 2018; Wazuda & Subayani, 2024). Games rooted in students' everyday experiences foster a positive learning environment and stimulate active participation in physical literacy activities. Second, the application of Quantum Learning principles, emphasizing active, enjoyable, and experience-based learning has significantly improved students' focus, involvement, and comprehension of physical literacy concepts (Monaliata et al., 2023; Aprilia et al., 2021; Mulasi et al., 2024). This approach maximizes physical, emotional, and cognitive engagement, thereby facilitating deeper internalization of physical literacy values.

Nevertheless, Permata et al. (2024) reported limited cognitive benefits of traditional games. These divergent results may be attributed to differences in instructional design. In contrast to previous research, the learning model employed in this study was developed through a systematic process involving needs assessment, expert validation, and iterative testing—making it more adaptive to primary school contexts. Moreover, the Merdeka Belajar (Freedom to Learn) policy provides schools with the flexibility to design learning models based on local resources, a feature that was not optimally utilized in earlier studies. Contextual factors such as geography, school culture, and student characteristics also played a significant role in the model's effectiveness, in line with the broader influence of sociocultural factors on physical activity development in schools (Mohammadi et al., 2023; Craig et al., 2023; Ré et al., 2025).

This study contributes to broadening the application of Quantum Learning in physical education by integrating traditional games as meaningful, culturally grounded learning tools. It demonstrates the adaptability of Quantum Learning to students' cultural backgrounds and needs, while reinforcing the relevance of other learning frameworks, such as constructivism, experiential learning, and situated learning in fostering the physical, cognitive, social, and emotional development of primary school students. The foundational principles of Quantum Learning, including multisensory engagement, motivation, and meaningful experiences, have been shown to be highly effective when implemented through traditional games. This aligns with Whitehead's (2019) concept of physical literacy, which encompasses physical competence, motivation, self-confidence, and an understanding of the lifelong value of physical activity.

The traditional game-based Quantum Learning model developed in this study offers physical education teachers an alternative instructional strategy for enhancing students' physical literacy. It presents an enjoyable, educational, and locally relevant approach that aligns with the Merdeka Belajar policy, which encourages pedagogical innovation grounded in local wisdom. The traditional games embedded in this model are well suited to the developmental characteristics of primary school-aged children and have proven effective in cultivating motivation, self-confidence, physical skills, as well as conceptual understanding. Additionally, this model has the potential to support a more holistic physical education curriculum by reducing the overemphasis on competitive sports content.

Conclusions

This study successfully designed and validated a Quantum Learning Model grounded in traditional games, demonstrating its effectiveness in fostering holistic physical literacy among primary school students. By integrating contemporary pedagogical frameworks with culturally rooted activities, the model significantly enriched physical education instruction while reaffirming the educational value of traditional games as contextual and meaningful learning tools. The implementation of this model contributed to notable gains in students' physical competence, motivation, self-efficacy, and conceptual understanding, simultaneously supporting the preservation and integration of cultural heritage within modern educational practice. Theoretically, the findings reinforce the relevance of culture-based active learning as a responsive approach to the developmental needs of Indonesia's basic education system. Practically, the model offers a viable and policy-aligned alternative to conventional PHYSICAL EDUCATION instruction, resonating with the principles of the Merdeka Belajar (Freedom to Learn) initiative. Nevertheless, given the study's limited geographical scope, further validation across diverse educational settings is recommended. Future developments should also consider incorporating digital elements into traditional game-based learning to increase student engagement in an increasingly digitized educational landscape.

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Authors' and translators' details:

Prayogi Nurfauzan	prayoginurfauzann@gmail.com	Autor/a
Guntur Guntur	guntur@uny.ac.id	Autor/a
Aris Fajar Pambudi	arisfajarpambudi@uny.ac.id	Autor/a
Ade Gusti Ningsih	adegusti.2023@student.uny.ac.id	Autor/a
Apriliana Nurulita Nur Fauzi	aprilianannurulita.2023@student.uny.ac.id	Autor/a
Andika Triansyah	andika.untan@gmail.com	Autor/a
Fatma Atik Mulyani	fatmaatik.2023@student.uny.ac.id	Autor/a
St. Nur Almaidah RS.	stnur.2024@student.uny.ac.id	Autor/a
Atina Atina	atina81067@ustjogja.ac.id	Autor/a
Maria Magdalena Sri Wahyuni	maria85086@ustjogja.ac.id	Autor/a
Arief Kuswidyanarko	ariefkuswidyanarko.2022@student.uny.ac.id	Autor/a
Irene Maria Wato	irenemaria.2023@student.uny.ac.id	Autor/a
Anna Mariyani	annamariyani89@gmail.com	Autor/a
Hidayatul Hikmah	hidayatulhikmah.2023@student.uny.ac.id	Autor/a
Amran Amran	amran0001fik.2022@student.uny.ac.id	Autor/a